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Developing business opportunities for biological by-products

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Key concepts: *Utilization of By-products, Front End of Innovation, Decision-making, Biological Waste*
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Abstract
A growing middle class and increased consumption call for better utilization of resources. For companies to make use of all resources in the production system is not only a way of meeting the changing customer demands and regulatory changes regarding sustainability, but also a way of increasing profits.

Finding new business opportunities for by-products can be considered as early stage innovation, commonly known as the front end of innovation. Management of the front end of innovation is however perceived by companies as being particularly difficult, and the research available in this area is limited.

This master's thesis aimed at providing corporations with a practical tool for innovating the utilization of biological by-products, to be used in the front end of innovation. The result was a conceptual framework that was developed through combining theory with practice. A literature study was performed in the areas of innovation and strategic-decision making in order to gain an understanding of how to be innovative and make good decisions. To gain knowledge from practice, three different companies that have experienced by-product innovation were interviewed using an unstructured interview approach. Critical aspects for by-product innovation in practice were analyzed and combined with findings from theory. The result was a conceptual framework that can be used to identify and evaluate business opportunities for biological by-products.

The developed conceptual framework was also applied on a case study performed at Lantmännen. Apart from validating the conceptual framework, the case study resulted in potential business opportunities for two of the three by-products examined. The examined by-products were three different types of forage seeds that are currently being digested for biogas. For one by-product, no alternative business opportunity was found, and for the other two, business opportunity potential within cosmetics and feed was identified.

Conclusions drawn from this master's thesis was that the developed conceptual framework was stated as useful for by-product innovation, but that further validation of the framework is needed.

Key concepts
Utilization of By-products, Front End of Innovation, Decision-making, Biological Waste

Sammanfattning

En växande medelklass och en ökad konsumtionstrend kräver bättre resursutnyttjande. Att utnyttja alla resurser i produktionssystemet är inte bara ett sätt för företag att möta de förändrade kundkrav och regulatoriska förändringar när det gäller hållbarhet, men också ett sätt att öka vinsten.

Att hitta nya affärsmöjligheter för biprodukter kan anses som tidig innovation, även benämnt den främre änden av innovation (eng. the front end of innovation). Hantering och ledning inom den främre änden av innovation uppfattas dock av företag som svårt och forskning inom området är begränsad.

Detta examensarbete syftar till att förse företag med ett praktiskt verktyg för att innovera utnyttjandet av biologiska biprodukter i den främre änden av innovation. Resultatet blev ett konceptuellt ramverk som utvecklats genom att kombinera teori med praktik. En litteraturstudie genomfördes inom områdena innovation och strategiskt beslutsfattandet för att få en förståelse för hur man är innovativ och samtidigt fattar bra beslut. För att få kunskap från praktiken intevjuades tre olika företag som har erfarenhet från biproduktsinnovation genom ostrukturerade intervjuer. Kritiska aspekter för biproduktsinnovation i praktiken analyserades och kombinerades med resultaten från teorin. Resultatet blev ett konceptuellt ramverk som kan användas för att identifiera och utvärdera affärsmöjligheter för biologiska biprodukter.

Det utvecklade konceptuella ramverket har även tillämpats på en fallstudie som utfördes på Lantmännen. Utöver att validera ramverket resulterade fallstudien i potentiella affärsmöjligheter för två av de tre biprodukter som undersöktes. De undersökta biprodukterna var tre olika typer av vallfrön som för närvarande röts till biogas. För en av biprodukterna hittades ingen alternativ affärsmöjlighet och för de andra två hittades potentiella affärsmöjligheter inom kosmetika och foder.

Slutsatser som drogs från detta examensarbete var att det utvecklade konceptuella ramverket ansågs vara användbart för biproduktsinnovationer men att ytterligare validering av ramverket krävs.

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Acknowledgement
This master's thesis was conducted at the division of Production Management during the spring semester of 2016. The master's thesis comprised of 30 credits, and was conducted as the concluding part of a five year education in Industrial Engineering and Management at the Faculty of Engineering at Lund University.

As this master's thesis has come to a close, there are a few people who we would particularly like to thank: Our supervisor Carl-Johan Asplund, Lecturer at the Faculty of Engineering at Lund University; for his advice, guidance and motivational support. Emma Nordell, our supervisor at Lantmännen, who has provided us with valuable contacts, feedback and above all, good advice. Margaretha Månsson and Peter Annas, for allowing us to take on the challenge that was the basis of this master's thesis. Maria Blomberg and Mattias Larsson Schölin, for helping us with illustrative work.

We would also like to thank the helpful and inspiring people who have participated in interviews, answered questions and in other ways contributed to our work.

Thank you all,

Andrea Larsson and Fanny Lundkvist
Lund, June 2016

List of abbreviations

DVFS = Desirability, Viability, Feasibility and Sustainability

FEI = Front End of Innovation

NPD = New Product Development

R&D = Research and Development

1. Introduction

1.1. Background

During the past few years, the customer pressure on companies to become more sustainable has increased (Davis, 2011). Furthermore, several policy initiatives have been introduced on an EU level, addressing climate change in general and circular economy in particular (European Commission, 2015). Climate change has long been a concern and with a growing middle class and increased consumption patterns (Ellen MacArthur Foundation, 2013), companies will have to adapt to this changed business environment.

Results from a 2013 global survey on sustainability showed that both changing expectations from customers regarding sustainability, as well as regulatory changes, are perceived by many companies as risks (Kiron, Kruschwitz, Rubel, Reeves, & Fuisz-Kehrbach, 2013). However, although many executives consider environmental sustainability issues as being significant to the company, few companies are able to address these issues in a constructive way (Kiron et al., 2013). It is clear that companies today need to find ways to adapt to limited resources and use the planet's resources in a smarter and more effective and efficient way, but for some companies it can be unclear how to take action.

> *"Waste as part of the linear system results in economic losses on all fronts"*
>
> - Ellen MacArthur Foundation, 2013, p. 16

One proposed opportunity for value creation in the circular economy is to "retain resource value by converting today's 'waste' streams into by-products - creating new effective flows within or across value chains" (Ellen MacArthur Foundation, 2013, p. 33). In other words, waste that is generated as an output in one production process can be an input in another production process, thus generating value to the company while reducing negative environmental impact.

In the agricultural supply chain, resource or material loss occurs at multiple stages (Ellen MacArthur Foundation, 2013). As the world population grows and becomes wealthier, the agricultural supply chain has been identified as the most important supply chain for the consumer goods industry (Ellen MacArthur Foundation, 2013) and it is therefore important to make sure value is retained throughout the supply chain. For the agricultural cooperative Lantmännen, resource loss in the supply chain has been identified as an area of improvement, with one example being refined seeds that are discarded for agricultural use if not

meeting certification requirements. This output, refined seeds, might be used as an input in another process, potentially leading to new business opportunities.

"The key to progress, […], is innovation"

- Nidumolu, Prahalad, & Rangaswami (2009)

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In the light of climate change, sustainability has emerged as a new driver of innovation, and as a competitive advantage for companies that succeed in the transition towards sustainability (Nidumolu et al., 2009). Innovation is a key factor for making change happen in practice, and can be used to create value throughout the value chain. We see innovation as an essential tool for improving resource utilization and value creation and, although there is an abundance of general innovation tools and research available, the particular area of by-product innovation has at time of writing not been as extensively researched.

We will in this master's thesis address the issue of value creation through the utilization of biological by-products as raw material, developing an innovation framework that can aid companies in finding business opportunities in under- or unutilized resources, and subsequently putting the framework to test in a case study conducted at the agricultural cooperative Lantmännen.

1.2. Purpose

The purpose of this study was to develop and test a framework which organizations can use to identify and evaluate business opportunities for a biological by-product.

Research questions

RQ1. How can an organization identify business opportunities for a biological by-product?

RQ2. Which aspects are important when evaluating business opportunities for a biological by-product?

RQ2a. How can these aspects be compared when making a decision on how the by-product should be utilized?

RQ3. Which alternative business opportunities exist for Lantmännen's by-products in the forage seed production?

RQ3a. Which one of these business opportunities is optimal for Lantmännen?

1.3. Delimitations

This master's thesis was delimited to the evaluation of **biological by-products**. The thesis was delimited to by-products that had already been identified and did not include the identification of different by-products. Elimination of waste in the production (such as lean manufacturing) was not included in the study.

In terms of the development of the conceptual framework, the framework was delimited to be used in **the front end of innovation** and therefore did not explore the following product development process. The reasoning behind this delimitation was that most companies already have a formal process (for example a stage-gate process) that defines the later phase of the new product development (see chapter 2.2).
For the case study, two types of by-product streams existed in the production process at Lantmännen forage and seed; one consisting of seeds that were discarded due to their low germination and another stream that was biomass residue consisting of a mix of various types of husks, small grains of gravel and other residue. Of these two, the former was deemed more interesting in terms of business opportunities. Within the group of discarded seeds, three types of seeds (timothy, red clover and white clover) make the greatest share of quantity discarded seeds. Thus, these three seed types were considered particularly interesting and the case study was therefore delimited to these **three types of by-products**.

1.4. Target group

This master's thesis investigates the area of innovation from a by-product perspective and aims to provide insights within this area for both students and researchers in academia as well as companies wanting to improve their business.

1.5. Disposition of report

A description of the disposition of the report follows below and is visualized in Figure 1.

In the introductory chapter, ***chapter 1***, a background to the problem investigated in this master's thesis has been provided, along with the purpose and research questions, delimitations, and target group of the thesis.

Chapter 2 includes the theoretical frame used in this master's thesis and provides the reader with a theoretical perspective on the early stages of the innovation process, by describing the *front end of innovation*. It also includes the concept of *design thinking*, used in innovation, as well as the *Decision Quality Chain*, a model used to strengthen decision quality.

In ***chapter 3***, the reader is guided through the research methods that were used in this study, including the research approach and process, data collection methods and analysis, ending with a discussion of the quality of the study.

Presentations of the three interviewed companies are provided in chapter 4, giving the reader an introduction to the companies and a context to the results presented in the subsequent chapter. The case company Lantmännen is also presented in this chapter, together with a description of the by-products explored in the case study at Lantmännen.

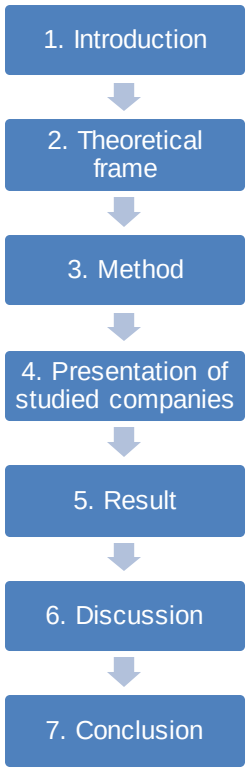

Figure 1. Disposition of report

The result described in ***chapter 5*** is divided into three parts; findings from the interviews conducted with three companies working with by-product innovation, the conceptual framework developed in this master's thesis, and the results from the validation of the developed framework conducted at Lantmännen.

Chapter 6 discusses and analyzes the results in relation to the research questions as well as the theoretical frame. The chapter is structured with discussions of the research questions in chronological order.

Chapter 7 concludes this master's thesis, by discussing the thesis' contributions, limitations of the study and proposing areas of future research.

2. Theoretical frame

2.1. Introduction

The following chapter will describe the theoretical frame that was used as a base for this master's thesis. Since the master's thesis was focused on the early phase of innovation, the chapter will begin with an introduction to the *Front End of Innovation,* including some interesting viewpoints. In order to answer the research questions regarding the identification of business opportunities, the theoretical frame will include the innovation concept *Design Thinking*. The theoretical frame will proceed with a presentation of *The Decision Quality Chain,* a strategic decision-making model that will provide insight in how the best possible decisions can be made when evaluating the utilization of a by-product. An overview of the theoretical frame is pictured in Figure 2.

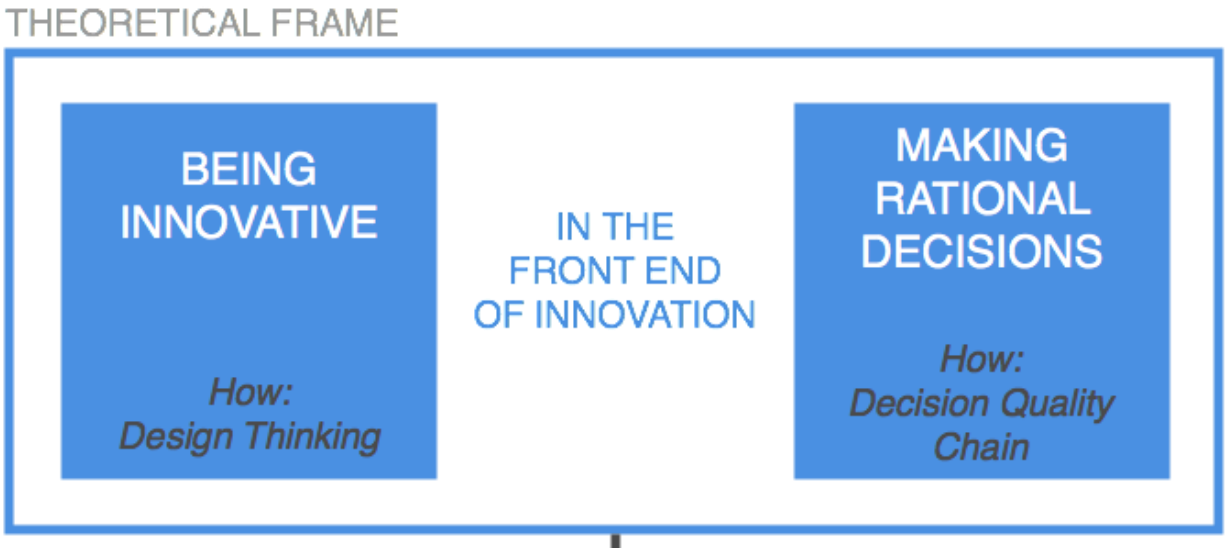

Figure 2. Overview of the theoretical frame.

2.2. Front end of innovation

Koen, Bertels, & Kleinschmidt (2014) divide the innovation process into three different stages:

- the front end of innovation (FEI) - sometimes called "the fuzzy front end" of innovation (Koen et al., 2001);
- the new product development process (NPD) - a structured process which is usually defined by a traditional stage-gate model (Jutbo & Wahlström, 2013); and
- the commercialization stage.

FEI activities

The front end of the innovation process is defined by Koen et al. (2001) as a number of activities that come before the new product development process. Unlike the NPD that is very much a structured process, the FEI activities are not structured in a chronological order and it is common to iterate between FEI activities (Koen et al., 2001).

More specifically, the five activities of the FEI included by Koen et al. (2001) are: opportunity identification, opportunity analysis, idea genesis, idea selection and concept and technology development. Gassmann & Schweitzer (2014) have identified similar activities: problem or opportunity identification, the screening process and the evaluation process in the early FEI; and idea generation and evaluation, concept development and concept evaluation in the later stage of FEI. Since this master's thesis aimed to answer research questions regarding the identification and evaluation of business opportunities, theories on the front end of innovation therefore seemed appropriate.

Strategic decisions in FEI

Another interesting aspect of the FEI for this thesis is the strategic decision-making in FEI. During the FEI, strategic decisions for NPD are made and Gassmann & Schweitzer (2014) suggest decision-making to be one of the improvement potentials for companies in the FEI stage. Gassmann & Schweitzer (2014) stress the importance of considering multiple perspectives in the FEI and using a cross-functional management approach in order to strengthen the strategic frame.

The uncertainty of innovation

Analyzing opportunities and selecting ideas in the FEI should not be as rigorously done as in the NPD, "since many ideas must be allowed to grow and advance with less certainty" (Koen et al., 2001, p. 51). Hard, quantifiable templates are therefore left to the NPD (Koen et al., 2001). Gutiérrez (2008) also notes that a high level of uncertainty and lack of information, such as in the early innovation phase, implies that a decision method based on intuition rather than rationality might be necessary (Gutiérrez, 2008).

Reduced uncertainty in the front end of innovation could lead to greater success in the later stage of product development (Verworn, Herstatt, & Nagahira, 2008). A study of Japanese companies conducted by Herstatt, Stockstrom, Verworn, & Nagahira (2006) concluded that companies use information to reduce uncertainty. Successful companies were the ones that often used their customers as a source of information in the new product development, and were able to integrate this customer knowledge into the

product (Herstatt et al., 2006). Liefer & Steinert (2014) recommend that the uncertainty is used as a tool to create better innovations at a faster pace.

FEI vs. NPD

In the final element of the FEI, a business case is developed where the formality level of the business case depends on how new the opportunity is to the company, but Koen et al. (2001) also point out that the business case can be developed in the first stage of the NPD. According to Koen et al. (2014), a lot of research has been done on the new product development process, while the front end of innovation has not been as thoroughly researched. One reason why the front end of innovation has not been as extensively researched as, for example, the stage-gate process is that the front end of innovation is perceived as more complex (Gassmann & Schweitzer, 2014). There seems to be a need of making the front end of innovation less "fuzzy".

2.3. Design Thinking

2.3.1. Introduction to Design Thinking

The concept *design thinking* has different meanings depending on context. According to (Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013), design thinking is a concept commonly used in two areas: design research and management. Within the management area, design thinking can be seen as 1) a way of working with design and innovation, as originated from the design company IDEO in Palo Alto, California; 2) a way to approach organizational problems and a skill for managers; and 3) part of management theory (Johansson-Sköldberg et al., 2013). The terminology of design thinking as it is currently used in the business environment, is the one originated from IDEO and its founder David Kelley and chief executive officer Tim Brown (Liedtka, 2015). In this chapter, chapter 2.3, design thinking as way of working with design and innovation according to Brown is presented.

2.3.2. Design thinking as an innovation approach

Brown (2009) describes design thinking as an explorative approach to innovation projects and not as a process with rational steps. The design thinking approach can either be described by the iterative phases inspiration, ideation and implementation, or, in terms of constraints (Brown, 2009). According to Brown (2009), constraints are needed for successful design and competing constraints are the foundation of design thinking. In design thinking, important constraints should be identified and a framework for evaluating these constraints should be developed (Brown, 2009). The constraints can be categorized in the

following overlapping criteria for success: feasibility, viability and desirability, as shown in Figure 3 (Brown, 2009).

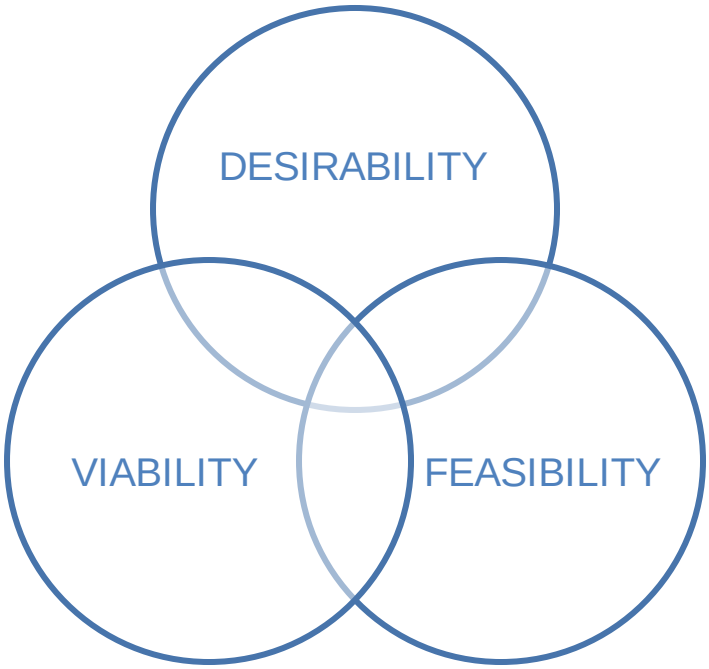

Figure 3. Visualization of the three constraint types that are the basis of design thinking as adapted from IDEO (2016).

Design thinking in the front end of innovation

Liefer & Steinert (2014) have a background in design and product development, and conclude that design thinking is a method that can be successfully used in the innovation process. More specifically, design thinking can increase innovation speed in the FEI, as well as lead to innovations that better fulfill customer needs because of the method's human, business and technical approach (Liefer & Steinert, 2014).

2.3.3. Feasibility, viability and desirability

In design thinking, all three types of constraints, feasibility, viability and desirability, should be considered iteratively throughout the innovation process (Brown, 2009). However, focus should be on fundamental human needs rather than volatile desires, i.e. focus on what people have a true need for rather than what people think they need in the moment. Brown describes feasibility constraints as "what is functionally possible within the foreseeable future", viability constraints as "what is likely to become part of a sustainable business model" and desirability constraints are defined as "what makes sense to people and for people" (Brown, 2009, p.18).

2.3.4. Diverging and converging - creating and making choices

Design thinking includes divergent and convergent thinking during the innovation project. Divergent thinking means creating multiple options, while convergent thinking is about making choices. Even though more options implies more complexity, which might affect the budget and timeline, creating multiple options will increase the probability that the final solution will be more disruptive and convincing. By creating multiple options, the project can avoid obvious and incremental solutions that prevent the company from getting inflexible to changes. The design thinking process iterates between divergent and convergent thinking, successively narrowing down the options and making them more detailed with each iteration (Brown, 2009).

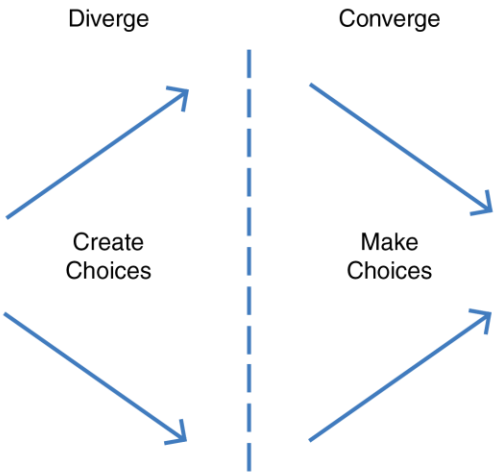

Figure 4. The process of diverging and converging in the design thinking approach. Adapted from Brown (2009).

2.3.5. Organizational culture supporting design thinking

In order for a company to successfully make use of design thinking, Brown suggests an experimental and optimistic mindset and practicing brainstorming. Companies need room to experiment, and Brown states that:

> *"A creative team must be given the time, the space, and the budget to make mistakes."*
>
> - Brown (2009, p. 43)

A culture and a business strategy that tolerates risk taking and encourages experimentation will less likely cling to efficiency and incrementalism over innovation (Brown, 2009).

2.4. The Decision Quality Chain - a tool for decision making

2.4.1. Introduction to the Decision Quality Chain

In the book "The Smart Organization" (Matheson & Matheson, 1998), Matheson and Matheson describe smart organizations as organizations that are making good strategic decisions and effectively carrying out those decisions. The decision making tool *The Decision Quality Chain* developed by Matheson and Matheson mainly focuses on making good strategic decisions in R&D. R&D is broadly defined by Matheson and Matheson as "any technologically related activity that has the potential to renew or extend present businesses or generate new ones". Matheson and Matheson also refer to R&D as "the fuzzy front end", a concept that was described in chapter 2.2. The following chapter will mainly focus on Matheson and Matheson's view of strategic decision-making, including a presentation of their six decision quality dimensions.

Strategic decisions

Matheson and Matheson (1998) describe strategic decisions as being different from operational decisions in several aspects. The operational decisions are described as having a "ready, fire, aim" approach where the decision-maker selects one alternative, "fires" and quickly gets feedback on the result. Strategic decisions on the other hand, usually involve commitments or investments that affect the company over several years, making failure more costly and the importance of the "aim" much greater.

2.4.2. The six dimensions of The Decision Quality Chain

According to Matheson & Matheson (1998), decisions with the best odds for creating value are based on facts and logical analysis, as opposed to "how we do things". To be able to make a successful decision, Matheson and Matheson suggest six dimensions, as shown in Figure 5, that together make *The Decision Quality Chain* and that should be fulfilled. Matheson & Matheson (1998) point out that *The Decision Quality Chain* as a whole is only as strong as its weakest link. The six dimensions are further described below.

Figure 5. The Decision Quality Chain (Matheson & Matheson, 1998).

2.4.2.1. Appropriate frame

The first of the six decision quality dimensions sets the foundation for the upcoming five. Ensuring the appropriate frame means assessing the background and context of the company, defining the assumptions that are made leading up to the coming decision, and making sure the decision is in line with the business purpose. (Matheson & Matheson, 1998)

Matheson and Matheson (1998) state that getting a high-quality frame requires a change in mindset - first of all, the problem should be viewed as a business opportunity rather than a technical opportunity, which is usually the case. It is also important to know whether the decision is operational or strategic and setting the frame accordingly. The appropriate frame also includes viewing the problem from multiple perspectives by using cross-functional teams when setting the frame.

2.4.2.2. Creative, doable alternatives

This link emphasizes the importance of identifying and evaluating several alternatives (Matheson & Matheson, 1998). Matheson and Matheson suggest generating alternatives that are *new* and "significantly different" (Matheson & Matheson, 1998, p. 44). The evaluation of an alternative should not take place as the alternative emerges, but when the alternative has been fully conceived (Matheson & Matheson, 1998).

"If there are no alternatives, there is no decision"

- Matheson & Matheson (1998, p. 24)

Matheson & Matheson (1998) describe creativity as a great source of alternatives because it frames the problem in a new way - sometimes all that is needed to solve a problem are fresh eyes and not accepting the apparent solution. Apart from creativity, the authors also stress the importance of doable alternatives in terms of a commercialization plan (Matheson & Matheson, 1998).

Apart from generating alternatives, this link also focuses on creating a plan for the chosen alternative, including a recovery plan in case the alternative should fail (Matheson & Matheson, 1998). The plan needs to be detailed enough to be clear, but not too detailed in order to stay flexible (Matheson & Matheson, 1998).

2.4.2.3. Meaningful, reliable information

The key to this link is primarily finding out what you do *not* know. The information that is required needs to be explicit, for instance by defining and mapping all uncertainties. Uncertainties should be communicated as ranges and probability distributions instead of being communicated as point estimates. Asking the right questions, gathering information from different areas of the company and getting valid answers is also important in order to understand the drivers of uncertainty and avoid biases. (Matheson & Matheson, 1998)

2.4.2.4. Clear values and trade-offs

In order to rationally choose between alternatives, the company needs to decide how to measure value and how to make trade-offs between them. This is done by establishing clear criteria. Matheson and Matheson state that for many companies, the value is usually measured in cash flow and this is true even for non-monetary values. For example, the values patents, strategic fit and unmet customer needs can be compared by calculating their net present value of cash flows. Having quantified values in comparable terms, trade-offs still need to be made in terms of time and risk preference. (Matheson & Matheson, 1998)

2.4.2.5. Logically correct reasoning

This simply means gathering all previous information and making sure that the decision follows a clear logic (Matheson & Matheson, 1998). Focus needs to lie on what is important to the decision instead of what people find interesting (Matheson & Matheson, 1998). The decision needs to "feel right", but Matheson and Matheson also recommend a formal model since "the world is too complex to rely on intuition" (Matheson & Matheson, 1998, p. 26).

A conflicting view is described by Gutiérrez (2008) who states that due to lack of available information when solving problems in the early stages of an idea, it might not be possible to use rational methods. Hence, decisions in this stage can be made using intuition (Gutiérrez, 2008).

2.4.2.6. Commitment to action

Commitment to actions means following through with the decision and making sure it is properly implemented. For this reason, it is important that the decision has support from different areas of the organization and that there is a plan for the implementation of the decision. Decision-makers and implementors should be involved throughout the decision-making process. (Matheson & Matheson, 1998)

3. Method

3.1. Introduction

This master's thesis was written during the spring semester of 2016 in the cities of Lund and Malmö, Sweden. The thesis was based on a challenge that was given by Lantmännen Lantbruk and the research questions were developed from the challenge in combination with an identified gap in the literature on innovation for by-products. To guide the reader through the research method used for this thesis, this chapter will first describe the research approach, the research process, data collection and data analysis. Quality of the study is discussed later in this chapter in terms of validity, reliability, generalizability, and objectivity.

3.2. The research approach

Since the primary purpose of this thesis was to develop a framework, the research had an exploratory approach. The method that was used was abductive, meaning the process has been iterative, continuously collecting data from both theory, the interviewed companies and the case company in order to obtain a result. The aim of using an exploratory approach in combination with an abductive method was both to get a holistic view of how organizations develop business opportunities from by-products, but also to understand in depth which factors were important when identifying and evaluating the business opportunities.

3.3. The research process

The research process was initiated with a literature study which was then conducted continuously during the entire research process. Keywords used for the literature study were: circular economy, environmental economics, sustainability, sustainable business model, innovation, business innovation, design thinking, strategic decision-making, decision quality chain, by-products, and utilization of resources. During the initial phase, experts from both academia and the business sector were interviewed within the areas of innovation, innovation within agriculture, sustainability and food science. These (unstructured) interviews were conducted primarily to get a better view of the theoretical base used in this thesis.

An overview of areas of research for the thesis and methods for addressing each area is visualized in Figure 6. Areas of research within the theoretical frame were theory on how to be innovative and how to make rational decisions. The former was addressed by *Design Thinking* and the latter by *Decision Quality Chain*, as described in chapter 2.1. By-product innovation in practice was explored by qualitative

interviews which resulted in a number of important drivers and barriers when identifying business opportunities for by-products. This result, together with findings from the theoretical frame, led to the development of a new innovation framework for by-products. A validation of this conceptual framework was performed through a case study further described in chapter 3.3 and chapter 5.3. Apart from aiming at validating the developed framework, the case study also resulted in business opportunities for the case company's by-products.

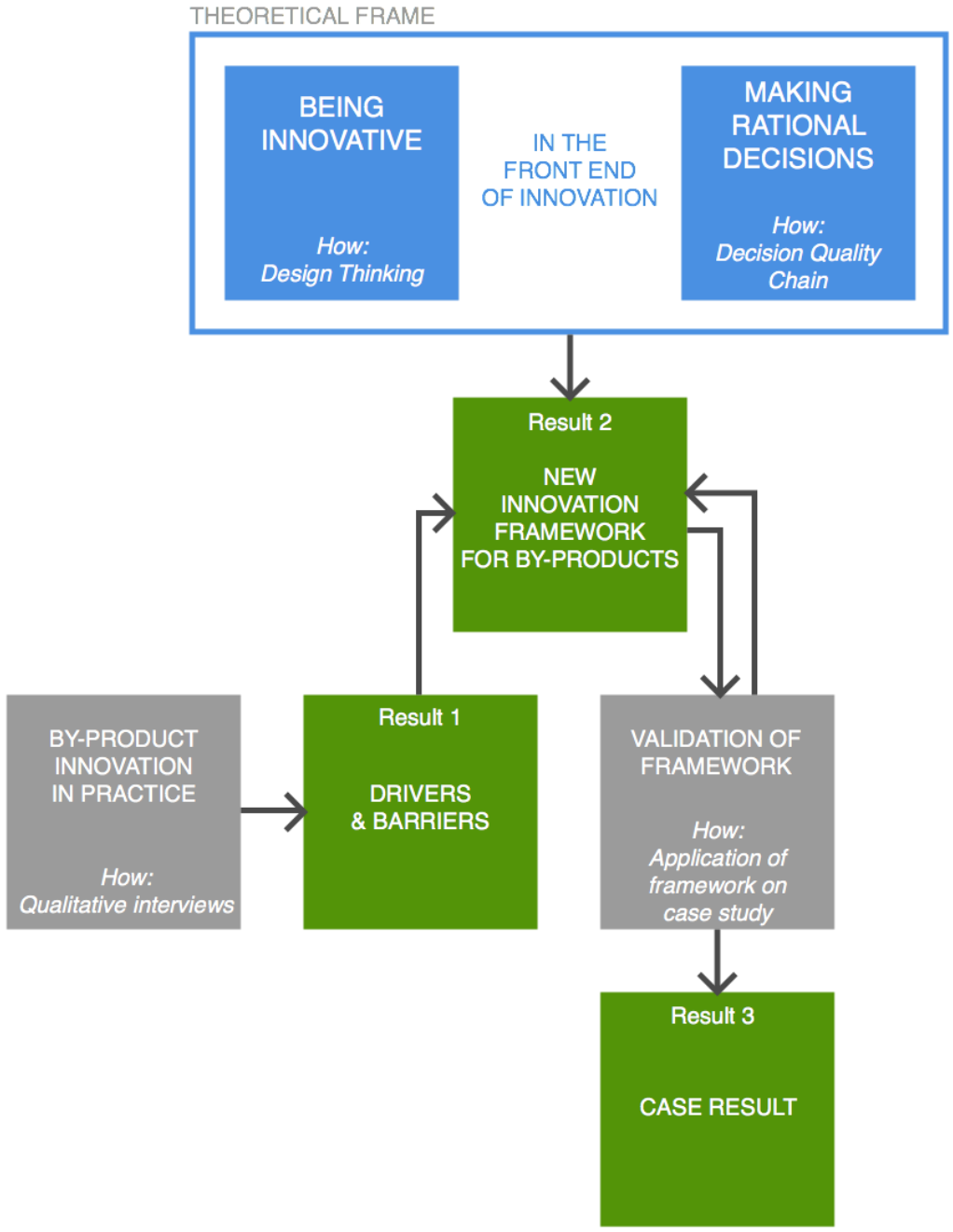

Figure 6. An overview of the research process.

Design thinking emerged as an important theoretical perspective when exploring innovation theory since we wanted to develop a framework for the early stages of innovation, a stage where exploration and creativity is of importance. Design thinking was regarded a suitable theoretical base for the early stages of innovation since it is a guiding framework rather than a strict step-by-step process, such as a stage-gate model process.

To ensure rational and well substantiated decisions, theory about strategic decision-making was explored. Within this academic field, the framework *The Decision Quality Chain* emerged as an important theoretical perspective as well as a practical model, since it is suggested to be used for the early stages of innovation, "the fuzzy front end" (Matheson & Matheson, 1998).

The conceptual framework that is presented as a result in this thesis was then developed with the theory on design thinking and strategic decision-making as a base. Primary data was collected from the companies presented in chapter 4 of this report, and the framework was revised repeatedly. Secondary data and literature were reviewed continuously during the research process.

Case study

The case study was based on a challenge suggested by Lantmännen Lantbruk and allowed the developed framework to be used and put to test on existing by-products in Lantmännen's forage seed production. The framework was used to find business opportunities for three by-products at Lantmännen, and the process and results will be presented in chapter 5.3.

3.4. Data collection

3.4.1. Primary data

For the developed framework, primary data was collected through qualitative interviews with selected companies. Companies were chosen by their experience from working with the phenomena being researched, i.e. companies that previously found a way to utilize a by-product as a business opportunity. The interviewed companies were identified through recommendations from employees at the case company, other companies or experts (as mentioned in chapter 3.3) but also through our own personal knowledge (for additional information, see Table 1). Within the selected company, the person with most experience of working directly with finding business opportunities for by-products was interviewed. An overview of the interviews that were conducted is presented in Table 1.

Table 1. Overview of the interviews conducted when developing the DVFS framework.

	How the interviewed companies were identified	Position(s) of the interviewed company representative(s)	Interview setting/type and timeframe	Aid
Company A	Internal knowledge at Lantmännen, provided by our supervisor at Lantmännen	One person: The innovation manager	30 minute phone interview	Interview guide (see appendix A). Since the interview was conducted via telephone, the interviewee was sent the interview guide beforehand
Company B	Recommendation from the supervisor at Lantmännen R&D	Three people: One business developer, the facility manager and the marketing manager (former market and product developer)	Two hour face-to-face interview at the production site	Interview guide (see appendix A)
Company C	Personal knowledge of the business. One of us had previously visited the company's production site.	One person: The marketing manager	Two hour face-to-face interview at the production site	Interview guide (see appendix A)

Since we were two people behind this master's thesis, one person conducted the interviews while the other took notes during the interviews with Company A, B and C (see chapter 4 for presentations of the companies). With Company A, the interview was conducted over the phone with a time restriction of 30 minutes, which was kept. The interviewee from Company A was the innovation manager who worked at the company during the time of the by-product case discussed. With Company B and Company C, both interviews were conducted at the companies' facilities as face-to-face interviews with two hours as a suggested time frame, which was kept. At Company B, the interviewees were a business developer, the facility manager and the marketing manager. The marketing manager had directly worked with by-product innovation. At Company C, the interviewee was the marketing manager.

For the case study, qualitative interviews were conducted with specialists and Lantmännen employees responsible for the area of interest (see Table 2). All but two of these informal interviews were phone conversations regarding specific topics, where the conversation had a timeframe of 5-30 minutes each. The other two were conducted face-to-face at Lantmännen's office in Malmö, Sweden. Additional primary

data for the case study was collected through shorter phone calls and email dialogues with already interviewed objects. An overview of the interviewees for the case study is provided in Table 2.

Table 2. Interviewees for the case study.

	Position	Conversation setting
Emilie de Craene	Nordic Brand Manager at GoGreen	Phone conversation
Håkan Nordholm	Product Manager Pre-Mixes and Mineral feed at Lantmännen Lantbruk. 25 years of experience in animal feed and pet food	Phone conversation
Håkan Tunón	PhD in Pharmacognosy, Senior Research Offices, The Swedish University of Agricultural Sciences (Swedish Biodiversity Centre)	Phone conversation
Jakob Söderström	Innovation and Business Development at Lantmännen R&D	Face-to-face conversation
Kerstin Sigfridson	Pig and Poultry Nutritionist at Lantmännen Lantbruk	Face-to-face conversation
Lars Hermansson	CMO of Animal Feed at Lantmännen Lantbruk	Face-to-face conversation
Lovisa Martin Marais	Nutrition Manager at Lantmännen	Phone conversation
Maritha Carlsson	Employee at Lantmännen Lantbruk's production facility in Eslöv	Email conversation
Interview Person 1	Executive Director at Producer 1	Phone conversation
Tomas Byström	Assessor of Cosmetic Products and Hygiene Products at the Medical Products Agency (Läkemedelsverket)	Phone conversation

Since the method for primary data collection was qualitative, the interviews were conducted with an unstructured approach where the questions and content were adapted during the interview as suggested by Lekvall, Wahlbin, & Frankelius (2001). The interview guide, which was used as a starting point for the interviews about business opportunities for by-products, is shown in appendix A.

3.4.2. Secondary data

Secondary data was collected through a desk study. Peer reviewed scientific articles were found mainly through the Lund University database LUB Search, but other databases such as Google Scholar were also used. The scientific articles were completed with literature written by experts within the areas of strategic decision-making and design thinking as secondary sources.

For the case study, websites such as the websites of the Swedish government's expert authorities The Board of Agriculture (Jordbruksverket), National Food Agency Sweden (Livsmedelsverket) and Medical Products Agency (Läkemedelsverket) were used to gather information mainly about laws and regulations. Access to the database Mintel was given by the case company which made market data available in the food and drink industry.

3.5. Data analysis - Method for compilation and analysis of data

Data for the case study was compiled and analyzed continuously. Data for the framework from theory was compiled early in the project while data for the framework from interviews were compiled after each interview. After all interviews had been completed, an analysis was conducted where the different companies interviewed were compared to each other in order to find similarities and differences in the way those companies approached by-product innovation. Critical success factors and barriers when working with business opportunities from by-products were outlined on flipcharts. The visualization helped to see patterns.

3.6. Quality of the study

3.6.1. Validity

Assessing the validity of the data means reviewing whether the collected data is of a suitable type to answer the research question, and if it has been measured accurately (Denscombe, 2009). The aim of the study was, as mentioned earlier, to understand certain areas of interest in depth. In order to get a deep understanding of the studied phenomena, a qualitative method is recommended by Denscombe (2009) but a consequence of using the qualitative method is that the validity is difficult to assess (Denscombe, 2009).

The interview guide, see Appendix A, that was used during the qualitative interviews worked as a starting point for the interviews and was thoroughly revised with the help from two Lantmännen R&D employees. The generous time frame of two of the interviews (with Company B and Company C) enabled us to further explain the questions in order to get accurate answers without misunderstandings and, as a result, we attained a great understanding of how these two companies have developed business opportunities from by-products. The shorter and stricter time frame for the interview with company A could imply that the validity of the data collected from this interview was weaker, however we perceived the interview as thorough and comprehensive despite the time constraint.

When data had been collected it was summarized and sent back to the participants of the study for validation, which according to Höst, Regnell, & Runeson (2006) and Denscombe (2009) can help increase the validity.

3.6.2. Reliability

During the interviews conducted in this study an interview guide was used, but because of the character of the study the questions were not followed to the letter and the responses and follow up questions that were asked during the various interviews were inevitably different. Therefore, it is not likely that a repeated study would receive the exact same results. However, we find it likely that the main findings of a repeated study would still be similar to those found and presented in this study.

During this study, a log was used to note our thoughts and important decisions. This documentation process is mentioned by Denscombe (2009) as a factor that can enhance reliability.

A factor that might affect the results generated from interviews is the amount of time that has passed since the situation being described, i.e. the innovation process for a by-product to become a business

opportunity, took place. A process that happened recently is more likely to be accurately described than a situation that took place several years ago. At the time of the study, it had been two years since the processes took place at two of the companies, whereas one company encounters these situations continuously.

3.6.3. Generalizability

The study sample consisted of four companies in different industries. This fact affects generalizability in two ways: the fact that the companies were present in different industries but still generated similar results indicates that the result of the study is generalizable for companies working with biological by-products regardless of industry. However, since the sample was so small, it is difficult to know if the results are coincidental or actually part of a larger pattern. The generalizability is therefore difficult to assess, and further studies of the phenomena are recommended.

In this study, and because of the qualitative nature of the study, we have tried to give a detailed description of the phenomena being researched, which according to Denscombe (2009) can help increase generalizability by giving the reader an opportunity to truly understand the phenomena.

3.6.4. Objectivity

The second result of this study, the developed framework, is based on theory and practice, but to a large extent it is also based on ideas and our own perceptions. These perceptions have inevitably had an effect on the result. Denscombe (2009) explains that since qualitative data is always a part of an interpretation process it can never be entirely objective. However, we have been aware of our preconceptions during the research process and have questioned conclusions and carefully interpreted our results.

4. Presentations of studied companies

A short presentation of the tree interviewed companies and their examples of having found a business opportunity for a by-product follow in this chapter. A longer description of the company for which the case study has been performed is also presented.

Company A - The Biofuel Producer

Company A
Turnover **1.7 Bn SEK**
Employees **93**
Year founded **2001**

Figures are for 2014 (Alla Bolag, 2016)

Company A is a large manufacturer and supplier of biofuel and animal feed based in Sweden. Its core competence is extracting ethanol and protein from grain. In 2014, Company A started selling off a **by-product** in its production to a customer, which refines the by-product and sells it as a product to its customers. The application for the raw material, which the by-product consisted of, was well-known beforehand, but the by-product had never been extracted from biofuel manufacturers before this collaboration was initiated. The customer placed a new production site next to Company A, where the customer refines the by-product from Company A. (Gundberg, Phone Interview, 2016)

Company B - The Meat Producer

Company B
Turnover **5 Bn SEK**
Employees **1100**
Year founded **2008**

Figures are for 2015 (Nordell, 2016)

Company B is a Sweden-based meatpacking company with slaughtering and butchering as core competencies. The company distributes both cuts and ready-made products. Company B's markets are Swedish retail, export, industry and food service. **By-product** innovation either occurs from a) *a customer request* where the customer has identified a consumer demand and Company B sees this as a chance to choose a by-product in order to increase the by-products value, b) *an international customer request* for a specific animal part; or c) *an idea from an employee* of a possible application for a by-product. (Nordell, Sundelöf, & Lundbladh, 2016)

Note: Company B does not refer to its products as "by-products" since it is currently able to gain some value from all animal parts. (Nordell, Sundelöf, & Lundbladh, 2016) *However, since Company B has a goal of utilizing these products in a more profitable way through innovation, we will refer to them as by-products.*

Company C - The Vegetable Foods Producer

Company C
Turnover **45 Mn SEK**
Employees **14**
Year founded **1990**

Figures are for 2015 (Alla Bolag, 2016)

Company C is a Swedish vegetable foods and feed company with core competence in producing and refining crops. Customers are both Swedish retailers and end consumers buying products from the company's farm shop. The product with the highest revenue share is a vegetable oil and when producing this oil, two thirds of the raw material remains a by-product. This **by-product** is sold as animal feed but was during 2014 investigated and developed as a food product. (Persson, 2016)

Case company - Lantmännen

Case company
Turnover **37 Bn SEK**
Employees **10 000**
Year founded **2001**

Figures are for 2015 (Lantmännen, 2015)

Lantmännen Group is an agricultural cooperative that manages the entire value chain, or as Lantmännen describes it "Together we take responsibility from field to fork" (Lantmännen, 2015). Divisions within Lantmännen Group are agriculture, food, machinery and energy (Lantmännen, 2015). Lantmännen's collective core competence could be described as the production and refinement of crops for various markets.

The case study at Lantmännen was performed at the agriculture division, Lantmännen Lantbruk. Streams of by-products emerge at several stages of the production processes at Lantmännen, but the focus of this master's thesis was by-products in the production of forage seeds in the division Lantmännen Lantbruk. As of today, Lantmännen Lantbruk does not actively seek business opportunities for by-products, but there seems to be an interest in utilizing by-products in a more value creating way, particularly among certain employees.

By-products in the forage seed production

Forage seeds are cultivated by Lantmännen's farmers and all seeds are received by the seed and grain production facility in Eslöv. The facility receives 5000-6000 tons of seeds per year. Husks, small grains of gravel and other residue is weeded out in a refining process and samples of the refined seeds are sent to the Swedish Board of Agriculture (*Jordbruksverket*). Seeds that do not fulfil agricultural criteria, such as criteria for germination and pureness, are if possible refined once again but if still not certified, sent to a biogas manufacturer in Jordberga. As mentioned in chapter 1.3, three by-products were identified as particularly interesting due to their quality and quantity, these three were; red clover, white clover and timothy seeds. These three seeds account for the greatest amount of discarded seeds in the production.

5. Result

5.1. Findings from interviews

During qualitative interviews with the three selected companies presented in chapter 4, a few aspects emerged that were stated to be either drivers or barriers for the success of the biological by-product innovation process for these companies. These drivers and barriers are described in this chapter and incorporated in the developed framework in chapter 5.2. When asked to describe which aspects were more important than others, the companies concluded that all aspects were important when finding and evaluating business opportunities. However, one aspect, gut feeling, stood out as more noticeable than others.

Commercial interest

For all companies, market demand or market need is or has been of significant importance to develop an idea. The companies were aware of the market need before developing the idea, either by knowing the application for the by-product from start, or through strong consumer knowledge, either from personal contact with end consumers or through customer requests from customers that have identified a consumer trend or need.

Company A described the commercial interest as a primary factor as to why it decided to investigate the by-product as a business opportunity (Gundberg, Phone Interview, 2016). The company was certain that there was a demand for the by-product since the by-product was renewable compared to the raw material that the manufacturers at the market refined at the moment, as well as manufactured in Sweden (Gundberg, Phone Interview, 2016). Company A was positive that the attributes renewable and locally manufactured were valued by these manufacturers (Gundberg, Phone Interview, 2016). Having identified a market need for the by-product early gave the company confidence to investigate the opportunity further (Gundberg, Phone Interview, 2016).

Company B uses the market need as a way of leveraging a by-product with a lower value into a product with a higher value (Nordell, Sundelöf, & Lundbladh, 2016). The company described the market need as the starting point of innovation processes a) and b) as described earlier. Moreover, when Company B identifies a market need for any new product, it will consider if that product is commutable to a by-product that is valued less today, thereby increasing the value of the by-product (Nordell, Sundelöf, & Lundbladh, 2016).

Company C stated to know its customers and their needs very well, as a result of continuous personal contact with its customers (Persson, 2016). The target group for Company C is customers that value products that are healthy, preferably organic and produced in Sweden (Persson, 2016). Customers of Company C tend to be loyal to the brand and curious about new products (Persson, 2016). The company does not explicitly claim to base its innovation process on a market need, however, the market need or commercial potential is, according to our conclusions, a box that is already ticked for Company C since all products, including the ones developed from by-products, fulfill the mentioned customer values.

Customer relationship

Two of the companies mentioned strong customer relationship as an enabler for technology push, something that is stated to be positive for innovation.

Company B claimed to have a strong relationship with its customers in retail, which allows it to push the boundaries when it comes to product innovation, including by-product innovation (Nordell, Sundelöf, & Lundbladh, 2016). If a business opportunity is developed according to innovation process c) (as described in chapter 4), and not from a customer request, Company B does not know whether the end consumer will like it or not (Nordell, Sundelöf, & Lundbladh, 2016). Company B stated that a strong relationship with a customer can enable it to pitch a more innovative concept to a customer (Nordell, Sundelöf, & Lundbladh, Email Conversation, 2016).

Company C described a good relationship with its end consumers and explained that sometimes, the company develops products without confirmed market demand, and starts selling small scale to end consumers (Persson, 2016). Personal contact with end consumers who are loyal to the company, makes it possible for the company to test their way and get instant feedback without affecting the relationship negatively even if the product would fail (Persson, 2016).

Utilization of all resources

All companies mentioned utilizing all resources in the production as a motivation to find better use for their by-products. Limited amounts of raw material and/or production facilities motivated increased utilization of by-products in order to increase the companies' profits.

Company A stated that it is striving to use all the resources in the production in the most efficient manner possible (Gundberg, Phone Interview, 2016). Company B said to be continuously seeking for ways to turn

lower value animal parts into a product with a higher value (Nordell, Sundelöf, & Lundbladh, 2016). Company C explained that acquiring new farmland is very expensive which made finding business opportunities for existing products important (Persson, 2016).

Seeing the entire value chain

In order to see all possibilities and application areas for the by-product, the companies identified seeing the whole value chain as an important factor.

Company A explained that understanding where in the value chain the company operates, and finding good partners, is of high importance for finding business opportunities for by-products (Gundberg, Phone Interview, 2016). When Company A viewed the entire value chain, it identified a potential customer to partner with that could take the by-product to the market (Gundberg, Phone Interview, 2016). Company B is gradually acquiring a larger part of the value chain, therefore it is natural for the company to view the entire value chain when innovating (Nordell, Sundelöf, & Lundbladh, 2016).

> *"Our by-product can be someone else's raw material – and vice versa"*
>
> - Gundberg, Phone Interview (2016)

A driving spirit

The companies mentioned dedicated people as drivers for developing an idea for the by-product. Two of the companies had a driving spirit, an enthusiastic person within the organization who was very passionate about finding a better way to utilize a by-product and had a vision of what to do with it.

Company A explained that without the driving spirit, in this case an employee working as a business developer, the idea of utilizing the by-product would probably never have been followed through (Gundberg, Phone Interview, 2016). At Company C, the marketing manager seemed to have been the driving spirit of the utilization of the by-product considering the fact that she initiated the project with great passion.

Having one person that has a vision and follows the idea through is not the case at company B, instead idea-generating employees and a by-product oriented business development team could be seen as a substitute for the "driving spirit". For company B, ideas for new applications emerge from individuals all around the company and are collected and possibly developed by the business development team (Nordell, Sundelöf, & Lundbladh, 2016). Finding and developing business opportunities that increase the value of a

by-product is explained to be part of the business development team's duties (Nordell, Sundelöf, & Lundbladh, 2016).

Gut feeling

All companies emphasized intuition as a considerable influence to developing an idea further. When evaluating different alternatives, intuition is preferred over formal models.

Company B explained that you usually *know* if an idea is good or not (Nordell, Sundelöf, & Lundbladh, 2016). Both Company A and Company C mentioned the "gut feeling" as being a valuable input (Gundberg, Phone Interview, 2016; Persson, 2016). Company C stated gut feeling, together with relatively low costs, to be the answer to the question of how different ideas were evaluated (Persson, 2016).

Sustainability and innovation as core values

The core values of the interviewed companies seemed to have had an effect on the willingness to use by-products as a basis in the innovation process. All companies expressed their belief that economic and environmental sustainability go hand in hand.

Company A said environmental sustainability to be its watchword and that the goal is to produce products as efficiently as possible (Gundberg, Phone Interview, 2016). Company B described environmental work as a key factor in the organization and that environmental and climate considerations are always included, to the point where it is technically and economically justified (Nordell, Sundelöf, & Lundbladh, 2016). Company B also shared that it sees a thorough environmental work as a prerequisite for a sustainable and healthy development of the company (Nordell, Sundelöf, & Lundbladh, 2016). For Company C, environmental sustainability is an outspoken core value and the company emphasized that it is important for businesses to see the economic benefits of finding environmentally sustainable solutions (Persson, 2016).

Two of the companies, Company B and Company C, also pointed out that renewal and innovation is important within the company (Nordell, Sundelöf, & Lundbladh, 2016; Persson, 2016).

Quantity

The available quantity of the investigated by-product seemed to be a factor that determined if business opportunities from the by-product were developed or not.

Company A explained that the idea of using the by-product was up for discussion several times, but it was not until the production facilities were expanded that the quantities of the by-product became large enough for management to realize its business potential (Gundberg, Phone Interview, 2016).

For Company C, the quantity of the specific by-product discussed was greater than the quantity of the main product (Persson, 2016). The by-product was already sold on the feed market, together with other similar by-products, but this particular by-product was investigated for business opportunities with higher value due to its significantly greater quantity (Persson, 2016).

Due to the nature of the meat industry, quantities for Company B's by-products in terms of volume or weight are large. Company B explained its need for balancing the total quantity of different parts of the animal (Nordell, Sundelöf, & Lundbladh, 2016). If there is an increased demand in one part of the animal, the company needs to find business opportunities for the other parts (Nordell, Sundelöf, & Lundbladh, 2016).

Time and resources

Having the resources needed for developing a business opportunity for a by-product, especially in terms of working hours, is mentioned by all companies as a key factor.

Company B has a business development team working with business development of by-products which allows the team to work on the utilization of by-products as part of their daily tasks (Nordell, Sundelöf, & Lundbladh, 2016). Company C decided to hire a product developer in order to find the time to work with a particular idea concerning the utilization of a by-product (Persson, 2016). Company C mentions that it is important to work with other people when developing ideas, and emphasizes the importance of feedback (Persson, 2016). When Company A developed its idea for the by-product, the initiator (the driving spirit) got help from a team to develop the idea (Gundberg, Phone Interview, 2016).

5.2. The conceptual framework for by-product innovation

5.2.1. Introduction

The conceptual framework for by-product innovation presented in this chapter was developed by combining theory on innovation and decision-making with insights from companies that had practical experience of by-product innovation. The theoretical base is described in chapter 2 while barriers and drivers for by-product innovation identified through qualitative interviews are summarized in chapter 5. Further validation of the framework was gained through practically testing the framework on the case company presented in chapter 4. Figure 6 in chapter 3 gives an overview of how the conceptual framework was developed.

The DVFS framework is an innovation framework that will work as a tool for companies and organizations to identify and evaluate business opportunities for a biological by-product. The framework is meant to generate one or several alternative idea(s) to the current application for the by-product. The idea(s) generated from the framework will hopefully be desired by users and/or stakeholders, economically profitable, technically and organizationally possible to implement and environmentally sustainable. The DVFS framework focuses on discovering possibilities dynamically and rapidly. Its main purpose is to ensure that important factors are not forgotten along the innovation process, but also to question assumptions and find solutions that might not seem obvious at first sight.

To successfully gain business opportunities from the DVFS framework, the framework is best carried out by more than one person. It is also important that the user(s) are given enough time and budget to fully discover innovative solutions and make well-grounded decisions.

5.2.2. When to use the framework

The framework is developed as a tool to be applied in the early innovation stage and will generate desirable, viable, feasible and sustainable ideas that can make a basis for a business case. The framework itself does not intend to provide a complete business case with hard numbers for implementation of the idea(s).

5.2.3. The five main aspects of the DVFS framework

- ❑ Defining market values for biological products for different industries
- ❑ DVFS criteria
- ❑ Iteratively creating alternatives and making decisions
- ❑ Balancing assumptions and estimations with intuition
- ❑ Gradually making more detailed estimations

5.2.4. How to approach the framework

The DVFS framework is illustrated in Figure 7 and is approached as follows:

Step 1. Define potential industries for biological products and prioritize them according to market value on a value axis

Step 2. Start the DVFS-loop at the highest level of the value axis

- If an idea does not fulfil all DVFS criteria, move to the next value level below

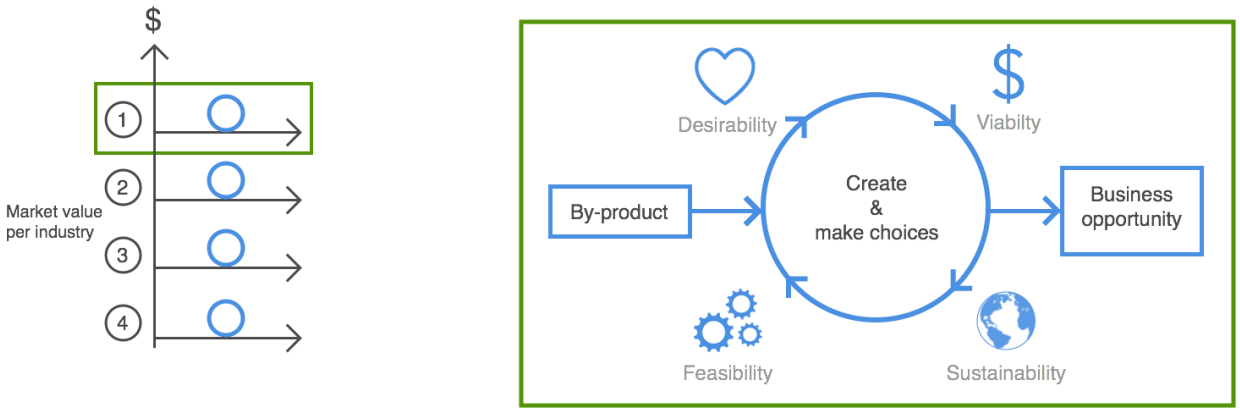

Figure 7. The DVFS framework.

Defining and prioritizing potential industries for biological products

First, before generating and evaluating business ideas for the by-product, potential industries for biological products in general (not just the currently examined by-product) should be identified and prioritized in terms of expected revenue per weight for the organization. Estimate within which area of application your organization gets the highest revenue ratio per weight and visualize this as a value axis, see Figure 8. Examples of general applications can be pharmacy, food, feed, biogas and heat.

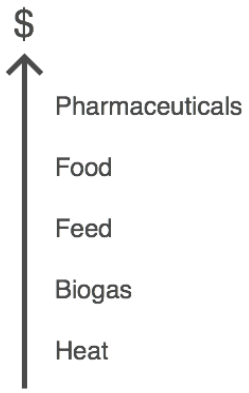

Figure 8. Example of application areas for a biological product and their relative value per weight.

An open mind is important when establishing the value axis. The potential industries do not have to be part of the organization's current business areas or the current customers' business areas. Refining the by-product for an industry that is not in line with the company strategy might not be optimal, but selling off the by-product as a raw material for a manufacturer further down the value chain might be.

DVFS - Desirability, viability, feasibility and sustainability

When identifying and evaluating business opportunities, there are four key criteria that have to be addressed and fulfilled: desirability, feasibility, viability and sustainability. **The desirability criterion** is about what people (customers, consumers and other stakeholders) need, want, desire and value. **The feasibility criterion** suggests what is technically and organizationally possible within the foreseeable future. **The viability criterion** explores ideas that are profitable and will become part of a sustainable business model. Finally, **the sustainability criterion** makes sure that the business idea is less harmful to the environment than the current solution. To get an understanding of what the different criteria can include, examples of important factors within each criterion are listed in Figure 9. The factors listed under each criterion in Figure 9 should be seen as suggestions and can be adapted to the company's preferences.

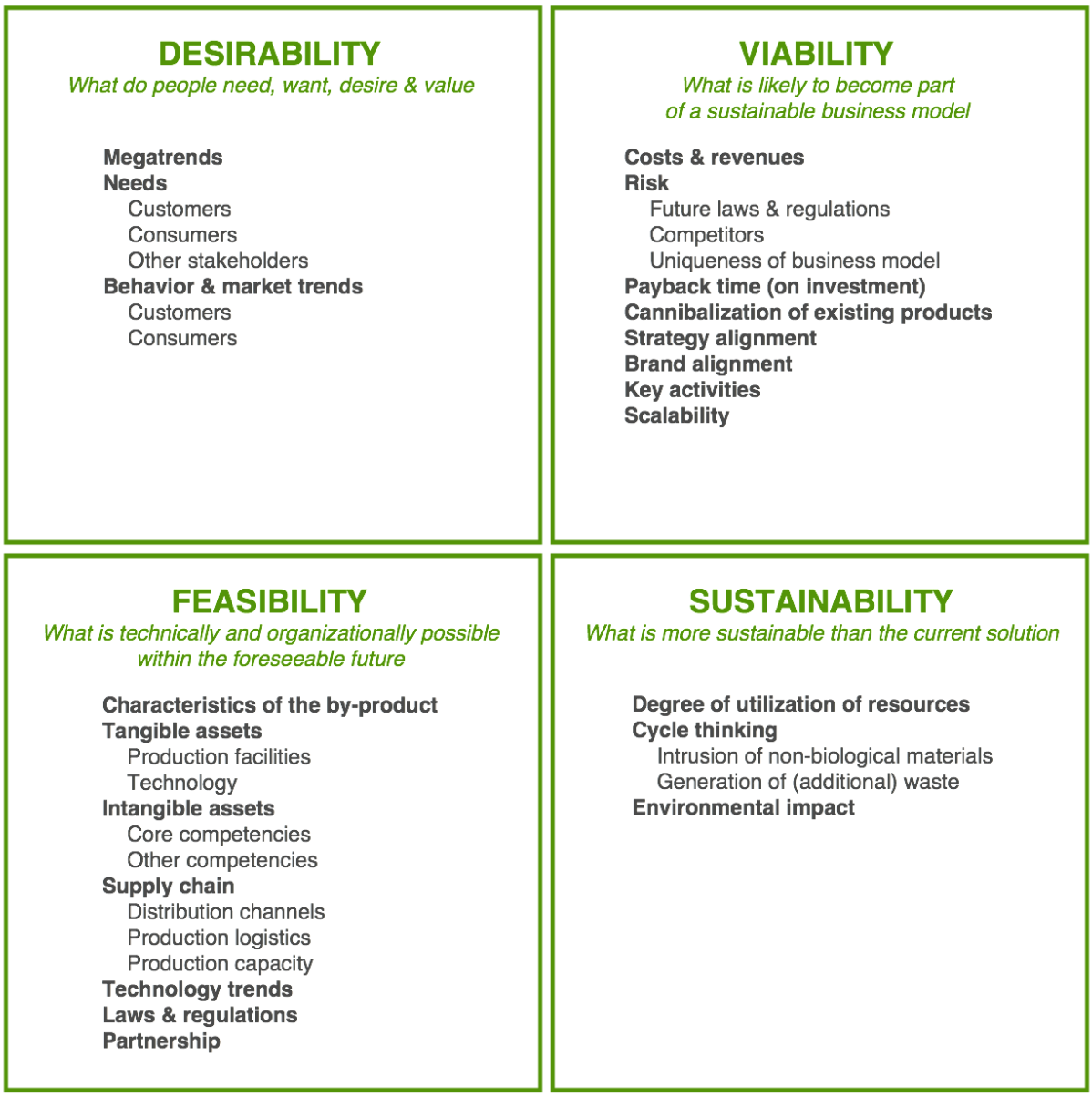

Figure 9. Suggested factors to examine within the DVFS criteria.

Looping the DVFS criteria

All four DVFS criteria should be considered iteratively throughout the innovation process. For each loop, the four criteria should be investigated if they are fulfilled. There is no right or wrong when choosing which criterion to investigate first, since all four criteria need to be investigated in a loop.

Balancing assumptions and estimations with intuition

To determine whether the criteria are fulfilled for an idea, estimations should be combined with intuition.

Iteratively creating alternatives and making choices

Throughout the process, the user(s) should create multiple options and then make choices, repeatedly as shown in Figure 10. Question what you think you know and explore possibilities within each criterion. Avoid choosing the first idea that comes to mind.

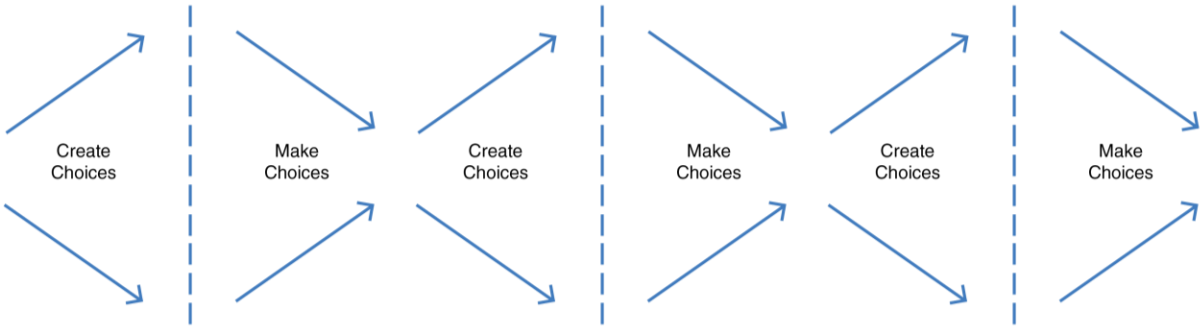

Figure 10. The process of diverging and converging: creating and making choices

Gradually making more detailed estimations

For the first loop, the four criteria should only be investigated briefly without detailed calculations. Estimations about each criterion should gradually become more detailed for each loop.

Where to start and when to quit

To generate ideas, the first DVFS-loop should start in the application area with the highest biological value level. Check if it *seems* desirable, viable, feasible and sustainable to develop the by-product within this application area. If yes, continue looping at this level. As soon as an idea does not seem to apply to one of the DVFS criteria, following should be determined: are the other three criteria well fulfilled? If yes, the idea can be explored further, and multiple new options should be created within the questionable criterion in order to find out if the idea is reasonable. However, if one criterion does not seem to be fulfilled, and the other three criteria are merely fulfilled, then the idea should be abandoned and a new loop should be initiated on the next value level below.

5.3. Result - Validation of DVFS framework

5.3.1. Introduction

The case study introduced in chapter 3.1 and further described in chapter 4 was conducted with an aim to validate the developed DVFS framework (see chapter 5.2). The results from the case study include explored business opportunities for the three by-products timothy seeds, red clover seeds and white clover seeds, which are presented in chapters 5.3.6-5.3.8 and summarized in chapter 5.3.9. Before presenting the results for the different by-products, a description of general findings for the case study is demonstrated in chapters 5.3.2-5.3.5.

5.3.2. Defining and prioritizing potential industries for biological products

The definition and prioritization of potential industries for biological products for Lantmännen was provided by Lantmännen's corporate function R&D and revised by us. The potential industries cosmetics, pet food and biogas were added to the value axis provided by Lantmännen. The value axis shown in Figure 11 was the result.

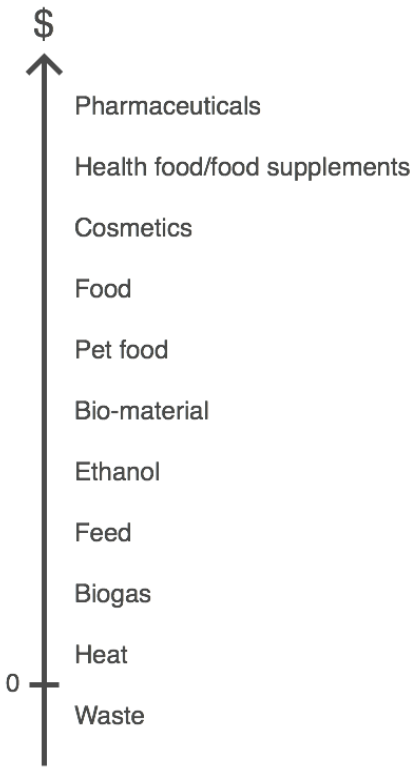

Figure 11.Value axis of Lantmännen.

5.3.3. Looping the DVFS criteria

For each of the three different by-products, a loop was initiated at the potential industry of the highest value, i.e. the pharmaceutical industry. Findings from the highest value level, the pharmaceutical market, is explained as an example in detail below whilst the concluding results on business opportunities for the three different by-products are listed separately Table 4, Table 5, and Table 6.

5.3.4. Example - findings from the highest value level

A quick desk research was conducted to see if there was a possible application area within the pharmaceutical industry for the by-product timothy seeds. An interview with Lovisa Björnsson (2016, see appendix B for interview guide), Professor at Environmental and Energy Systems Studies within the Faculty of Engineering at Lund University, resulted in us getting the insight that exploring the technical feasibility of producing "fine chemicals" from forage seeds for the pharmaceutical industry was too advanced for the scope of this master's thesis. Since no possible applications within pharmaceuticals were found, this potential industry was determined not to be feasible or viable. This was based on several factors: both because of lack of the advanced competencies necessary to enter the pharmaceutical industry, but also because the volumes of the by-products available were not considered to be large enough to generate the revenue needed to cover the investment costs associated with entering this market, such as research costs. A visualization of the result from this level is summarized in Table 3.

Table 3. Findings from the first DVFS loop for the pharmaceutical industry for timothy.

Findings from first DVFS-loop for the pharmaceutical industry for timothy	
Desirability None found at first loop, but not eliminated	**Feasibility** Not considered feasible, too advanced with regards to the available resources
Viability Not considered viable	**Sustainability** -

After this first loop, it was apparent that taking the seeds to the pharmaceutical industry was not DVFS. The same conclusions were drawn for red clover and white clover seeds. Therefore, the next loop was initiated separately for each of the three by-products on the level below: food supplements. Results from food supplements and following levels for the different by-products are summarized in Table 4, Table 5, and Table 6.

5.3.5. Interpreting the results from the DVFS framework

The framework was used continuously during the identification and evaluation of the possible business opportunities for all three by-products. On some value levels, several loops were necessary to decide with certainty if there were any possible business opportunities on the value level in question. Since the current use for the seeds is biogas, the lowest potential level that could be investigated was the feed industry. Table 4 describes which criteria were or were not fulfilled at every value level for the timothy by-product, with a short explanation where necessary. Table 5 lists the results for the red clover by-product and Table 6 lists the results for the white clover by-product.

5.3.6. Results by-product timothy seed

Table 4. Result from DVFS framework for potential industries for timothy.

Result **Potential industries for timothy *(Phleum pratense)***				
	1. Desirability	2. Feasibility	3. Viability	4. Sustainability
A. Pharmaceutical	?	X	X	?
B. Food supplement	**X**	**X**	X	?
C. Cosmetics	**X**	X	X	
D. Food	Yes	Yes	**X**	Yes
E. Pet food	X	X	X	
F. Bio-material	?	X	X	Yes
G. Ethanol	X	Yes	X	X
H. Feed	X		X	

A. See chapter Example - findings from the highest value level5.3.4.

B. Timothy is not listed as a food supplement according to EU law (European Commission, Novel Food Catalogue, 2015). No specific health claims were found for timothy or timothy seeds and no food supplement products containing timothy were found on the market, therefore the feasibility and desirability criteria did not seem to be fulfilled and the search was continued on the next value level.

C. Timothy is not listed in CosIng, the European Commission database for information on the EU's cosmetic ingredients and substances (European Commission, n.d.). No specific cosmetic claims were found for timothy or timothy seeds, and no cosmetics containing timothy were found on the market. Since

no traces of desirability of timothy seeds in cosmetics were found, and no other criteria were strong, next value level was explored.

D. Nutritional analysis of timothy seeds showed relatively high protein and fiber content, which are nutritional contents that were stated as valuable for consumers on the market according to Emilie de Craene, Nordic Brand Manager at GoGreen (de Craene, 2016). However, timothy is not listed as a food according to EU law (European Commission, Novel Food Catalogue, 2015). Taste tests led to the conclusion that timothy seeds need to be peeled to be consumed as food, and thus, another refining step in the production process would be needed. These two latter factors, together with the small quantity, prevented viability on this value level.

E. Large quantities of an ingredient are needed in the production of pet food, *if* the ingredient does not have a proven health claim, according to animal nutrition specialist Nordholm, who has worked in the pet food industry for several years (Nordholm, 2016). Since no specific animal health claims were found for timothy or timothy seeds, desirability and viability criteria were stated to be unmet for the pet food industry. Since no content in timothy seeds was found desired as pet food, the feasibility of producing pet food of timothy seeds was stated as non-existing.

F. For the by-product to be profitable as bio-material, the quantity of the by-product would have to be much greater. This was confirmed by Söderström (2016), Lantmännen employee working with Innovation and Business Development at R&D, who is knowledgeable within the area. Thus, the by-product could not fulfil the viability criterion at this value level.

G. Extracting ethanol from the seeds was stated technically feasible, but the amount ethanol that could be extracted from all three seed types was estimated to be approximately 0.025 percent of the weight, see appendix C for calculations. In relation to the insignificant quantity of ethanol possible to extract from the seeds, the desirability was perceived as non-existent. The significant distance between Eslöv and the ethanol production site in Norrköping made viability and sustainability criteria unfulfilled.

H. Although the protein content of timothy was stated as relatively high for the food industry, as animal feed, the timothy seed was claimed to have too low protein content. Due to the low protein content (relatively other vegetable alternatives on the animal feed market), timothy seeds were claimed to have no demand on the feed market according to Hermansson (2016), CMO of animal feed at Lantmännen Lantbruk and Sigfridson (2016), feed least cost formulation manager at Lantmännen Lantbruk. Moreover,

feed production requires large quantities of an ingredient and the quantity of the seeds was considered too small to uptake a silo according to Hermansson (2016). Thus, desirability and viability criteria were not met.

Since the next level of the value axis is biogas, the DVFS framework resulted in no alternative business opportunities for the timothy seeds. The current biogas production of timothy seeds was concluded to be the optimal solution.

5.3.7. Results by-product red clover seed

Table 5. Result from the DVFS framework for potential industries for red clover.

Result **Potential industries for red clover *(Trifolium pratense)***				
	1. Desirability	2. Feasibility	3. Viability	4. Sustainability
A. Pharmaceutical	?	X	X	?
B. Food supplement	?	?	?	?
C. Cosmetics	Yes	Yes	Yes	

A. See chapter 5.3.4.

B. Aerial parts of the red clover plant are classified as food supplements according to EU law (European Commission, Novel Food Catalogue, 2015) and food supplement products including red clover extract were found online. However, there are no manufacturers of plant extracts in Sweden according to herbal medicine and natural remedies researcher Tunón (2016), and Byström (2016), assessor of cosmetic products and hygiene products at the Medical Products Agency *(Läkemedelsverket)*. Both Tunón (2016) and Byström (2016) said that plant extract manufacturers are commonly located in Central Europe, mainly Germany and Austria, which was confirmed by searching for manufacturers online. One manufacturer was found in Denmark, Producer 1 (Herrens Mark, n.d.), which was contacted. Producer 1 uses the plant without seeds to produce the extract and the Executive Director was not familiar with any red clover *seed* extract producers in Denmark (Interview Person 1, 2016). Without any manufacturers in Sweden, a closer investigation of whether the red clover extract used in food supplement is (or could be) made from the plant's seeds, would be too time-consuming.

C. The name trifolium pratense and trifolium pratense seed extract is listed in CosIng (European Commission, n.d.). According to Byström (2016), the fact that an ingredient is listed in the CosIng database is an indication that this ingredient is on the market and that a company has performed a safety assessment for the ingredient. Claimed functions for the seed extract in the CosIng catalogue is antioxidant effects (European Commission, n.d.). The antioxidant effects for red clover seeds were also confirmed in literature (Çölgeçen, Koca, & Büyükkartal, 2011; Oleszek & Stochmal, 2002).

In a study from 2014 on the potential of renewable antioxidant extracts for cosmetics, antioxidants from agro-industrial by-products were proposed to meet the growing need for natural antioxidants in cosmetics (Balboa et. al., 2014). Thus, extracting antioxidants from the by-product red clover seeds seemed desirable. The market size was not further investigated due to time constraints.

Red clover seed extract is regulated by general cosmetics regulations which require documentation and traceability for the raw materials and the finished product (Byström, 2016). Lantmännen's seed production is well documented today and traceability is already a requirement for the production, which makes it possible in terms of regulations for Lantmännen to be a supplier in the cosmetics industry.

Two potential business opportunities were identified within the cosmetic industry: selling off red clover seeds to an extract manufacturer or producing red clover seed extract to sell to a cosmetics manufacturer. Both alternatives were stated to be desirable, feasible and sustainable. The viability criteria of producing seed extract or selling red clover seeds was discussed with Martin Marais (2016), nutrition manager at Lantmännen, who did not see that refining the by-product one step further, i.e. producing seed extract, for a new market would be an unreasonable future strategy for Lantmännen. Details about selling price for seeds and seed extract were difficult to estimate within the time constraints, which was why no decision between the two business opportunities (selling off the seeds or producing seed extract) was made. Both business opportunities where stated as having potential but needed more research.

5.3.8. Results by-product white clover seed

Table 6. Result from the DVFS framework for potential industries for white clover.

Result **Potential industries for white clover *(Trifolium repens)***				
	1. Desirability	2. Feasibility	3. Viability	4. Sustainability
A. Pharmaceutical	?	X	X	?
B. Food supplement	?	?	?	?
C. Cosmetics	?	?	?	
D. Food			X	Yes
E. Pet food			X	
F. Bio-material	?	X	X	Yes
G. Ethanol	X	Yes	X	X
H. Feed	?	Yes	Yes	Yes

A. See chapter 5.3.4.

B. White clover is not listed as a food supplement according to EU law (European Commission, Novel Food Catalogue, 2015), but since the plant is similar to red clover, which is, as mentioned, classified as a food supplement, it might also have the same functional claims as a food supplement. However, since no data was found regarding the possibility of using red clover *seeds* for food supplements, further investigation of white clover seeds as food supplements were not stated reasonable within the given time frame.

C. The name *trifolium repens* is listed in CosIng, but not the seeds specifically (European Commission, n.d.). As explained by Byström (2016) this means that the ingredient white clover seed is not reported to be present on the market. Thereby, white clover seed extract manufacturers that would buy the seeds are most likely non-existent. Just as for red clover seeds, understanding all the technical aspects of extracting additives from white clover seeds in order to evaluate the DVFS criteria were stated unfeasible for this thesis.

D. A nutrition analysis of the white clover seeds showed a high content of protein and fiber, even higher than for timothy seeds. As earlier stated, protein and fiber are desired on the market. However, the trifolium repens plant (and seed) is not classified as food according to EU law (European Commission,

Novel Food Catalogue, 2015). Classifying a product as food is a process that demands time and resources, i.e. the viability criterion would have to be greatly fulfilled for this value level to be interesting. The quantity of seeds was deemed too small in comparison to the investments needed to take the food to the market (applying for novel food, changing production facilities etc.), which implied that the viability criterion was not fulfilled.

E. The quantity of white clover seeds limited the utilization possibilities within the pet food industry as well, as explained in chapter 5.3.6 for timothy seeds. However, if the white clover seed would possess extraordinary health claims for pets, it might still be of interest in this industry. One example of a health claim is if the seed would contain lutein, which is a yellow pigment that treats impaired vision for dogs (Nordholm, 2016). Since white clover seeds are yellow, there might be a possibility that the seeds contain lutein according to Nordholm (2016), but no evident data regarding this was found. Since no evident data on health claims for white clover seeds was found, utilizing the white clover seed at the pet food industry level does not seem viable.

F. For the by-product to be profitable at this value level, the volume of by-product would have to be much greater (see the discussion on value level F for the timothy seed, chapter 5.3.6). Thus, the by-product white clover seed did not fulfil the viability criterion.

G. Regarding ethanol production, the amount of ethanol that can be extracted from the by-product is extremely small, see chapter 5.3.6 and appendix C, meaning it would not be profitable or sustainable to extract ethanol from white clover seeds.

H. Because of the white clover seeds' high protein content, it might be desirable as animal feed, according to Sigfridson (2016) and Hermansson (2016). However, just like on industry level E and F, the quantity of the seed set boundaries for the viability in this industry level. If Lantmännen were to find a customer that desires only a small quantity of the by-product, however, it would most likely be more profitable and sustainable than the current application. Further search for such a customer was not accomplished due to time constraints.

5.3.9. Conclusions case study result

No functional claims were found for timothy seeds within food supplement, cosmetics, pet food and feed, which indicated that there was no desirability for timothy seeds within these areas. Combining the lack of functional claims with a small quantity, resulted in classifying these areas as unviable as well as

undesirable. Within food, timothy seeds seemed to be desirable thanks to nutritional contents appreciated by consumers, however, the factors that timothy seeds are not classified as food, the small quantity and the need for another refining process (for peeling) made this area highly unviable.

For both timothy and white clover, ethanol extraction was stated feasible but not viable due to the low percentage of extracted ethanol possible. Bio-material was stated to be unviable for timothy and white clover seeds since greater quantities would be needed to make it viable.

Since no alternative business opportunities were found for the timothy seeds, the current biogas production of timothy seeds was stated to be the optimal solution. If the quantity would have been greater, however, bio-material could have been further investigated.

For red clover seeds, an indication of a possible application within food supplements was discovered since aerial parts of the plant is classified as food supplements. However, since only food supplements containing red clover flower and not seeds were found, further research was terminated. Functional claims for red clover seeds as cosmetic ingredients together with a growing demand for natural additives in cosmetics indicated a desirability of either selling off the seeds or producing seed extract for the cosmetics industry. These were the two business opportunities identified for red clover seeds that were both stated to be feasible and sustainable but where viability needs more research.

6. Discussion

6.1. Introduction

This study aimed to respond to five research questions as presented in chapter 1.2. How the results from this study respond to each research question is, in chronological order, discussed in this chapter.

6.2. How can an organization identify business opportunities for a biological by-product?

The developed DVFS framework, presented in chapter 5.2, is a suggestion of an innovation framework for companies to use in the early innovation stage, the so called front end of innovation, when identifying business opportunities for biological by-products. In the following chapter, we will discuss the how companies can identify business opportunities by using the DVFS framework, and discuss the DVFS framework in connection to the theoretical frame presented in chapter 2.

Implications of the developed framework

We suggest that the use of the DVFS framework might challenge companies to think outside the box, thereby allowing them to find business opportunities that might not seem obvious at first glance. According to us, the strength of the framework lies in its ability to balance intuition with rationality, and providing companies with a structured way of innovating.

The aim of using the DVFS framework is seeing the by-products' potential from various perspectives, thereby finding alternatives along the way and evaluating the potential of the business opportunities continuously. This is not in line with Matheson and Matheson (1998) who argue that alternatives should not be evaluated until they have been fully conceived.

Both innovation and decision-making theory highlights the importance of generating multiple, significantly different alternatives (Brown, 2009; Matheson & Matheson, 1998; Koen et. al, 2001). During interviews however, creating multiple alternative ideas for the by-product did not appear to be the case for the companies. An application for the by-product was either well-known or suspected to function beforehand and investigated further. The companies only investigated the application for one market, e.g. investigated the food market for a by-product currently used for feed. These companies seemed to be successful in having identified a match on the market for their by-products, however, they might have missed even better business opportunities within other industries. To address the lack of alternatives, the

DVFS framework emphasize generating multiple alternatives but for one industry at a time, starting at the industry with the highest potential for profit.

The value axis of the DVFS framework, presented in chapter 5.2.4, could be seen as a part of what Matheson and Matheson (1998) refer to as the appropriate frame and finding out what you do *not* know. By starting to explore business opportunities at the highest value level, even if that industry might not seem obvious at first, and collecting information at that level, the company can avoid jumping to conclusions about what to do with the by-product based on preconceived opinions.

However, it could be discussed whether the DVFS framework really is successful in helping companies find better and a greater number of business opportunities. The value axis could potentially be seen as an inhibitor of the creativity leading to innovative ideas, since it prevents the user of the DVFS framework to investigate more than one industry at a time. For example, Matheson & Matheson (1998) state that in order to make the best possible decision, one should gather alternatives that are "significantly different" (Matheson & Matheson, 1998, p.44). In the DVFS framework alternatives within the same industry are successively compared to each other, which implicates that alternatives are not necessarily "significantly different". For instance, if the by-product would be assessed on the cosmetics value level, one alternative could be that the company produces the product itself and another that the company sells it as a raw material to another manufacturer further down the value chain. In that situation, the company would not compare the possibility of using the by-product to produce cosmetics to the possibility of producing ethanol, since this alternative is associated with another level on the value axis.

Matheson and Matheson (1998) also state that gathered alternatives should be new. In that respect, the use of the DVFS framework and its value axis could be beneficial since it, as previously mentioned, forces companies to consider industries and alternatives that might be new to the company.

Our perceptions of by-product innovation in comparison to "ordinary" innovation, based on the interviews and our own conclusions, is that it seems more likely that a company has a solution from start when it comes to by-product innovation. For by-products, the innovation approach seems to be less explorative, than as suggested by Brown (2009). In other words, the company has an identified "match" that it tests, rather than exploring multiple alternatives. To support exploration for by-products, a framework like the developed DVFS framework might be useful for by-product innovation.

Target user of the DVFS framework

The DVFS framework developed in this thesis does not specify who should be part of the innovation team and leaves that option open for the user(s) to decide. However, as mentioned in chapter 2.3.1.1, Matheson and Matheson (1998) emphasize the importance of approaching the problem from different perspectives, and therefore recommend that in order to make the best possible decisions, the team should be cross-functional. Thus, we recommend that this is worth having in mind when putting together the innovation teams.

Aspects of an open framework and empowering the users

The DVFS criteria are supposed to make sure that no important factors are overlooked. However, since the aim of the DVFS framework is to support new ideas and let intuition play a significant role, the factors within each DVFS criterion (see Figure 9) are not set in stone but should be seen as a suggestion. According to us, the importance and relevance of the criteria and factors within each criterion, for the individual company, is best determined by the company/user(s). The level of detail of the information gathered within each loop is also left for the users to decide. In other words, the framework is not telling the users what to do to the letter. We regard this empowering of the users a strength of the framework, but a potential pitfall of such an open framework will be discussed in the following paragraph.

If the users of the framework have preconceived opinions of what is possible and not possible to do with a by-product, and maybe even a hypothesis of what is the best solution, an open framework might not prevent the user from favoring preconceived ideas and ignoring new, alternative ideas. Thus, the DVFS framework relies on the user to have an open mind in order to explore new ideas. To avoid subjectivity and biases the framework should not be used by one person only, but preferably, as mentioned earlier, by a cross-functional team.

6.3. Which aspects are important when evaluating business opportunities for a biological by-product?

During interviews, a number of aspects were found that seem to have a critical effect on the evaluation of by-product business opportunities. These aspects, presented in chapter 5.1, gives a proposed answer to research question number two and will be further discussed in the following chapter.

Quantity

As presented in the result, the quantity has a big impact on the utilization of the by-product. A large quantity can work as a driver for companies, while a quantity that is too small is a barrier. This is not surprising, as the quantity greatly affects the viability of utilizing a by-product in a new way. If the quantity of the by-product in question is small, the profits made from utilizing it as a business opportunity are less likely to cover the investment, production and administration costs associated with the utilization of the by-product.

We believe that a small quantity of by-products should not be disregarded as pointless in terms of business opportunities since it might have uncovered value. Thus, the quantity of the by-product is not mentioned in the DVFS framework. However, the quantity still plays a part in the identification of business opportunities. It is recommended that companies carefully assess the quantity of the by-product before using the DVFS framework, since this will affect which opportunities will be viable and feasible, or if the identification of business opportunities for the by-product will be worthwhile evaluating at all. In the case study described in chapter 5.3, the quantity of the by-product was initially thought to be of a certain size, but was later discovered to be much smaller. This greatly affected the utility of the by-product, since nearly all application areas identified using the DVFS framework demanded a greater quantity of by-product in order to be considered viable business opportunities. From the case study, the quantity seemed to be of greater importance further down the value axis, which is not surprising since the revenue per weight decreases when moving down the value axis.

Customer relationship

As presented in chapter 5.1, two of the interviewed companies mentioned that strong customer relationships allowed them to push innovations onto the market without formally confirming the market demand beforehand. They also mentioned that the customer relationship allowed them to gain feedback from customers. One reason for the strong customer relationships being perceived as success factors could be that the information gained from customers reduces uncertainty (Herstatt et. al., 2006), thus leading to greater success of the product development (Verworn et. al., 2006).

Another aspect could be, in line with design thinking theory, that companies should give their innovation teams space to innovate and allow them to fail, too (Brown, 2009). In that situation, we believe that a strong customer relationship might be beneficial since it could imply that the customer is more forgiving of a product that does not achieve the desired result.

Commercial interest

Both design thinking theory (Brown, 2009) and the DVFS framework address the aspect of commercial interest or market need when speaking about "desirability". In order for any product to be successful, including by-products, a prerequisite is that customers find it desirable, which is something that all interviewed companies were highly aware of.

Being aware of market needs can in some way be seen as a way of having an appropriate frame, in line with Matheson and Matheson (1998). To gain knowledge of the market need, the interviewed companies rely, to some extent, on their customer relationships and tacit knowledge or intuition about market need rather than using formal models in order to find out what is not already known. To find out what you do *not* know, as emphasized by Matheson and Matheson (1998), gathering information about market needs from others than current customers could be of interest. The value axis in the DVFS framework and the emphasis on creating alternatives are tools for addressing this.

Company core values

One interesting aspect when discussing the interviewed companies is the fact that all companies have sustainability and innovation as core values and have realized the importance of utilizing all resources in the production. For companies that might not value utilizing all resources in the production and seeing sustainability as a core value, we distinguished the importance of a sustainability criterion in the DVFS framework. Since sustainability was an underlying factor in developing a framework for by-product innovation, it was natural to make it a criterion.

Seeing the entire value chain

Based on findings from interviews, business opportunities for by-products appear to be easily identified when seeing the entire value chain. This was a finding that we wanted to incorporate in the DVFS framework. There is no need for the company to refine the by-product to the final stage of the value chain if this is not in line with strategy. For example, if the company's current strategy is to produce ethanol, it might not be reasonable for the company to start producing pharmaceuticals. Yet, the company might be able to sell the by-product to another company that produces pharmaceuticals and thereby increase the value of the by-product. We do not consider the latter to be against company strategy, since the by-product is a consequence of strategy-aligned production, i.e. left-overs when the company achieves its primary goal that are not utilized in the most value creating way.

Time, resources and the driving spirit

Whether it is a driving spirit with a vision, or a business development team accustomed to finding business opportunities for by-product, dedicated people seem to be a key for by-product innovation amongst the companies interviewed. We are not claiming a driving spirit to be a prerequisite for the DVFS framework, however, a team that is identifying opportunities for the by-product as part of their daily tasks is suggested. In addition to human capital and time, a budget is needed to be able to experiment (Brown, 2009), which is why a budget for exploring business opportunities was added to the DVFS framework.

Gut feeling

Some of the interviewed companies stated gut feeling as an important aspect when deciding which ideas to develop further. When considering the front end of innovation, this practice is in line with theory that concludes that in situations with high levels of uncertainty intuition is preferred to rationality (Gutiérrez, 2008), but opposes Matheson and Matheson's (1998) recommendation of using a formal method. This is further discussed in chapter 6.4.

6.4. How can these aspects be compared when making a decision on how the by-product should be utilized?

When interviewing the companies on how the various aspects mentioned in chapter 5.1 can be compared when making a decision on how the by-product should be utilized, we expected to gain a perception of which aspects were more important than others. This was not the case since the companies did not rank the aspects in any particular order, but let intuition be the determining factor of how the by-product was utilized. In the following chapter, we will discuss how to compare different alternatives and how the mentioned aspect, gut feeling or intuition, can be balanced with rationality.

6.4.1. The value axis

How to practically evaluate feasibility, viability and desirability, and compare alternatives is not expressed by Brown (2009), and Koen et. al. (2001) suggests to leave hard, quantifiable templates to the later new product development process in order to let ideas grow. Matheson and Matheson (1998), on the other hand, emphasize the importance of measuring values and making trade-offs between them to be able to choose between alternatives, as explained in chapter 2.3.1.4. It is also described in chapter 2.3.1.5 that Matheson and Matheson (1998) propose the decision to "feel right" but also be completed with a formal model for correct reasoning.

However, all interviewed companies emphasized the importance of intuition and gut feeling rather than having a formal model where different values are calculated and trade-offs are made. Even though Matheson and Matheson supports intuition *together* with a formal model, it seemed like this theory differs from practice due to the predominance of intuition amongst the companies interviewed.

Because of the lack of focus on formal calculation models to compare alternatives in innovation theory and in practice, the developed by-product innovation framework focused on intuition and balancing desirability, viability, feasibility and sustainability. However, to allow many ideas to grow but still support rational decision-making, the value axis, as presented in chapter 5.2.4, was added to the framework. By defining and prioritizing potential industries before generating ideas, a valuation in terms of cash flow is made beforehand, which is meant to minimize the need for a formal evaluation model. Having evaluated cash flow before generating ideas is supposed to make trade-offs easier when comparing the alternatives generated but still make room for making decisions based on intuition.

6.5. Discussion of the case result

6.5.1. Answering the research questions

The case study aimed at answering the research questions:

- RQ3. Which alternative business opportunities exist for Lantmännen's by-products in the forage seed production?
- RQ3a. Which one of these business opportunities is optimal for Lantmännen?

It is safe to say that we had high expectations on the DVFS framework and our vision was to identify more than one alternative business opportunity for the by-product, which the research questions display. In a sense, multiple business opportunities were identified since the by-product was divided into three different by-products (i.e. timothy seeds, red clover seeds and white clover seeds) and business opportunities were identified for two of them. Yet, multiple business opportunities for each by-product were not identified and chosen between, and in that sense, the two research questions were not fully answered. The reason for why the research questions were not fully answered could be found in the DVFS framework, the limited quantity of the by-products and the timeframe.

The nature of the DVFS framework is exploring one potential industry at a time and only moving on to the next industry, or value level, if no business opportunities are found in the previous industry. Thus, for the

DVFS framework, multiple business opportunities can only be developed within the same potential industry. This limited the amount of business opportunities identified.

During the course of the case study, as discussed in chapter 6.3, the quantity of the by-products was found to be much smaller than the initial estimation. This affected the number of business opportunities identified since a poorly fulfilled criteria combined with a small quantity was stated to not make further investigation worthwhile. The small quantity in itself was only a deal breaker for biomaterial, where no further research was made due to the claim that great qualities are needed for biomaterial.

The time constraint affected both how business opportunities were identified and evaluated and was found to be the most critical constraint for the case study.

6.5.2. The business opportunities

Although the amount of identified business opportunities were not as many and as accurately investigated as expected due to constraints mentioned earlier, the application of the DVFS framework on case study still resulted in a suggestion of business opportunities to be further explored.

The by-product timothy seeds were found to have no potential alternative application due to the lack of functional claims combined with the small quantity. Even without time constraints, we believe that this conclusion would have been reached. However, a greater quantity would have made the timothy seeds as bio-material further investigated. However, for the red clover seeds, time constraints affected the results to a greater extent. Research on red clover was time consuming due to our lack of knowledge within nutrition and extraction of substances. Thus, when the DVFS framework resulted in an indication of potential business opportunities within cosmetics, either through producing seed extract or by selling off the seeds to an extract manufacturer, we decided to end the research there in order to explore business opportunities for the other by-products (white clover seeds and timothy seeds) as well.

An interesting aspect of the potential business opportunity within producing seed extract is that if Lantmännen were to explore this business opportunity further, by calculating investment costs and estimating the market potential of seed extract for the cosmetics market, it would be reasonable to also explore selling the extract to the food supplement industry. As declared in the result for red clover, chapter 5.3.7, no proof whether red clover seeds are used for food supplements were found, but it was not disproved. It would make sense to investigate all potential markets if an investment for seed extract manufacturing would be made.

We regard replacing synthetic additives in food supplement and cosmetics with by-products to be valuable at a macro level, since we estimate that less resources and toxic chemicals are used when extracting additives from by-products. At a micro level, i.e. for Lantmännen, we believe that producing seed extract from discarded seeds is a future business in line with the company's core competence, refining crops, and a way of creating value, given that the market need is confirmed.

For white clover seeds, the DVFS framework resulted in the seeds being appropriate for the feed market, *if* a customer is found that only wants a small quantity of seeds. A customer needs to be found in order to get more information about what other food ingredient the by-product white clover seeds would replace, in order to assess the value at a macro level. Also, more customer information is needed to be able to estimate transportation costs and the sustainability criteria for the transportation. For Lantmännen, value could be created in terms of increased profit when selling. However, more information is needed in order to determine whether this possible, supposedly small, increase in profits would cover the associated costs, thereby making the deal profitable for Lantmännen.

6.5.3. Critical aspects of the DVFS framework

6.5.3.1. The value axis

When validating the developed conceptual framework with the master's thesis' case study, the first version of the value axis was provided by the supervisor at the case company without any revision at first. Other industries (cosmetics, pet food and biogas) than the ones included in the value axis given were however added during the course of the case study, see Figure 11. Pet food and biogas were added from our own knowledge and the cosmetics industry was encountered during research on clover seeds within another industry. The revised value axis was validated by the supervisor at the case company. Since using one of the by-products for cosmetics was stated as a potential business opportunity, a weakness in the application of the value axis for the case study was exposed. If all industries would have been known from start, less time could have been spent on investigating opportunities on lower levels.

Thus, one obvious critical aspect when applying the value axis was to thoroughly identify all possible industries for which the by-product could be used, and not just the ones commonly known to the company. On the other hand, without using the value axis, companies might tend to only explore one business opportunity that is known from start and not necessarily the one with the highest value.

6.5.3.2. Time

As mentioned earlier, time had the greatest impact on the results of the case study. This was an important finding that cannot be emphasized enough.

6.5.3.3. Relying on intuition and having an open mind

Another difficulty when using the DVFS framework was balancing intuition and rationality. Intuition regarding business opportunities seemed to call for tacit knowledge within the company of the by-product, which was something that we, as non-employees, lacked.

Thus, it could be argued that "our" intuition was in fact only a mix of information, but also opinions, from different employees at the case company. We considered ourselves to have an open mind, as suggested in the DVFS framework, chapter 5.2, and tried to encourage the respondents to have an open mind as well. This was achieved by asking open questions, and not leading questions such as "is it possible to sell clover seeds as food?". However, it cannot be guaranteed that the respondents answered the questions with an open mind and without biases. The probability that the respondents answered by what they know for certain is possible within the current business. Thus, there is a risk that relying on information and opinions from employees might have led to biased results.

6.5.4. Case study as validation of framework

The developed conceptual framework was meant to be validated through the case study. However, one case study is not considered by us to be enough in order to validate a new framework. Although some aspects of the framework were confirmed by the case study such as the need for time, more validation is needed.

Due to the lack of time, the level of detail in each loop was relatively low and only some of the suggested factors to examine within the DVFS criteria, as shown in Figure 9, were examined.

7. Conclusions

7.1. Contributions to industry and academy

This master's thesis aimed at exploring how companies can identify business opportunities for biological by-products, and which aspects are important when evaluating business opportunities. A conceptual framework has been developed in order to address the question of "how?". The developed DVFS framework is a tool that can contribute to companies identifying business opportunities in under-utilized by-products, by guiding the user through the "fuzzy" front end of innovation.

The study has also provided insight into how companies work with by-product innovation in practice, and which aspects critically affect this process. The study identified nine aspects that companies believe affect the outcome of the utilization of a by-product as a business opportunity. These were:

- Commercial interest - the awareness of a market need gave companies the necessary push to fully test a business opportunity
- Customer relationship - a strong customer relationship enabled technology push
- Utilization of all resources - the wish for utilization of all resources, whether it be because of a limited supply of resources or a wish to increase profit, was a motivation to explore business opportunities
- A driving spirit - dedicated people were often a driver for developing ideas for by-products
- Gut feeling - intuition was often the factor that could make or break an idea
- Sustainability and innovation as core values - the core values were perceived as affecting the willingness to use by-products as a basis in the innovation process
- Quantity - a significant quantity of a by-product worked as an incentive for companies to evaluate business opportunities, while a quantity that was too small was perceived as a barrier to the viability of the business opportunity
- Time and resources - having the working hours available to be able to pursue an idea was crucial.

These insights are valuable to academy since they begin to explain which aspects are important when identifying and evaluating business opportunities for by-products. The critical aspects can also provide valuable insights to companies that wish to better capture value from their by-products, since they can be used in order to identify improvement areas within their organizations.

In addition to the available theory on design thinking, the developed DVFS framework has provided a summary of which aspects within the desirability, feasibility and viability constraints are considered by companies when working with innovation. A contribution to theory has also been made by linking innovation and strategic decision-making concepts to by-product utilization.

7.2. Limitations of the study and recommendations for further research

The DVFS framework is suggested to help companies find business opportunities for biological by-products, however, it is unclear whether the framework is successful in achieving this. The case study used to validate the framework generated some business opportunities, but the value of these remains unclear indicating that further validation is needed. In order to assess the usefulness of the DVFS framework, it is recommended that the framework is further validated using additional case studies.

Another aspect that would be interesting to investigate, is whether the framework could be extended with innovation tools that could be used in the divergence stages of the framework, i.e. in the creation of choices or ideas, and if so: if this would be useful for the utility of the framework. There is a wealth of idea generating and brainstorming tools available that could prove useful in this context. Yet another question worthy of investigation is the impact of a formal framework in the creativity in the front end of innovation.

While the nine critical aspects mentioned by companies in this study are interesting, the sample consisted of solely three companies, which limits the generalizability of the research. Further research is necessary in order to fully establish the generalizability and implications of these critical aspects.

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Appendices

A. Interview guide

The following interview questions were used as a starting point for the interviews about business opportunities for by-products.

- Vad är företagets strategi, vision, värderingar och varumärkesstrategi?
    - Hur ser man på miljömässig hållbarhet? Vilka delar av miljömässig hållbarhet är viktiga?

När ni utvecklat en affärsidé utifrån en restprodukt

- Vad var anledningen till att ni ville utforska affärsmöjligheter med restprodukten? Varför just vid den tidpunkten? Vilken var den utlösande faktorn? Vems initiativ var det? Vilka arbetade med projektet?
- Gick detta affärsutvecklingsprojekt in under företagets befintliga struktur?
- På vilket sätt gick idén i linje med företagets strategi, styrkor och mål?
- Hade ni en idé från början om vad biologiska restprodukter kunde användas till?
    - (Utöver ert företags befintliga produktområden)
    - Värderas dessa användningsområden på något sätt?
- Hur gick processen till? Skiljer sig processen (när man utgår från en restprodukt) från en "vanlig" innovationsprocess? Vad är skillnaden?
    - Hur många alternativ hade ni?
    - Vilka faktorer var viktiga när ni identifierade olika affärsmöjligheter?
    - Vilka faktorer var viktiga när ni utvärderade de olika affärsmöjligheterna?
        - Vilka faktorer var avgörande för att en idé skulle vidareutvecklas eller skrotas (kritiska framgångsfaktorer eller dealbreakers)?
    - Vilka värden (för t.ex. kund, konsument, intressenter, anställda) identifierades hos idén?
        - Hur mättes de olika värdena?
    - Vad fanns det för risker?
        - Räknade ni ut riskerna?
        - Vilka var de största riskerna?
    - Använde ni en formell modell när ni utvärderade olika idéer?
    - Hade ni en plan för ett eventuellt misslyckande?
    - Vilka enheter var inblandade i affärsutvecklingsprojektet?

För vårt ramverk:

- Är alla aspekter i ramverket relevanta?
- Vilka aspekter har vi glömt?

B. Interview guide

Interview guide for interview with Lovisa Björnsson, Professor at Environmental and Energy Systems Studies within Faculty of Engineering at Lund University.

- Vad kan man göra med biomassa?
- Vad bör man göra med biomassa?
- Hur ser företag på avfallshantering? Företag inom jordbruksindustrin?
- Vad är best practice när det gäller hur företag hanterar bioavfall? Vad gör företag generellt av sitt bioavfall?
- Vilket sätt är bäst ur miljösynpunkt? Vilka möjligheter/svårigheter finns?
- Hur går man tillväga när man har identifierat avfall/produktionsspill och vill kartlägga och analysera användningsområden/affärsmöjligheter för spillet? (tillvägagångssätt/process/ramverk)
- Vad måste man veta om resursen för att kunna utnyttja den på bästa sätt? (Mer än näringsinnehåll)
- Hur räknar man på fördelarna (miljömässiga och ekonomiska) med att utnyttja resurser?

C. Case study – Calculations ethanol

Data on raw material weight for the by-products was provided by Karlsson (2016) and their glucose content were found in nutritional analysis that were performed by laboratory group Eurofins on behalf of Lantmännen for this thesis. Data on ethanol extraction was provided from Gundberg (2016), i.e. that the weight ethanol that can be extracted from a substance, is 0.45 kg per kg glucose.

	Raw material weight (kg)	Glucose content (<kg/1 kg)	Total glucose weight (kg)	Ethanol (0.45 kg ethanol/kg glucose)
Red clover seeds	11000	0.0007	7.7	3.5
White clover seeds	5000	0.0004	2	0.9
Timothy seeds	4000	0.0004	1.6	0.7
Total	20000		11.3	5.1