OULUN YLIOPISTO
UNIVERSITY of OULU

FACULTY OF TECHNOLOGY

# BUSINESS ECOSYSTEMS OF SIDE STREAM UTILISATION IN METAL INDUSTRY – PETRIT-T CASE STUDY

Saara Väänänen

Supervisor: Haapasalo H. Kinnunen P.

INDUSTRIAL ENGINEERING AND MANAGEMENT

Master's Thesis

January 2017

# ABSTRACT
# FOR THESIS

University of Oulu Faculty of Technology

| Degree Programme (Bachelor's Thesis, Master's Thesis) | Major Subject (Licentiate Thesis) |
|---|---|
| Industrial Engineering and Management | |
| **Author** | **Thesis Supervisor** |
| Saara Väänänen | prof. Harri Haapasalo, D.Sc. Päivö Kinnunen |

**Title of Thesis**

Business Ecosystems of Side Stream Utilisation in Metal Industry – Petrit-T Case Study

| Major Subject | Type of Thesis | Submission Date | Number of Pages |
|---|---|---|---|
| Industrial Engineering and Management | Master's Thesis | January 2017 | 95 p., 1 app. |


**Abstract**

Side stream utilisation is an important research area in the world today. More and more new ways are developed to diminish the amount of waste, recycle waste and utilise the side streams into good use instead of throw a good business opportunity and the valuable side stream away. Side stream utilisation possibilities should be investigated not only in technology point of view but also in the business point of view also to find the best possibilities for utilisation and have the longest possible lifecycle to the raw materials according to principles of sustainable development.

Petrit-T is a lime rich side stream that is created in the production of sponge iron. It has been handled and managed as a waste and it has been thrown to the landfill but now the production company Höganäs AB is keen on utilising the Petrit-T as efficiently as possible in the products in the world by selling the substance to other companies that are willing to produce end products made of it. After getting the secondary raw material status through REACH regulation in EU, Petrit-T is managed as stabile material and different laws and taxes apply to it. It is usable material to post-processing and to add value to the network around the company and profitable end-products.

This thesis studies the utilisation of Petrit-T in the business utilisation point of view. It is an economic feasibility study in European Institute of Innovation & Technology (EIT) funded project called MIN-PET and it is one of three pre-studies in the beginning of the project. The goal to the feasibility study and to this thesis is to give a proposal of the business ecosystems of the selected end-product scenarios, business models and business case analysis in this case and to find an answer to following research questions: 1. How can the industrial side streams be analysed in the economic point of view? 2. What are the value streams and business model scenarios of the side stream substance of Höganäs AB? 3. What are the business cases of the side stream utilisation?

A descriptive study method has been used in this thesis. A literature review provides a framework needed in the research and the empiric study fulfils the practical need. The methods used are workshop group discussions and visual modelling, interviews and detail gathering to an excel sheet. Finally the theoretical knowledge is joined together with the empirical research to form a business case analysis and business case proposal.

The most important findings are that the ecosystems can be formed in many ways depending on the end-product scenario. In this study the end-product scenarios are acoustic panels and cementious binder that have their own ecosystems and concrete elements as a combined ecosystem from the two previous. The business case analysis reveals that all the end-product scenarios can be profitable. Analysis reveals that the acoustic panels have the best profitability possibilities available with 850 000 € annually. The outcome of this thesis is a business case proposal which encourages to go for all selected end-products separately. The research has not taken into account the simultaneous production of two of more different products and the cases considered are mutually exclusive.

The results of the research can be used in the upcoming MIN-PET project as a proof of the profitability of the project goals and as a guideline to establish the business around the Petrit-T in this case. Also the results can be generalised into similar side streams in the iron production industry in Europe. Theoretical study can be used in different industries but the research results are applicable only in this particular case. There are many similar side streams unutilised in the steel industry that need examples how to utilise them and make profitable business out of them.



Keywords: Business ecosystem, business model, circular economy, business case analysis, side flow, side stream, by-product


Additional Information

# TIIVISTELMÄ
# OPINNÄYTETYÖSTÄ Oulun yliopisto Teknillinen tiedekunta

| Koulutusohjelma (kandidaatintyö, diplomityö) | Pääaineopintojen ala (lisensiaatintyö) |
|---|---|
| Tuotantotalous | |
| **Tekijä** | **Työn ohjaaja yliopistolla** |
| Saara Väänänen | prof. Harri Haapasalo, TkT Päivö Kinnunen |

**Työn nimi**

Sivutuotevirtojen hyödyntämisen liiketoimintaekosysteemit metalliteollisuudessa – Petrit-T tapaustutkimus

| Opintosuunta | Työn laji | Aika | Sivumäärä |
|---|---|---|---|
| Tuotantotalous | Diplomityö | Tammikuu 2017 | 95 s., 1 liite |

**Tiivistelmä**


Sivuvirtojen hyötykäyttö on puhuttanut paljon maailmassa nykypäivänä. Yhä enenevässä määrin keksitään keinoja vähentää jätteiden syntyä ja kierrättää sivuvirtatuotteita hyötykäyttöön sen sijaan, että jätettäisiin liiketoiminnalliset mahdollisuudet hyödyntämättä ja heitettäisiin sivuvirtatuotteita maan täytteeksi. Jotta raaka-aineiden käyttö olisi mahdollisimman tehokasta ja elinkaari pitkä kestävän kehityksen periaatteiden mukaisesti, sivuvirtojen hyödyntämisen mahdollisuus tulisi tutkia niin teknologian kuin liiketoiminnankin näkökulmasta. Tämä opinnäytetyö tarttuu tähän teemaan syvällisemmin kiinni.

Petrit-T on huokoisen raudan valmistuksessa syntyvä kalkkipitoinen tuotannon sivuvirta, jota ennen on pidetty jätteenä ja käytetty maan täytteenä, mutta nykyään sitä tuottavalla yrityksellä Höganäs AB:lla on kiinnostusta hyödyntää sivuvirtaa mahdollisimman tehokkaasti uusissa tuotteissa liiketoimintaekosysteemiä hyväksikäyttäen. Lainsäädännöllisen REACH-prosessin käytyään Petrit-T luokitellaan hyvin stabiiliksi sekundääriseksi raaka-aineeksi, jota koskee erilaiset luvat ja verot kuin jätettä. Se on käyttökelpoinen materiaali jatkojalostukseen arvoa lisääviksi ja liiketoiminnallisesti kannattaviksi tuotteiksi.

Diplomityössä on tutkittu Petrit-T:n hyötykäyttöä liiketoiminnan näkökulmasta. Diplomityö on osa European Institute of Innovation & Technology (EIT) rahoittamaa MIN-PET projektia, jonka ensimmäisessä vaiheessa tarkoituksena on tehdä teknillisen ja ympäristöllisen esitutkimuksen lisäksi liiketoiminnallinen esitutkimus. Tämä diplomityö on liiketoiminnallinen esitutkimus Petrit-T:n hyödyntämiselle. Tarkoituksena on luoda ehdotus liiketoimintaekosysteemin rakenteesta, liiketoimintamalleista eri lopputuoteskenaarioille, tehdä liiketoiminta-analyysi tästä tapauksesta ja vastata seuraaviin tutkimuskysymyksiin: 1. Kuinka teollisuuden sivutuotevirtoja voidaan analysoida taloudellisesta näkökulmasta? 2. Mitkä ovat Höganäs AB:n sivutuotevirran arvovirtaketjut ja liiketoimintamalliskenaariot? 3. Mitkä ovat sivutuotevirran hyödyntämisen liiketoimintatapaukset?

Tutkimus on deskriptiivinen tapaustutkimus. Teoriaosuus koostuu pääosin tieteellisten artikkeleista ja tutkimusaineisto kerättiin workshopissa projektiin osallistuvilta tahoilta käyttäen visuaalista mallinnusta ekosysteemeistä hyödyksi. Aineistona käytettiin workshopin tukena myös haastattelutuloksia ja tietojen keräämistä erilaisin keinoin. Tuloksissa teoriatieto yhdistettiin empiiriseen tutkimukseen business case analyysiksi ja business case ehdotukseksi.

Tuloksista tulee ilmi, että liiketoimintaekosysteemit voidaan muodostaa monella eri tapaa riippuen lopputuotteesta. Lopputuotemahdollisuuksista tarkasteltiin tässä tapauksessa kolmea eri lopputuotetta: akustisia paneeleja, sementin sidosainetta ja betonielementtejä. Kahdella ensimmäisellä ovat omanlaisensa ekosysteemit, mutta kolmas lopputuotemahdollisuus on yhdistelmä kahdesta ensimmäisestä. Liiketoiminta-analyysistä käy ilmi, että kaikista näistä lopputuotemahdollisuuksista on mahdollista tehdä kannattavaa liiketoimintaa. Kannattavin tuote kuitenkin on akustiset paneelit, jonka vuotuinen rahallinen hyöty on arvioitujen kustannusten ja tulojen mukaan 850 000 €. Liiketoiminta-analyysin lopputuloksena liiketoimintaehdotus suosittelee lähtemään suunniteltuihin uusien tuotteiden valmistukseen ja ekosysteemien luomiseen kuhunkin yhteen kerrallaan. Tutkimuksessa ei ole otettu huomioon kaikkien lopputuotteiden yhtäaikainen tuotanto.

Tutkimuksen tulokset voidaan käyttää täysin MIN-PET projektin tuleviin toimintoihin täysin sellaisenaan osoittamaan projektin tavoitteen mukaisen Petrit-T sivuvirran liiketoiminnalliset mahdollisuudet. Tuloksia voidaan soveltaa suoraan tämän tietyn sivuvirran hyödyntämisen liiketoiminnan perustamiseen. Tutkimusta voidaan soveltaa osittain samankaltaisen sivutuotevirran liiketoimintamahdollisuuksien kartoittamiseen Euroopassa teräs- ja metalliteollisuudessa. Teoreettista osuutta ja metodeja voidaan käyttää minkä tahansa sivutuotevirran analysointiin soveltaen, mutta laskelmat ja tulokset ovat spesifejä vain tähän tapaukseen.



Asiasanat: Liiketoimintaekosysteemit, liiketoimintamallit, business case analyysi, kiertotalous, sivuvirta, sivutuote


**Muita tietoja**

# PREFACE

In this research a feasibility of the industry side stream is evaluated through literature research and empiric material about the business ecosystem in an industry point of view, business models and side stream business case analysis creation in those ecosystems. This master's thesis is a part of the master of science of technology studies in the field of Industrial Engineering and Management. The research is done during the autumn period, from the first of June in 2016 and the last of January in 2017.

The thesis was requested and funded by an EIT Raw Material upscaling project called MIN-PET: Mineral products from Petrit-T sidestream. The research journey has been a challenging adventure to me in the scientific and business world through the project. The interest towards the side stream utilization industry and circular economy has sparked in me during the process and the curiosity keeps me searching my own way in the future.

To this thesis I have got support from various persons whom I would like to thank. I want to thank professor Harri Haapasalo for valuable guidance throughout the thesis process and studies in the University of Oulu. I also wish to thank Dr. Päivö Kinnunen for the knowledge and great support in the research. Thank you Mr. Björn Haase for the important support in the empiric part information gathering and all other MIN-PET project participants for collaboration and a good working ambience. I have had enough strength to do this research with the help of my dear friends and with the contribution of other classmates. I have got also unwavering support throughout the studies from my family and relatives which I am grateful for.

Oulu, 24.1.2017 Saara Väänänen

# TABLE OF CONTENTS

# ABBREVIATIONS

| | |
|---|---|
| B2B | Business to business |
| BCA | Business Case Analysis |
| B/C | Benefit-cost ratio |
| CBA | Cost-benefit analysis |
| ECHA | European Chemicals Agency |
| EIT | European Institute of Innovation & Technology |
| EIT-Minerals | Independent organisation and financier under EIT |
| EoW | End-of-Waste |
| EU | European Union |
| IRR | Internal rate of return |
| ISO | The International Organization for Standardization, International Standard |
| KU Leuven | Katholieke Universiteit Leuven |
| MIN-PET | Mineral products from Petrit-T sidestream, project name |
| NPV | Net present value |
| PBP | Pay Back Period |
| TEV | Total economic value |
| WFD | The Waste Framework Directive |
| ZAG | The Slovenian National Building and Civil Engineering Institute |

# 1 INTRODUCTION

## 1.1 Background

In the world of business it is important to keep moving and discover new ways to improve modes of operation to keep the businesses alive. Developing new products brings new business to the company and when doing the right things at the right time the new products can become a success. One of the ways to find new opportunities is to follow and forecast the trends in the world. New innovations and ideas can be a page turner for the company if they are evaluated carefully in terms of costs, benefits and if the intended course of action is aligned with the company goals and strategies.

The circular economy is gaining more and more attention in the western world at the moment (*e.g.* Monosi *et al.* 2016; Diao *et al.* 2016; Ma *et al.* 2014). The world economy has developed through industrial revolutions to the point where the manufacturing and consumption are not in the sustainable level (Hirschnitz-Garbers *et al.* 2016). The world and its people need to develop new innovations to preserve the nature and the environment we live in. The aim today is to minimise waste, to use natural resources more efficiently and make business more profitable via recycling and process optimisation (*e.g.* Winans *et al.* 2017; Abu-Ghunmi *et al.* 2016). Developed technologies enable the material efficient use, recovering and recycling the raw materials according to sustainable development principles and use the recycled material in new products (De los Rios and Charnley 2016). Also EU has set goals towards zero waste with different laws and acts (European Commission 2008; ECHA 2010). The paper *Towards a circular economy: A zero waste programme for Europe from European Commission (2014)* explains that raw material resources are underutilised at the moment. The goal by 2050 is to reduce material use by 60–80 % towards 6–10 tonnes per capita in Europe (Hirschnitz-Garbers *et al.* 2016). In the European Union the metal industry also has awaken to recycle the steel slags into use instead of landfilling the slag side stream (Menshov 2014). In the recent research the business opportunities of the steel slags has been studied a little (Menshov 2014; Husgafvel 2016). In the practice the slag technological feasibility has been studied in the companies but the optimising and the business ecosystem still would need more attention to have more interest into the side stream utilising industry (Monosi *et al.* 2016).

Sustainable solution to utilise the side streams is to build the business sustainability around these technologies. Business model structures need to be investigated and business opportunities evaluated to have more commercial interest around the products, technologies and circular economy overall (Geissdoerfer *et al.* 2017). One of the tools to study the business benefits of the new innovation is the economic feasibility. The economic feasibility of the selected innovation to industry side stream end-product scenarios is one key evaluation tool in the process. It proposes a structure of the business ecosystem and value creation system around the selected investments or new products. Business ecosystems have been studied extensively from the 90's (*e.g.* Moore 1993; Iansiti and Levien 2004; Zahra 2012; Galantenau 2013). Business models have also been studied widely (*e.g.* Osterwalder 2005; Al-Debei *et al*. 2008; Suikki *et al*. 2006; Bocken *et al*. 2013). The link between the business models in the side stream business ecosystems is not researched a lot in the present studies. A financial pre-study in the form of Business Case Analysis (BCA) for different end-product scenarios is included to the economic feasibility to give detailed evidence to support decision making to go or not go and build the business around the intended innovation (Kinnunen T. *et al*. 2011; Randall 2012).

## 1.2 Objectives

The main goal of this research is to verify the economic feasibility of side stream Petrit-T utilisation for the EU funded MIN-PET project lead by a Swedish metal coating company Höganäs AB. The study aims to find knowledge about the business ecosystems in circular economy and find business solutions to the side stream productisation. The economic feasibility study of the selected metal industry side stream end-product scenarios proposes a structure of the business ecosystem and value creation system around these products. Also the financial pre-study in the form of Business Case Analysis (BCA) for different end-product scenarios is conducted to support the project continuation decision. The outcome for the research is a business case analysis in side stream utilisation end-product possibilities and business case proposal about the business feasibility for the decision making purposes in the project. The objectives are met when the thesis answers to the following research questions.

1. How can the industrial side streams be analysed in the economic point of view?

2. What are the value streams and business model scenarios of the side stream substance of Höganäs AB?
3. What are the business cases of the side stream utilisation?

Petrit-T is a side stream that comes from the process of Höganäs. One of the company's strategic goals is to have zero waste in the production. Their answer to the waste reduction is to recycle and process the side streams further and make feasible secondary raw materials that can be used in different products. Höganäs not only benefits from the landfilling savings but also it can make profitable business out of the Petrit-T and other side streams. The main business for Höganäs is the metal powders and these side streams are the side business to the company. Another ambition is to use the Petrit-T internally in some form of end-product. The project success is in many ways overall beneficial to Höganäs when making a waste into a valuable product. Project MIN-PET and Höganäs presentations in detail are in the chapter 3.

The aim is to find the right ways to analyse side streams in the economic point of view and study the business cases of the Petrit-T in Höganäs case company. The thesis has been outlined to be in an optimal extent. Therefore some of the relevant dimensions of the themes has been excluded from the research. The internal accounting principles and practices are excluded in this research because the situation is to study the feasibility of the solutions and very precise details are not available in this phase of the project and the aim is to give a proposal to continuum of the project. Also different marketing principle plans to gain detailed knowledge about the markets have been excluded but they are lightly estimated in the empirical analysis.

## 1.3 Research Process

The research starts with the study of the scientific literature of the side stream utilisation and business network themes (figure 1). Literature review includes the themes of the business ecosystems, business models and business case analysis combined into the side stream utilisation mechanics. After the theoretical synthesis the industry and all the main partners in the MIN-PET project is described as well as the side stream substance Petrit-T. The empiric data and information of the project is gathered from MIN-PET project and in the empirical part of the research different business ecosystems in industry side stream

productisation are discussed and created in workshops. Also the details of business case analysis were collected and value creation system invented to the industry context. In the later part of the research the theory and the empirical part are combined to form a holistic understanding of the possible business cases in this side stream case. The last phases of the research process include validation of the study, reliability study and conclusions with the further research suggestions.

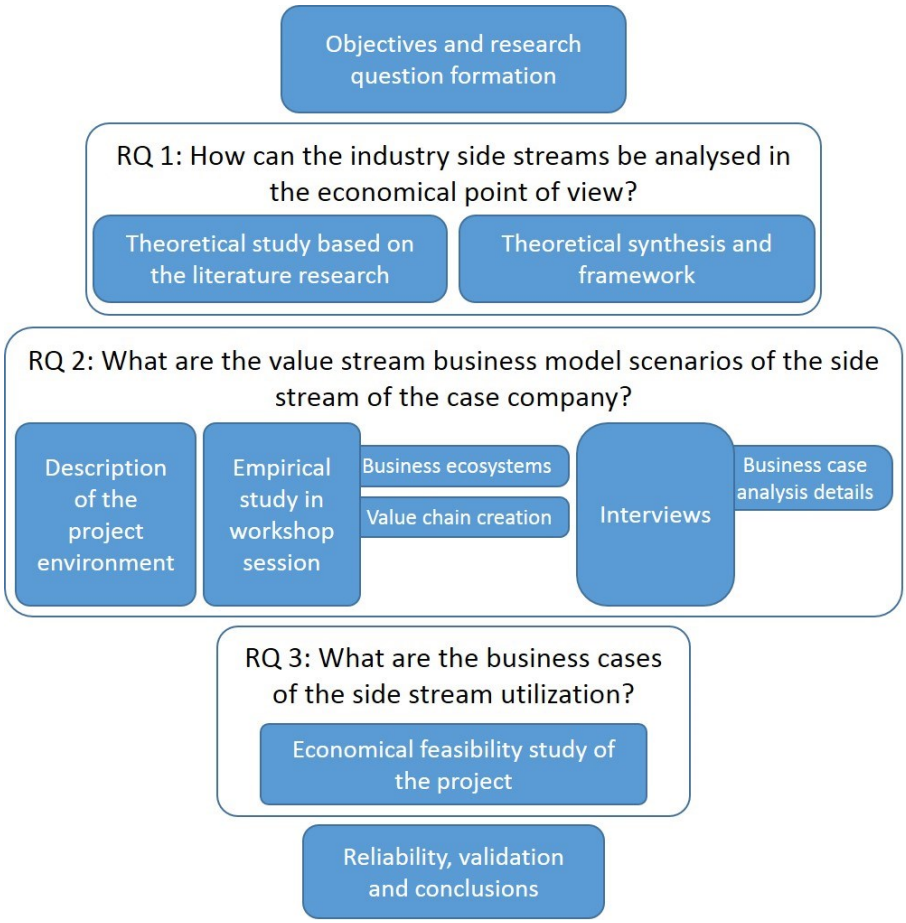


**Figure 1**. Research process.

In the first step the research motivation needs to be clear to understand what the need for the study is and how it is going to be useful. The scoping the field of study happens with precise research question formulation which was done the previous chapter 1.2. The research question design is based on the need what the research wants to achieve. In this

thesis there is three research questions which define the goal and the next steps of the study.

The answer for the first research question is found through the theoretical study from the research of the scientific papers, publications, European Union guidelines and doctoral theses. This research needs a base from the scientific publications and previous studies about the topics to have a solid understanding about the research environment and concepts examined. Then the synthesis is made from the literature research to gather a big picture about the scientific research of the side stream utilisation, its business ecosystems, value creation and business case analysis. Theoretic examination will answer the first research question and gives a holistic view how the side streams can be analysed in the economic point of view.

After the theoretical part the description of the project and the side stream substance Petrit-T is explained in the empiric part of the study. It is important to find out the practical environment and the context in which the research is implemented for scoping the research. The project need is one of the main motivation for this research in addition to scientific advancement. Project environment defines also the objectives which the research is aiming to. The description details are gathered via interviews, internal introduction papers and internal project documents.

The empirical study continues with the information gathering about the practical formulation of the business environment towards the ecosystem, value stream and business case analysis creation. In this part the practical aspect of the research is gathered as a case study. The information is gathered in the group discussion and interview at the workshop where all the MIN-PET project participants are invited as well as EIT representatives. Business structure and financial details are gathered in the discussion interviews with the key participants. This information gathered will give an answer to the research question two of what are the business scenarios of the side stream in this case.

The third research question leads the study to evaluating the business case of the side stream. The step combines the theoretic knowledge with the practical need into one entity and the answer to the economic feasibility in the form of business case analysis and proposition of the side stream. This is made by combining the financial details with the

business ecosystem and value structure into an outcome what are the business cases of the side stream utilisation in this case. At the very end of the research the validity and contribution of the research is evaluated to give an explanation why the research was done and how reliable the research is scientifically.

# 2 LITERATURE REVIEW

The scientific literature is studied to understand the theoretical background of the themes and gain knowledge to conduct the research in the most efficient and reliable way. The theoretical study begins with the business ecosystem review with its structures and participants to investigate how the ecosystems are formed and what mechanisms are needed when forming the ecosystem continuing with the business model and business case analysis. In this case study also the side stream analysis mechanisms are needed to examine. They give an insights of the industry context to this research. The side stream analysis themes are examined via European Union legislation and other analysis tools. The internal accounting practices and tools are excluded from this study since it is not the focus in the goals.

## 2.1 Business Ecosystem

Moore (1993) states that to keep up in the market, companies have to evolve themselves and their business quickly. This can be achieved if a company attracts customers, suppliers, investors and other actors of its business network. When creating a business ecosystem, the plan and ambition should be visible in the corporate strategy. (Moore 1993). Zahra and Nambisan (2012, 220) refers that "Strategic thinking focuses on visualising the future before it happens, a process that entails building and considering different scenarios". In business ecosystem the interaction between network actors is ever changing and dynamic (Zahra and Nambisan 2012). These business networks are communities that can create new innovations to its' business environment which brings success and capital. Business network is a framework that managers can use in order to comprehend the strategic meaning of the changes in the market. (Moore 1993)

The business ecosystem as a concept is to look the network actors which relationship with each other is symbiotic, co-evolving and dynamic (Hearn and Pace 2006). In the business ecosystem point of view, company should be considered as a part of a cross-industry business ecosystem rather than as a one actor of a single field of industry (Moore 1993). Frosch and Gallopoulos (1989) entitles the importance of the industrial ecosystem with the fact that using raw materials in industry inefficiently producing waste, burden would

be huge on earth in the future. Also Schulte (2013) reminds that linear supply chain creates waste and disposal of the waste. A broader mindset of product life cycle should take into account more to optimise the material flow efficiently (Schulte 2013). To cycle raw material better more integrated ecosystem model is a base of recycling processes, energy and material consumption is optimised and waste minimised (Frosch and Gallopoulos 1989). The circular economy thinking in new business models in ecosystem creation benefits both the economy and environment (Schulte 2013). The core of the business ecosystem is the cooperation and connection between the suppliers and partners, states Gossain and Kandiah (1998). Together, companies can endorse each other around an innovation with collaboration but also with competition which arouses the need for the second generation innovation to keep the leadership in the market. (Gossain and Kandiah 1998) Moreover, competition between business ecosystems are changing the industrial world nowadays. This balance between cooperation and competition forms a complex interaction and co-evolution. (Moore 1993) Relationships can be changeable in time or in different seasons so they are not frozen and stationary. (Gossain and Kandiah 1998).

Moore (1993) refers the business ecosystem as a biological ecosystem in the nature. As the biological ecosystem, business ecosystem moulds gradually from a complex randomness into a systematic network. Also the life cycle is the same in business environment as in nature. Ecosystem is born, expanded in the growth phase, domination of the environment and in the last phase, renewal or death. If the self-renewal occurs, the cycle can continue and ecosystem thrives even more. These four phases of a company's life cycle are represented in the table 1 based on Moore's (1993) proposed The Evolutionary Stages of a Business Ecosystem. (Moore 1993)

**Table 1.** The Evolutionary Stages of a Business Ecosystem (modified from Moore 1993).

| The Evolutionary Stages of a Business Ecosystem | | |
|---|---|---|
| | Cooperative Challenges | Competitive Challenges |
| Birth | Work with customers and suppliers to define the new value proposition around a seed innovation. | Protect your ideas from others who might be working toward defining similar offers. Tie up critical lead customers, key suppliers, and important channels. |
| Expansion | Bring the new offer to a large market by working with suppliers and partners to scale up supply and to achieve maximum market coverage. | Defeat alternative implementations of similar ideas. Ensure that your approach is the market standard in its class through dominating key market segments. |
| Leadership | Provide a compelling vision for the future that encourages suppliers and customers to work together to continue improving the complete offer. | Maintain strong bargaining power in relation to other players in the ecosystem, including key customers and valued suppliers. |
| Self-renewal | Work with innovators to bring new ideas to the existing ecosystem. | Maintain high barriers to entry to prevent innovators from building alternative ecosystems. Maintain high customer switching costs in order to buy time to incorporate new ideas into your own products and services. |

In the evolutionary stages of a business ecosystem, there are cooperative and competitive challenges in addition to benefits. In the birth phase the company should have a seed of innovation and discuss with the customers and the suppliers about the value creation around the innovation but also to protect the newly discovered innovations from rivals. This is achieved when making tight and close partnerships with all other stakeholders and design the business the way it serves the customers and potential markets. In the growth and expansion phase ready product or service is going through a ramp-up phase and introducing the value to the big markets. Challenge in this phase is the competition. The company has to make bold moves to defeat competition and gain a control of the market. But realistic demand and supply planning takes place in cost efficiency. Leadership of the ecosystem makes the company to set the pace in the innovations of its field of study with encouraging stakeholders. To reach leadership the company must not only satisfy the customer need but also develop the business agilely and strive towards continuous improvement. Challenge is to keep the position and negotiating power in the market in a constant competition. A strong actor in the market can be also called a central ecological contributor. Central contributor attracts suppliers to stay in the ecosystem due to investments they have made to cooperate with the contributor. Self-renewal phase

demands new ideas and innovations in the obtained ecosystem as well as preventing new actors, ecosystems and innovations entering the market. (Moore 1993) Gossain and Kandiah (1998) reminds that before extending product or service portfolio with the new innovation, it is important to review the business strategy and core businesses, is the new field complementary of competitive product to existing products and does the new innovation fit to the value proposition towards the customers. To keep rival from entering the market, the company can use high product or service switching costs or other high barriers. The renewal can mean also transforming into a new ecosystem. If the self-renewal does not happen the ecosystem, as it is, will face the death of its life cycle. (Moore 1993)

Ecosystem can be presented in many ways. The research shows that the business ecosystem is a complex and dynamic business network that includes horisontally and vertically different companies. The innovation or the new joint value proposition connects the relevant stakeholders together (figure 2).

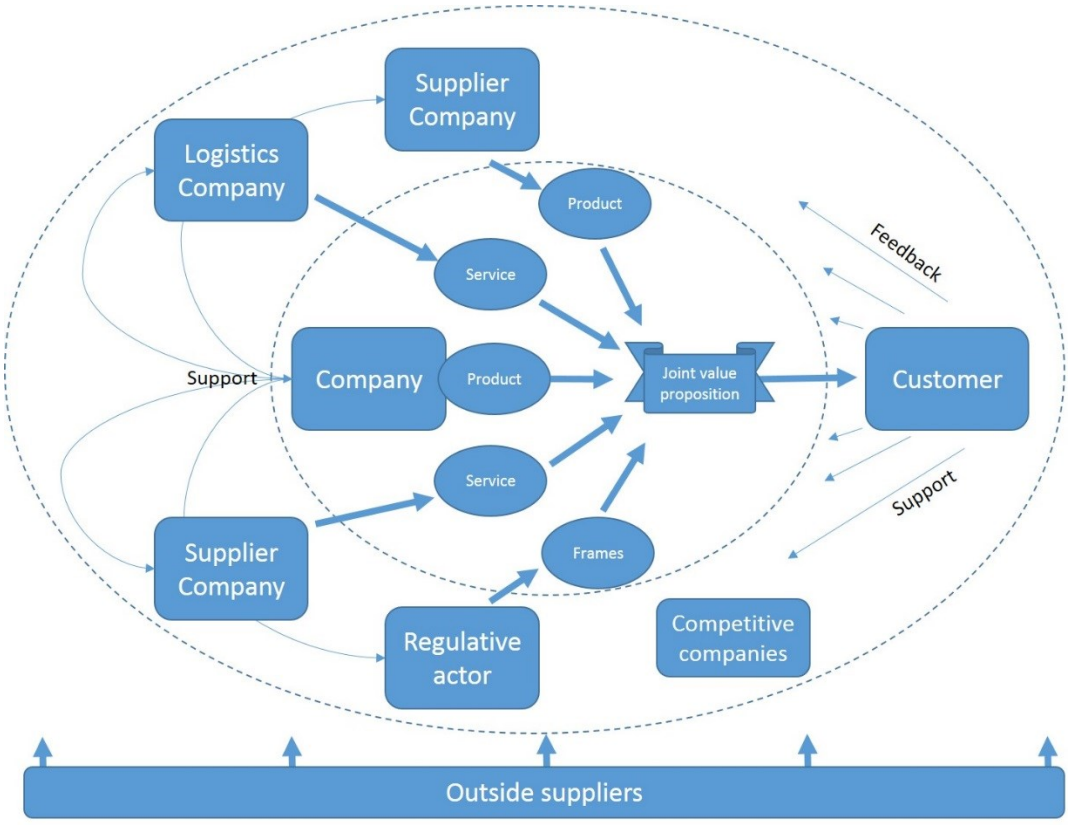


**Figure 2**. Business ecosystem (combined from Moore 1993; Gossain and Gandiah 1998; Frosch and Gallopoulos 1989; Schulte 2013; Hearn and Pace 2006).

### 2.1.1 Forming the Ecosystem

Ecosystems can be classified into categories in ecosystem health and type point of view. Galateanu (2013) has divided different aspects as the figure 3 shows based on the previous literature findings. Iansiti and Levien (2004) categorises the ecosystem health in a very similar way: instead of the innovation they presented Niche creation. When an ecosystem has diversity in members and industries, ecosystem is more flexible in the economy and competition fluctuation times. (Iansiti and Levien 2004).

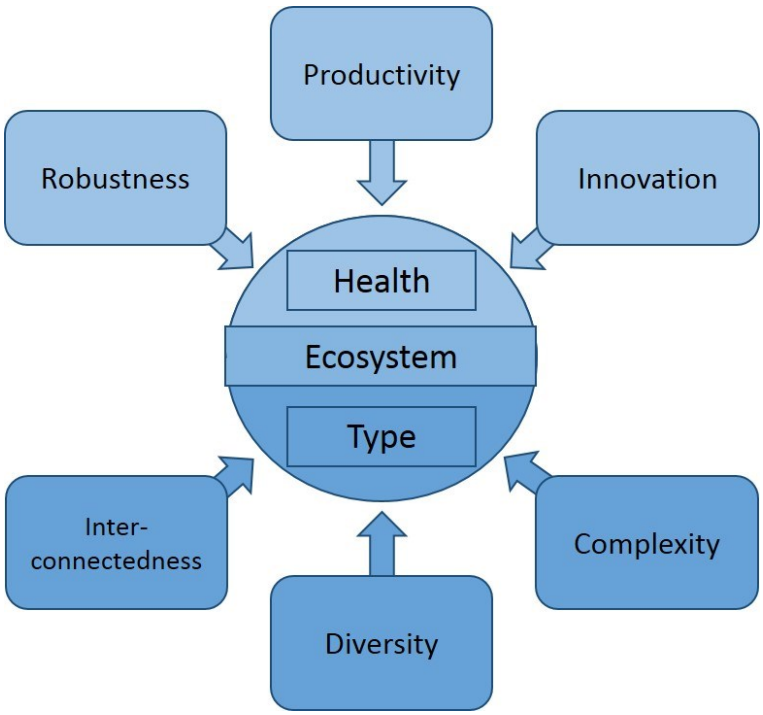


**Figure 3.** Business ecosystem classifications (modified from Galanteanu 2013).

When forming the business ecosystem from individual organisations, the existing businesses can be modified with adjustments to match to the ecosystem model. The ecosystem doesn't need to build from the scratch but moulded from the present businesses to save time, effort and costs. One of the means to create an ecosystem from building blocks is to make the business parts to modules that can be collected together and form an entity. (Zahra and Nambisan 2012; Tsvetkova and Gustafsson 2006) Strategic planning of the business ecosystem considers the linkages between the members. The entrepreneur point of view it benefits the most when instead of managing the steady state, the ecosystem bonds are modified and redesigned with the principles of continuous improvement whenever it is beneficial. (Zahra and Nambisan 2012)

### 2.1.2 Strategy Roles in the Ecosystem

In ecosystem it can be seen different roles in the ecosystem structure and dynamics based on the strategy. Main strategies are a keystone, a niche player and a dominator role. The keystones are, as the word itself states, in the core of the ecosystem. They give the ecosystem steady assets, increase ecosystem productivity, improves robustness and advances niche creation. If the keystones collapses and are removed from the ecosystem it is most likely that the whole ecosystem goes with it. The development of the ecosystem is the core intention to keystones who want to assure the survival and prosperity to themselves. They have the power, means and resources to do that and benefits from the investments. The two main strategies that keystones have is to create value in the ecosystem with innovation, platform, tool or technology creation and to share value with other players in the ecosystem. (Iansiti and Levien 2004)

Dominators avails their leading, powerful role in more old-fashioned way compared to keystones. Dominators are a threat to the ecosystem as they only utilise the value and they take over the network. However, they are accountable for the utilised and consumed value in the network. Physical dominators want to possess the ecosystem and lead it themselves outright aggressively. Dominators can be either physical or value dominators. As physical dominator has a lot of control over an ecosystem, value dominator doesn't and it creates a bit of value itself to the ecosystem even though it extracts the value as much as possible and sooner or later the ecosystem crashes down taking the value dominator with it. (Iansiti and Levien 2004)

Niche players are keen on building up their own capacity, knowledge and assets. They focus on developing their strengths and produce resources to other members of the ecosystem. As they focus on their own speciality and keystones give the possibility, niche players thrive and provides a lot of value and innovations to the ecosystem. Niche players have power in numbers. Usually there is tens or hundreds niche members in the ecosystem and together they can have their voice heard. If the keystone start to take too much control and consumes the value or in other way start to behave badly in the ecosystem, niche players have influence prevent keystones to transform into dominators. (Iansiti and Levien 2004)

Commodity role is a strategy which is low in complexity of relationship and level of innovation and innovation. Part of the companies act independently or don't have a strong dependency towards other industry players in a mature and steady industry. Business ecosystem strategies are not relevant with these type of companies. (Iansiti and Levien 2004; Koivisto *et al*. 2004)

All in all, roles are dynamic and changing in the ecosystem. Niche players can grow into keystones and keystones can evolve into dominators. Keystones can also become niche players if a niche grows in business. The same company can be in a different role in a different ecosystem, niche player in one and a keystone in another. (Iansiti and Levien 2004)

### 2.1.3 Competition

It is important to take in consideration also the competition situation. Rivals also create their own ecosystem and network of suppliers and customers. It is important to try to find these relationships and analyse them against our own ecosystem. (Moore 1993) Zahra and Nambisan (2012) mentions that in a business ecosystem there is huge amount of knowledge and know-how that needs to be protected. But also the ecosystem as a business entity is very efficient and powerful against the rivals. Also the ideas and innovations must be considered to be protected. What innovations and supplier support does the competitor have and could it be the one that replaces our solution? If it replaces, what would it take to make new innovations and what kind of processes and cooperation it requires to stay in the leadership position. (Moore 1993)

Developing the business ecosystem even further, it is possible to take customers into the ecosystem as a partner. Customers can be involved to the business with giving the company product reviews, recommendations and feedback to enhancing the customer experience. This way everyone in the ecosystem including the customer will benefit the collaboration. (Gossain and Kandiah 1998)

## 2.2 Business Models

To understand a concept ‘Business Model’ we need to understand the definition of the two used words in this context ‘business’ and ‘model’. Osterwalder *et al*. (2005) have defined business as “the activity of providing goods and services involving financial, commercial and industrial aspects”. A word ‘model’ they have defined as a “simplified description and representation of a complex entity or process". (Osterwalder *et al*. 2005, 5)

In the studies regarding business models, there has been many different definitions as a concept. Researchers have a little bit different point of view depending on the field of study. The business model can be viewed differently if your area of interest is either organisational structure, revenue sources or product architecture. Al-Debei *et al*. (2008) have developed the guidelines to make a consensus for the concept of business model. The concept consists 10 different perspectives (table 2). (Al-Debei *et al*. 2008)

**Table 2**. Guidelines to develop a consensus for the business model (modified from Al-debei *et al*. 2008).

| | Perspective | Authors |
|---|---|---|
| 1 | A way in which organizations create value. | Amit and Zott, 2001; Kallio et al., 2006. |
| A | The ways in which an organization, along with its suppliers and partners (business actors) creates value for its customers. | Magretta, 1998, 2002; Petrovic et al., 2001; Torbay et al., 2001; Stähler, 2002; Osterwalder et al., 2005; Haaker et al. 2006. |
| B | The ways in which an organization, along with its stakeholders (business actors), create value for each party involved. | Bouwman, 2002; Stähler, 2002; Haaker et al., 2006; Andersson et al., 2006. |
| 2 | A way in which an organization generates revenue. | Timmers, 1998; Magretta, 1998, 2002; Rappa, 2000; Linder and Cantrell, 2000; Torbay et al., 2001. |
| 3 | An abstraction of the existing business and a future planned business. | Stähler, 2002. |
| 4 | An architecture for the organization, including its assets, products, services, and information flow. | Venkatraman and Henderson, 1998; Timmers, 1998. |
| 5 | As business logic relating to the ways in which businesses are being conducted. | Petrovic et al., 2001; Osterwalder et al., 2005. |
| 6 | A way in which an organization enables transactions through the coordination and collaboration among parties and multiple companies. | Amit and Zott, 2000; Bouwman, 2002; Haaker et al., 2006. |
| 7 | An organization's strategy or set of strategies. | Leem et al., 2004; Kallio et al., 2006. |
| 8 | An interface or a theoretical layer between the business strategy and the business processes. | Camponovo and Pigneur, 2003; Tikkanen et al., 2005; Rajala and Westerlund, 2005; Morris et al., 2005. |
| 9 | A conceptual tool, a business abstraction, and a blueprint. | Stähler, 2002; Haaker et al., 2004; Osterwalder et al., 2005. |
| 10 | A way of understanding a single organization or a network of organizations | Bouwman, 2002; Haaker et al., 2006 |

As we can see, business model concept is strongly linked to the company's ability to create value to customers, company strategy and organisation internally and the network externally. Also revenue making and a manuscript of a company and its core business are in focus. Al-Debei *et al*. (2008) summarises all these definitions into one definition: "The business model is an abstract representation of an organisation, be it conceptual, textual, and/or graphical, of all core interrelated architectural, co-operational, and financial arrangements designed and developed by an organisation presently and in the future, as well as all core products and/or services the organisation offers, or will offer, based on these arrangements that are needed to achieve its strategic goals and objectives." (Al-Debei *et al*. 2008, 8)

Teece (2010) also combines the different meanings of business model as a practical demonstration of the logic of company's actions, provides data and evidence which shows how it "creates and delivers value to customers" (Teece 2010, 173). As it is like a map or manuscript of the company's existence and purpose as an entity. (Teece, 2010)

The importance of business model as a concept is young and slowly coming into the consideration in revenue gathering. Teece (2010) states that customers do not want only the product but the solution to their need. In some cases markets do not even exist when organisation of a company has been initiated to exist and in this situation the value creation towards the customer who does not know yet that they need a solution, has to be designed. (Teece 2010) Porter (2001) criticises the business model thinking. Only the business model plan doesn't cover enough information before starting a business, the value creation to the customer as a concept should be taken into account. (Porter 2001) It is a good and necessary foundation but alone it is not enough. Alongside the business model, a company needs a plan to face the competition and the value chain and revenue model concepts covers this issue. (Margetta, 2002) Business model design is a part of building a business to implement transactions and gain revenue in the long term. (Teece, 2010)

Different business model types that also used word taxonomies are tightly linked to the industry type according to Osterwalder (2005). Osterwalder (2009) has created a framework of business model canvas for building the business models simply (figure 4). The business model canvas is a practical tool for companies to design and evaluate the business models. In this literature review we concentrate on the very core of the definition which is the value chain, networking and revenue model aspects of the business model instead of creating a whole business model and business plan of one company.

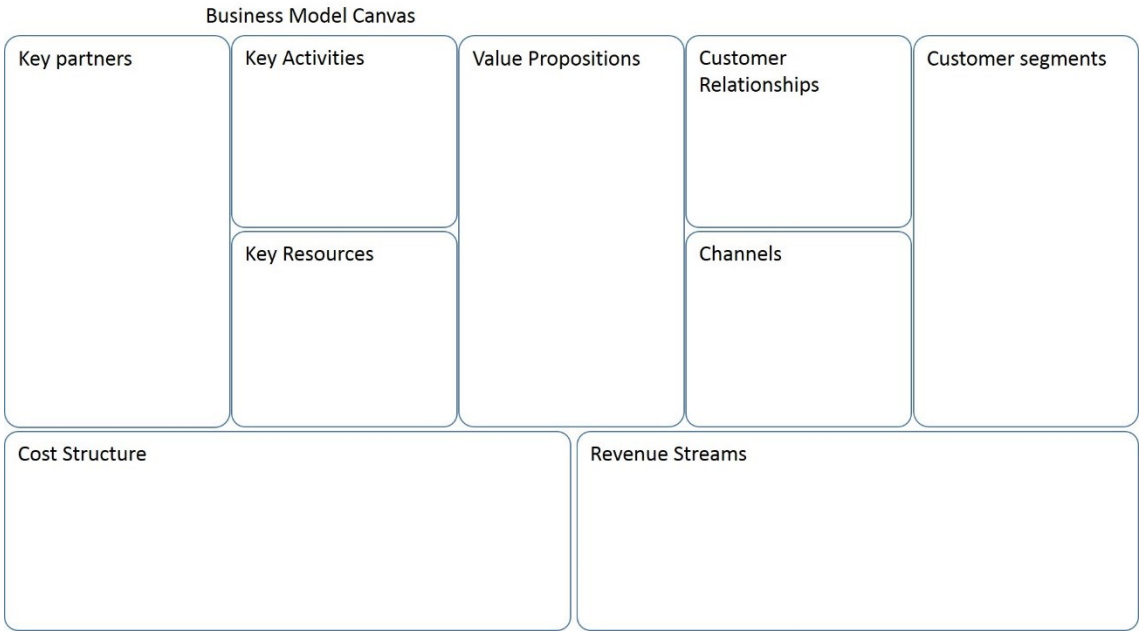


**Figure 4.** Business model canvas (modified from Osterwalder 2009).

### 2.2.1 Circular Business Model

Schulte (2013) introduces a circular economy concept of a circular business model to reduce waste in the landfills in linear supply chain thinking and create circular model to utilise the materials more efficiently to benefit not only the economy but also the environment around us. There is five main principles to the circular business model according to Schulte (2013). They are presented in the figure 5 below. (Schulte 2013)

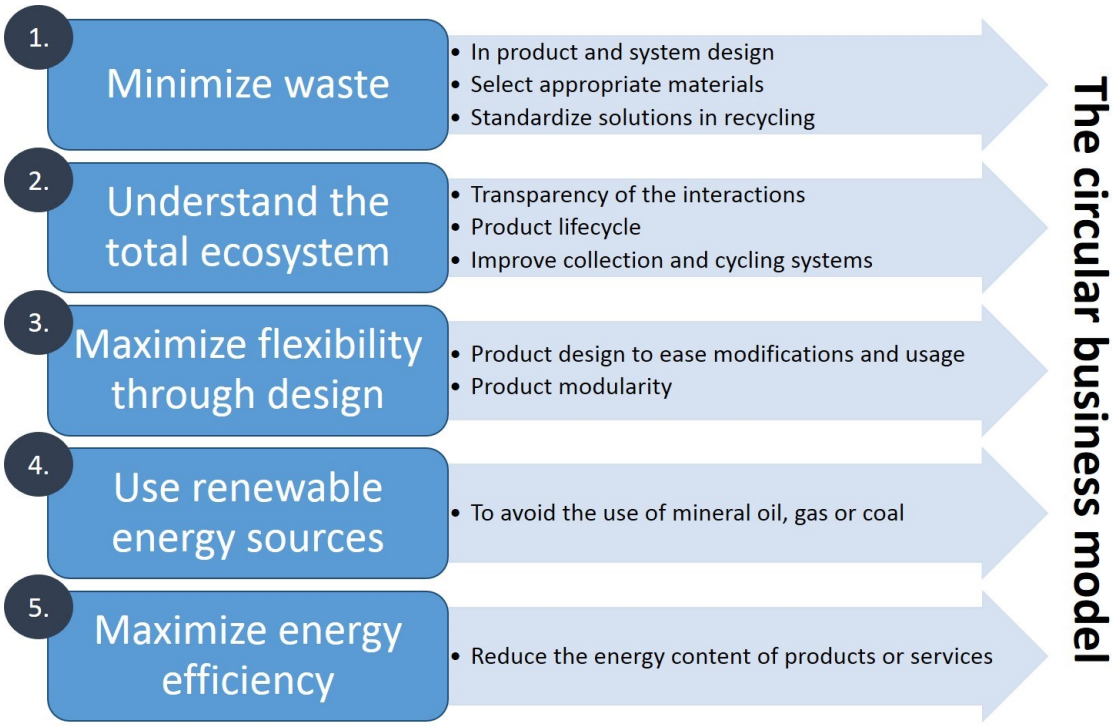


**Figure 5**. Five principles of circular business model (modified from Schulte 2013).

The circular business model is strongly linked to the business ecosystem mindset as the degradation and cycling activities can be passed to other companies which are specialised to that. With this ecosystem partnership the circular process can be accelerated. The ecosystem in waste or side stream material collection need careful planning and extra attention in infrastructure and recovery technologies. These actions are closely regulated and requires permissions from authorities. (Schulte 2013)

Also other research have been done regarding sustainable business models which focus on also ecological aspects of an economical business models (Bocken *et al*. 2013). Bocken *et al*. (2013) summarises that to aim for sustainable economy, ways to achieve it is to design a closed-loop business models where raw materials would be used as efficiently as possible and creating as least waste as possible, establish the system that highlights the end value, customer experience and deliverable instead of just product ownership in the companies and build an ecosystem based on cooperation and sharing of knowledge and capabilities instead of competition. These fit well to the ecosystem mindset. (Bocken *et al*. 2013)

### 2.2.2 Business Model Framework

Suikki *et al*. (2006) have created a general business model creation framework from a theoretical study of related research. They introduce the frameworks to business model evaluation in mobile telecommunications field but the general framework is applicable also to other industries. Table 3 shows the introduced framework what can be used in building a business model around different industries.

**Table 3.** Framework for describing and building business models (form Suikki *et al*. 2006).

| Dimension | Component | Description |
|---|---|---|
| Offering | Composition | What is the offering: what physical, information and service aspects are included? |
| | Customer | Who is the customer? (If relevant, identify both end and direct customer.) |
| | Sales approach | Sales channel, distribution, billing (how do customers pay) |
| Value creation system | Structure | Networked or chain? Position of the firm? |
| | Network players | Who are the players? What are their roles? The relationships between playeres and the firm? |
| | Network size | The number of the players, how many customers, suppliers etc. |
| Revenue model | Basic logic | How and from whom is the revenue generated, where in the business system the firm takes profit? |
| | Cost and pricing structure | What kind of cost structure is in producing the offering (fixed and marginal costs)? Value-based or cost-based pricing? For what customers pay, bundling or unbundling? |
| | Market | Which market is served? Size of the market? Market structure (dominant player, diversified)? |
| | Share of total value | How big portion of the total value created in the network can the firm capture with the revenue model? |

In the framework the business model components are divided into three classes: Offering, value creation system and revenue model. On offering a company should investigate what do they offer to customers, who is the customer and how the sales brings the money to the company. When regarding the value creation system company should define what is the entity around the core business of the offering, *e.g.* who are the players, stakeholders, suppliers and retailers. Third dimension is the revenue model that describes the profit

paths, cost structure, market details and share of total value created in the network. (Suikki *et al*. 2006)

This framework presented is very similar to other frameworks that have been suggested in the literature. Tsvetkova and Gustafsson (2012) have four main dimensions in their focal business model framework to the business ecosystems: Customer, capabilities, value proposition and revenue model. They introduce three business configurations related to biogas supply chain ecosystem and evaluate all the configurations with the presented dimensions. (Tsvetkova and Gustafsson 2012)

Suikki *et al*. (2006) have also created a framework to evaluate the existing business model and it has been composed based on the criteria of Slywotzky (1996) and Hamel (2000). The framework is presented in the table 4. The framework has been established to consider is the business model up-to-date but it doesn't tell straight does the model work or not. (Suikki *et al*. 2006)

**Table 4.** Business model evaluation framework (from Suikki *et al*. 2006).

| Dimension | Questions to consider |
|---|---|
| Suitability | How well does the model meet customers' most important priorities? Are there priorities that are not served? Is it likely that the priorities will change and thus make the model obsolete? |
| Internal consistency | How internally consistent is the model? Do all the parts work together for the same goal? Do the elements positively reinforce each other? Are there conflicting elements or elements that do not support the meeting of customer priorities? |
| Uniqueness | Does the model differ from those of competitors, or the 'average' within the industry in conception and execution? Is it unique in ways that are valued by customers and benefit them? |
| Efficiency | What value do customers derive from the offering? What costs does the firm incur in providing that value? Does the value customers place on the benefits exceed the cost of producing them, i.e. is the model an efficient way of delivering customer benefits? |
| Ability to capture value | Can the model recapture value? Does it capture sufficiently large portion of the total value created in the network? Are these mechanisms sustainable ond defensible? |
| Economic considerations | Is the revenue model sound? Are the cost and pricing structures reasonable? Is the market large enough? How cost effective is the model? |
| Future potential | Does the model represent a better way than the existing alternatives? Will the model meet the customers' priorities also in the future? How long will the model be sustainable? Are alternative models being empoyed that meet the next cycle of customer priorities better? |
| Feasibility | Is the model realistic? How easy is it to implement? Is it possible to 'sell the idea' to other network players? How probable is it that the model would work in practice? |

### 2.2.3 Value Streams

Original concept of the value chain is from Porter (1985) who described the company's internal processes as a value chain. Porter (1985) defines a value chain as an entity of activities that are identified and in the process-like chain and as a product flow, how the offering is made. The value chain analysis and representation describes all departments of the company, their activities and how they are linked to the production of the offering. All activities, direct or indirect, in the company should be linked to the value chain that creates the value to the customer (Porter 1985). Later on the basic concept has been expanded to include network concept into a horisontal value chain as well as vertically industry wide value chain and even combination of these two as a value network (Kotler 1997; Hoover *et al*. 2001; Allee 1999). Tsvetkova and Gustafsson (2012) explains that value network is a certain number of value chains in different industries and business ecosystem is formed when the value network is linked with each other. The individual

value chains are connected to one another over industry interfaces (Tsvetkova and Gustafsson 2012).

Value chain can be created defining the scope of the regions, industries, segments and departments in-house. Porter (1985) represents these four dimensions as competitive scope. When looking for the right value chain configuration these four dimensions shown in figure 6 can be assessed. Business boundaries can be assessed investigating the relationship between the value chain and competitive dimensions. (Porter 1985)

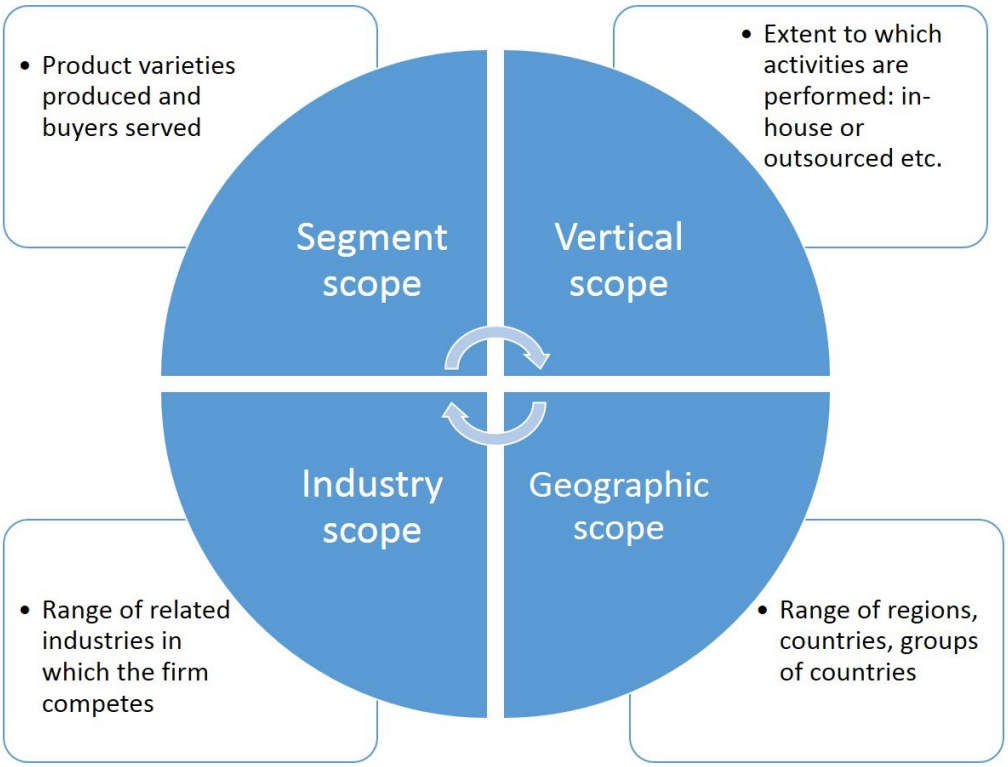


**Figure 6.** Four dimensions of competitive scope affecting to the value chain (modified from Porter 1985).

### 2.2.4 Revenue Models

The revenue model is one of the key topics business model want to explain and represent. It explains how the revenue is built and from whom to cover expenses and other financial activities. This includes the different pricing methods to different products and sources. In this research we concentrate on the revenue from the product instead of other methods of financing the operations. (Rajala *et al*. 2001)

In the revenue model creation there is five attributes to take into account: Compensator, Effect, Rating, Charging and Timing. Compensator is the actor who gives the compensation in the chain. This can be the customer internally or externally. In revenue model the compensator actors and possibilities should be assessed as well as what are the products or services they want to compensate. Effect means if the compensation happens or not and how. Compensation can be absent, money, other products or services or some other payment in other ways. Causality shows the connection between a revenue model and a business model. There can be many business models but revenue model is always linked only to one business pattern inside the business model. Causality study clarifies to which business pattern the revenue model is referring. Rating is a tool to measure the utilisation of products or services. Ratings can be estimated by amounts or time used. Amounts used measure *e.g.* the number of users or the volume of products. Rating by time in the article of Popp (2011) is described via software business and he explains that it is estimated for time used, for a limited time or forever. Just how long consumers can have the software for the money they consume. Charging is defined by Popp (2011, 80) as the "way to define the compensation amount for a certain rating of goods and service consumption". Charging dimension is defined but the rules are modifiable and can be defined by the company itself in many different ways. The last dimension is the timing of compensation. It defines at what time the compensation will happen from a customer. Also it can cover all other additional conditions to timing. Aspects as is the product or service prepaid, paid when consumed or paid during the consumption can be determined. Overall payment scheduling is the main activity of the timing dimension. (Popp, 2011)

Schulte (2013) states in the circular business model introduction about financing models to the circular economy models. The change from the linear business model structure to a circular business model and ecosystems need new revenue creation models (Tsvetkova and Gustafsson 2012). To sustain a good level of profit through the transformation and forming new ecosystem business models companies needs to create new financing models to make a switch from quick profit and return on investment to more constant financial structure and streams of cash. (Schulte 2013)

## 2.3 Business Case Analysis

Business Case Analysis (BCA) is a tool to examine the potential investments and for choosing the best investments to implement when a company is spending scarce resources. It describes which and why a certain investment opportunity should be selected. The aim for these evaluations and business reasons is to help company management make the decisions rationally by comparing the possibilities of value of potential investments. (Kinnunen T. *et al*. 2013; Business Case Pro 2010) Compared to other investment comparison tools, business case analysis is wider and more comprehensive than a simple cost comparison between investment options (Randall 2012). The BCA procedure is vastly used in the new product development in the stage-gate evaluation in different phases of the new product introduction. (Kinnunen T. *et al*. 2013; Business Case Pro 2010)

The business case analysis includes three aspects to take into consideration. Financial analysis is needed to evaluate the numbers behind the investment suitability to the company strategy. In the base of the financial analysis lies the technical assessment that gives knowledge about technical complexity, technological competence needed, uncertainty, synergies and work effort estimation. Market assessment is another small entity needed in the financial analysis and it defines target market, total market size, potential and expected growth in the markets and it takes into account the competitor extent and intensity. All these affects to the decision, is the investment match to the company's strategy. (Kinnunen T. *et al*. 2011) The financial data, competitor data and technical or technological data should be gathered to make a beneficial business case study (Kinnunen T. *et al*. 2013). After the investigation of these three dimensions, strategic fit evaluation can be done to review how the plans fit to the product and technology strategy of a company before executing sales and cost estimates and financial return assessment. (Kinnunen T. *et al*. 2011)

The business case checklist by Business Case Pro (2010) has very similar phases as the framework presented by Kinnunen T. *et al*. (2011). When starting to evaluate the investment BCA procedure has 3 different main actions according to Business Case Pro (2010). The first step for evaluating the target process in which the investment is related to. Process mapping studies the stakeholder inputs, intellectual and financial capital, the

process itself and outputs in short and long term. The second phase is to measure the performance the investment brings to the company and to the process. Main focus in this phase is to how the improvements can be measured and with which metrics after the operational changes has been done. This is the technical assessment to have an overview to the cost estimate. Also the customer have to be defined was it internal of external. (Business Case Pro, 2010) This represents the market potential evaluation in the framework by Kinnunen T. *et al*. (2011). The third and the last step is to value the performance improvements and transform the value into the financial calculations for evidence and measurable units that different investments can be compared. (Business Case Pro, 2010) This is the last phase in the BCA framework by Kinnunen T. *et al*. (2011) which is the financial return analysis. With the fundamental evaluation, a company can find the best investment for their business. Inside these three main principles there is twelve steps in the checklist by Business Case Pro (2010) that guide the business case evaluator through the investment assessment. The differences between these two approaches in the business case is the strategic fit evaluation. In the BCA checklist the strategic fit qualitative assessment is embedded in other parts of the analysis with numbers but in the BCA framework by Kinnunen T. *et al*. (2011) the strategic fit is a qualitative analysis phase of its own in addition to the cost and market estimations. (Business Case Pro, 2010; Kinnunen T. *et al*. 2011)

Another approach to business case analysis is the Harvard Business Case Analysis presented by Otto and Wood (2001). The Harvard Business Case method consists 8 phases: Problem statement, assumptions, major factors, minor factors, alternatives, discussion about alternatives, recommendation and implementation. The problem statement is a one sentence about the problem in the market that the investment is answering to. Assumptions that are limiting the business case and giving the direction to the proposal are also listed. These are for example costs and direction of the strategy. Considering major and minor factors, you estimate the limitations or possibilities of the environment impacts to the decision whether they were grand or secondary. These can be the state of business or a goal for certain revenue amount. Alternatives to the investment come naturally but if there is not any alternatives present in the decision making moment, hypothesised alternatives with pros and cons gives perspective to the evaluated case. Discussion about the alternatives compares the options and in the end chooses the most executable. After the assessments recommendation is the seventh step. The evidence

behind the statement of recommendation is covered in previous steps. Last phase is the implementation plan creation and execution. In the plan resource availability, time frame, measurements or key performance indicators should be visible. (Otto and Wood 2001)

Kinnunen T. *et al*. (2011) have combined the business case analysis principles from the previous research to a simple process to follow when analysing business cases (figure 7). In the framework the market assessment through value definition will bring knowledge about sales estimates and on the other side the technical feasibility study will bring information about the cost estimates. After the strategic fit evaluation the sales estimate and cost estimate comparison results in financial return overview and eventually to decision proposal. (Kinnunen T. *et al*. 2011)

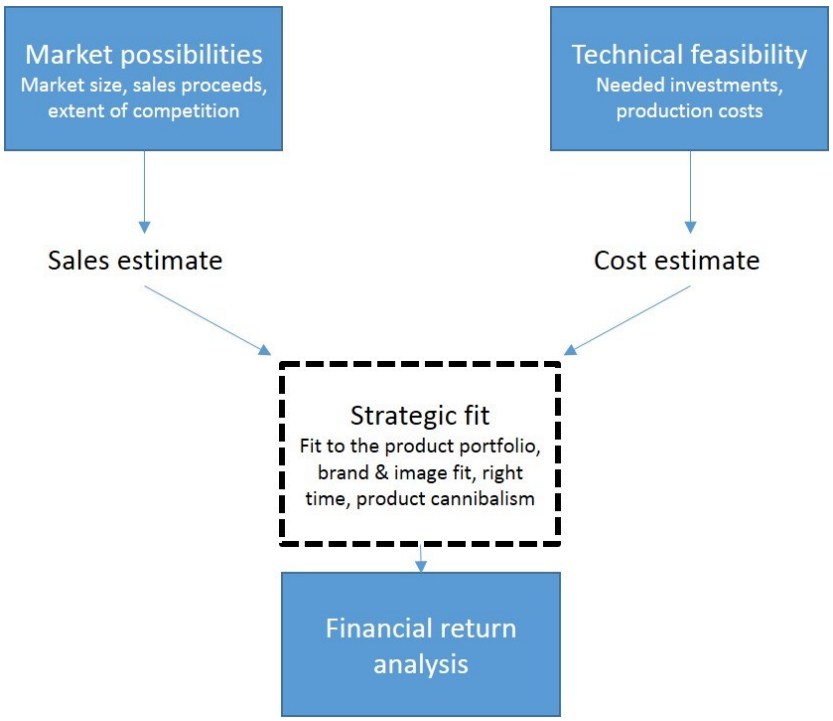


**Figure 7**. Business case procedure (modified and simplified from Kinnunen T. *et al*. 2011).

The next paragraphs will explain in detail what the building blocks of the business case analysis by Kinnunen T. *et al*. (2011) are and why they need to be taken into account in evaluating the new product introduction and investment decisions.

### 2.3.1 Cost Estimate

Cost estimates for business case analysis comes from technical, technological and process related details. Technical feasibility gives a base to conduct a comprehensive study about the costs of the business case which a company is seeking business opportunities from. The business case cost analysis is mainly a quantitative analysis that include all the fixed and variable costs of the new product production in addition to the investment costs from product development to business sustainability investments. (Kinnunen T. *et al*. 2011)

Technical feasibility is a key factor in analysing the costs. The readiness of the technology in producing the products needs to be in acceptable level and mature enough to be able to estimate the development costs now and in the future. Also the process capabilities need to be taken into account how the ecosystem can manufacture the planned product. In addition to all product specified details as performance and technologies used, the risk factors and success probabilities needs to be taken into account in the technical feasibility. These technical aspects then can be translated into measurable units and assess fairly. Cost estimate includes the technical feasibility in monetary units. Measurable information used are for example development, production and other lifecycle costs. (Kinnunen T. *et al*. 2011)

### 2.3.2 Sales Estimate

Sales estimate is both qualitative and quantitative when analysing the business case through market assessment. The reason to assess the market opportunities and customer acceptance is to produce the right product and find the best business opportunities in the market. The revenues can only be gathered if the demand is present in the market. To find the right markets is crucial factor to have sustainable business. (Kinnunen T. *et al*. 2011)

Market estimate includes also the value definition for the case. It needs to be known what the customer need is and how the customer need can be satisfied and value delivered. The market assessment itself consists of four elements. Target market definition, total market size, market growth estimations and intensity and extent of competition are the elements that give as overview about the market situation at the moment. The future market situations and prospects are difficult to predict but if it is possible, the forecasting the market movement supports the strategic planning of the business case after the analysis.

After these descriptive evaluations of the market assessment is done, the sales estimate can be formed with the measurable units as sales revenues, market share, price estimation, impact on sales and annual demand. (Kinnunen T. *et al*. 2011)

### 2.3.3 Strategic Fit

Strategic fit is a qualitative analysis where the new opportunity will be assessed next to the company strategy and purpose in the business. Besides the relatedness to strategy, other concerns that needs to be taken into account are fit to the future plans, strategic importance, alignment to the company's strategy and consistency with all the plans and goals. This assessment, when done in extreme honesty, gives a truthful insights about the company's commitment to give resources to the new product or investment and to support the prospective case when selected to continue it. (Kinnunen T. *et al*. 2011)

Also the product and technology strategy inside the company is useful to discuss. The assessment, what is the new product position in the product portfolio and how the new product will affect to other products' position in the company, is needed to avoid unnecessary losses. In some cases the new product can cannibalise other products' sales if they are substitutive or similar products. Also the technological and product timeline evaluation helps to determine the right time to introduce the product to the markets. (Kinnunen T. *et al*. 2011)

### 2.3.4 Financial Analysis and Business Case Proposal

From the sales and cost estimates the financial analysis can be conducted in monetary units to support the decision making about the new product or investment. Sales estimate gives details to the revenue side and cost estimate provides the information about the investment costs and other expenses. Strategic fit is a supportive knowledge to the financial analysis. It does not give any measurable factors to the calculations but is as important as the cost and sales estimates to the result and business case proposition. In financial analysis the profitability is calculated as well as payback level and cash flow statement presented. To support the business case proposal, the simplest way to present the financial analysis is through few figures and charts. (Kinnunen T. *et al*. 2011)

## 2.4 Analysing Industrial Side Streams

In European Union there has been recently changes in the waste policies that enable waste and side stream utilisation as a recycled raw material in products. The Waste Framework Directive (WFD) that has been enacted in 2008 allows to use raw materials more efficiently and encourages companies to recycle their side streams more in the future. This is an act for a more sustainable consumption of natural resources through circular economy mindset. Besides the WFD, the landfill and waste handling costs have increased which gives the companies incentive to utilise the waste flows more efficiently to minimise the actual waste amounts to landfills. (Husgafvel 2016) Also the ash and slag waste recycling is supported by European Union. After the EU required processes from waste to secondary raw material the cost of producing building materials can be diminished by 15-30 %. (Menshov *et al*. 2014)

Husgafvel (2016) presents the idea of symbiosis products. Different industry side streams can be processed further and combine into symbiosis products. For example the side streams from paper mill and steel plant can form a new product. This industrial symbiosis rises from economic and environmental forces in the companies that strives for new revenue sources through eco-industrial development, local industry knowledge and new business opportunities. (Husgafvel 2016)

European commission (2008) has set the conditions to define the by-product that isn't the produced product in the process but has resulted in the production. The by-product can also be mentioned as the side stream substance. If the substance can meet the following conditions, it can be used as a side stream by-product instead of waste (European commission 2008);

1. Further use of the substance or object is certain.
2. The substance or object can be used directly without any further processing other than normal industrial practice.
3. The substance or object is produced as an integral part of a production process.
4. Further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

### 2.4.1 End-of-Waste Criteria

In the side stream utilisation and in the analysis of it, end-of-waste criteria is relevant in European Union. If the substance doesn't meet the by-product criteria, it can be categorised as a secondary raw material or a product through end-of-waste evaluation. Through these different evaluations the aim is to make a useful commodity out of the disbenefit or in this case waste. End-of-waste (EoW) criteria is a set of criteria that a side stream material have to fulfil in order to have a status of a product or a secondary raw material instead of waste. This assessment have to be made in the legislation point of view to have a status to a substance and further to be treated like the status permits. EoW evaluation consists 4 criteria in the Waste Framework Directive in the article 6 (European commission 2008):

1. The substance or object is commonly used for specific purposes.
2. A market or demand exists for such a substance or object.
3. The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products.
4. The use of the substance or object will not lead to overall adverse environmental or human health impacts.

Some substances are excluded from the directive. Those are for example gaseous effluents, contaminated soil, permanently connected to the land buildings, soil that is used again in the construction of the natural state of the site, radioactive waste, dismantled explosives, faecal matter that are going to use in other industries than agriculture, forestry or energy production through biomass processes. Also other material have been excluded since those are covered in other directives. After the evaluation when a substance has got the status of the secondary raw material or a product, it can proceed to the REACH protocol. (European commission 2008)

### 2.4.2 REACH Regulation

REACH regulation is in 2006 regulated protocol in European Union to ensure the high level of human health and environment protection against chemicals that are not categorised as waste or not already under some other regulation in EU and the production is over 1 metric tonne per year (European Chemicals Agency 2010). A substance is not a

waste if it has overcome appropriate recovery and recycling activities. The protocol has been established also for the manufacturing and movement of the chemicals inside EU as well as made import more reliable. Also new product introduction, innovation and competitiveness enhancement are few of the goals that have been improved due to the regulation. The regulation is not applicable to the radioactive substances, non-isolated intermediates, dangerous substances that travel by rail, road, inland waterways, sea or air, or substances that need customs clearance. These are covered by other regulation. (European commission 2006)

REACH regulation has several steps and processes through which the substance can be authorised to be safe to the environment. First a substance have to be pre-registered affording information about the substance such as the name, address of a contact person and estimated registration deadline. In the registration phase more detailed info about the substance is examined carefully. The processes that includes in the REACH regulation are registration, evaluation, authorisation and restriction. (European Chemicals Agency 2010)

### 2.4.3 Brand Image Effect to the Revenue Stream

Corporate reputation and the ethical branding has a distinct connection (Fan 2005). Corporate reputation, also mentioned image, includes two dimensions: the functional and the emotional. The functional components can be weighed with ease but the emotional, the customers' psychological emotions can be more challenging to capture in the analysis. The emotional attitudes rise from experiences, information provided from the company and from overall corporate image. The image can also differ from the point of view and people might have even controversial views from the same company, depending on the person's personal schemas. Corporate image forms in a process where ideas, feelings and experiences are collected from the memory into mental image. (Nguyen and Leblanc 2001)

Brand equity is according to Aaker (1991) "a set of assets and associations that are linked to the company's name and symbol and add or subtract value of a product or service". Leek and Christodoulides (2012) also mention these two brand value components, functional and emotional, as the financial and customer loyalty benefit brings also in B2B

business. Branding has a positive effect to the feel of the quality and therefore also to the demand, sales and eventually to revenue streams. The importance of the brand equity is widely accepted and recognised, however, the results have been varied. (Leek and Christodoulides 2012)

Keller (2003) introduced a pyramid to determine how the brand equity is formed. Kuhn *et al*. (2008) has applied this Keller's pyramid into the B2B environment. The customer-based brand equity pyramid form Keller (2003) and Kuhn's (2008) revised model for B2B are compared in the picture. To put it short, Keller's (2003) pyramid starts with the strong identity of the company that clear product attributes follow in the second step. Customers want to judge the price, design, the service it provides. Third step is all about opinions and assessment of the brand. The brand and product quality comes under assessment in this step. The highest step is the resonance, which is achieved when the loyal relationship has emerged with the customer. The same elements are the judgments, performance and partly salience. (Keller 2003) In the applied model it is salience of manufacturer's brand that is observed. In the Kuhn's (2008) B2B pyramid the salience of the corporate brand is more significant than the separate product brands. The comparison of these two band equity pyramids shows a subtle change in terms and point of view in B2B environment (figure 8). (Keller 2003; Kuhn 2008)

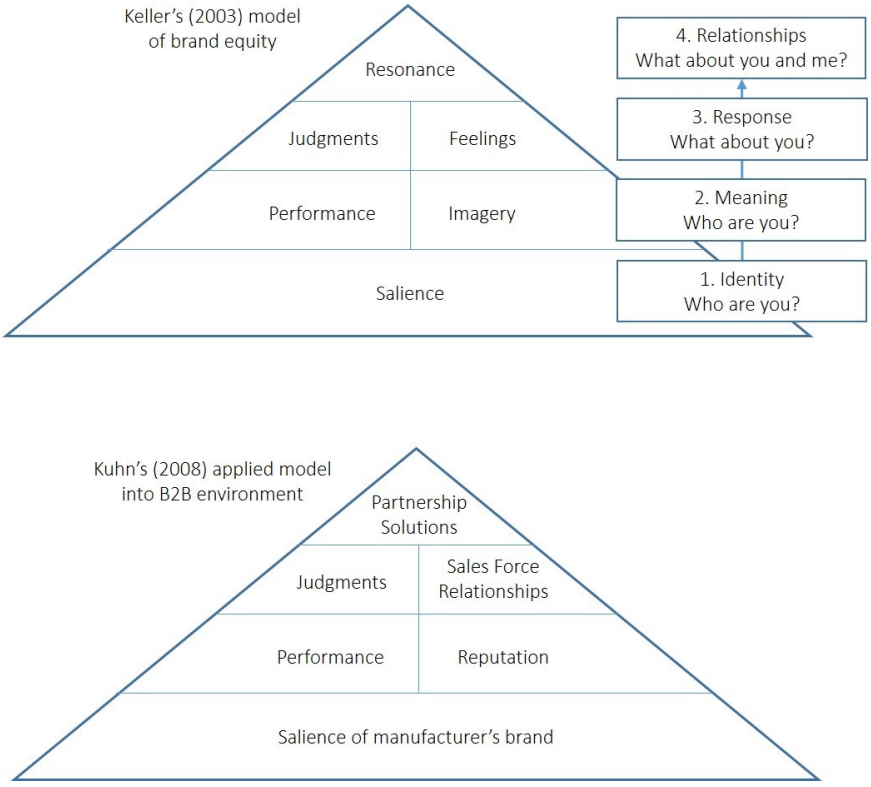


**Figure 8**. Brand equity pyramid comparison (modified from Keller 2003, p. 76; Kuhn 2008, p. 50).

### 2.4.4 Cost-Benefit Analysis

Cost-benefit analysis (CBA) is decision making tool just like a Business Case Analysis. In short, CBA is about evaluating positive aspects (benefits), negative effects (costs), examine in monetary currency of the positive and negative impacts and compare the net benefits to the status quo (Boardman *et al*. 2006). The difference to investment evaluation formulas where they evaluate only the costs and benefits, CBA aims to take into account the social costs and benefits also as an entity in the political and environmental surroundings. The CBA has been used in environmental, transport and healthcare problem solving since late 1960s especially in governmental decision making. In the CBA the benefits has been defined as how the product or solution will bring prosperity and the costs that what downsides are there when implementing the solution. Benefits should exceed the costs to make the "go" decision. (OECD 2006)

When making a decision to implement the suggested decision, in the CBA there is many measurable metrics that show the feasibility and fit to the business. One of them is Net

present value (NPV). Rule is that only positive NPV projects should be accepted. If there is a budget limitations, the evaluation becomes more complex. Then the benefit-cost ratio (B/C) ranking practice is needed. Another is the internal rate of return (IRR) but this is not applicable to mutually exclusive projects. IRR is a good tool when evaluating the alternative option to interrupt the status quo. (OECD 2006)

CBA can be implemented in different phases of the project. If it is conducted before the project to see is the project feasible or not, it can be done as *ex ante* and if the CBA is evaluated after the project implementation it is *ex post*, done as lessons learned exercise. *In medias res* CBA is done during the project lifecycle, is quite similar to *ex ante* analysis and is used when investigating would the resource change to alternatives be efficient. The last type of CBA is the one that compares *ex ante* and *ex post* analyses. The table 5 shows the different types of CBA and which one to use in which purpose. (Boardman *et al*. 2006)

**Table 5.** Value of Different Classes of CBA (modified from Boardman *et al*. 2006).

| Class / Value | Ex Ante | In Medias Res | Ex Post | Ex Ante / Ex Post or Ex Ante / In Medias Res Comparison |
|---|---|---|---|---|
| Resource allocation decision for this project | Yes. Helps to select the best project and make "go" or "no-go" decisions. | If low sunk costs, can still shift resources. If high sunk costs, usually recommends continuation | Too late. The project is over. | Same as in medias res or ex post analysis. |
| Learning about actual value of specific project | Poor estimate. High uncertainty about future benefits and costs. | Better. Reduced uncertainty. | Excellent. Although some errors may remain. May have to wait long for study. | Same as in medias res or ex post analysis. |
| Contributing to learning about actual value of similar projects | Unlikely to add much | Good. Contribution increases as performed later. Need to adjust for uniqueness. | Very useful. Although ma be some errors and need to adjust for uniqueness. May have to wait long for project completion. | Same as in medias res or ex post analysis. |
| Learning about omission, forecasting, measurement and evaluation errors in CBA | No | No | No | Yes. Provides information about these errors and about the accuracy of CBA for similar projects. |

When conducting the CBA analysis it takes effort, time, money and skills so it has costs itself. It needs to be evaluated carefully that is the CBA the most efficient analysis to make. After analysis the procedure consists from 9 phases. Phases are presented in the

table 6. In the CBA analysis prediction is strongly present. Prediction about the impacts or costs of the project might be hard to know very accurately and even impossible but the wise guesses have to be made to ground the analysis to the facts and numbers. (Boardman *et al*. 2006)

**Table 6**. Nine phases of the CBA (modified from Boardman *et al*. 2006).

| Step | Phase | Details |
|---|---|---|
| 1 | Alternative projects | Different sets of the solution. Inside the project there is a lot of variables to modify. |
| 2 | Whose benefits and costs count | Regional/stakeholder perspective. |
| 3 | Impacts and measurement indicators | Impacts are resources and outputs. Negative and positive impacts. Different stakeholders might see impacts differently. How to measure these? |
| 4 | Quantify impacts over project lifecycle | Impacts over time. |
| 5 | Monetize impacts | Value the impacts per certain time unit in monetary currency. |
| 6 | Discount benefits and costs | Future impacts in present time values. |
| 7 | Net present values | Difference between present values of the benefits and present values of the costs. |
| 8 | Sensitivity analysis | Indicate how sensitive net benefits are to changes in assumptions. |
| 9 | Recommendation | Largest NPV project is the most recommendable. |

Even though the Cost-benefit analysis is very similar to Business Case Analysis procedure, they have differences. Both evaluates the costs and benefits but only business case analysis takes the strategic fit into consideration and assesses the benefits to the focus company. However the Cost-benefit analysis includes the impacts over project lifecycle and society also that Business Case Analysis does not. The method that is going to be used in the analysis of the investment or new side stream product development needs to be examined case by case and according to the characteristics of the project. (Boardman *et al*. 2006; Kinnunen T. *et al*. 2001)

### 2.4.5 Sensitivity Analysis

Sensitivity analysis is one tool to evaluate the robustness of the investment or the decision that is planned theoretically. As the world around us is not certain, all the plans need to

be assessed how the plans will work under the uncertainty. Suitable management actions can only be done with carefully made predictions about the future and in that includes the different possible outcome analyses. Sensitivity analysis can be therefore a part of risk analysis in the business. The absolute certainty is only found in the history. (Jovanović, 1999)

Sensitivity analysis is a set of tools to evaluate the investment to take. It is a calculating procedure that include for example NPV, IRR and Pay Back Period (PBP) (Jovanović 1999). Sensitivity analysis is a part of the cost-benefit analysis (*e.g.* Hadley 2011; Boardman *et al*. 2006). There is three types of sensitivity analysis methods according to Boardman *et al*. (2006). Partial sensitivity analysis comes in place when variating only one part of the net benefits. It is used when an analyst wants to examine which net benefits equals to zero or find the breakeven point. Another method is the worst- and best scenario analysis. It gives information that with which combination of assumptions gives the worst case scenario or in other words net benefits are zero. The third method is the Monte Carlo sensitivity analysis. Boardman *et al*. (2006) explains that this sensitivity analysis method asks "What distribution of net benefits results from treating the numerical values of key assumptions as draws from probability distributions? The mean and variance, or spread, of the distribution of net benefits convey information about the riskiness of the project." This analysis method provides details via statistical information analysis. It takes more effort but the results are more detailed compared to the two other methods. It is both accurate and reliable. (Boardman *et al*. 2006)

## 2.5 Theoretical Synthesis

In the new product development in the side stream context the three level examination is needed to have a holistic view about the profitability in the business ecosystem. In the highest level the companies form an ecosystem and the network through which the value is created. In the medium level the company or companies needs to define their business models for themselves how they are going to do business in such a way that the company makes profit with its actions and activities in order to survive in the business environment. The detailed level is the business case analysis that is needed in certain case to evaluate is this certain product, product or investment worth to engage in. Business case analysis is one tool to help making business decisions.

In the business ecosystem and business model creation the value capture and delivery to the customer is commonly the wanted outcome. Zott (2010) explains in the literature about the business models in e-business, strategy and innovation point of view the concept of the value is the core of the business. So also the ecosystem should be built around the value stream and revenue model. Also the business model concept needs to be separated more clearly from the other similar concepts as other organisational forms, ecosystems, activity systems and value networks. (Zott 2010) In some research there has been propositions that these two different concepts – business ecosystem and business model, can be combined and work together in the practice. Tsvetkova (2012) sees that a business model can be built in the business ecosystem and even more the functions in the ecosystem can be formed on modules to solve the complexity problems. (Tsvetkova 2012)

When looking the business network thinking as the ecosystem and the revenue models, we have to take into account the importance to match all the key actors in the ecosystem and their individual revenue systems to function simultaneously. One solution is to create a hybrid business model and hybrid revenue model to cover all the players' policies. Popp (2011) introduces the concept of hybrid business model and states that when different companies have their own business patterns, these several patterns can be summed up as a hybrid business model. This collects the patterns under the same roof and creates synergies and competitive advantages. Also all the companies have their own revenue streams and to combine them together the hybrid revenue model needs to be created. And because of the definition of the causality dimension, when there is hybrid business model there is also always a hybrid revenue model. (Popp, 2011)

All in all, in the big picture a business ecosystem concept is clearly linked to the business model and business case analysis (figure 9). Business ecosystem is seen as a value network that consists of several different stakeholders, partners, regulators and suppliers. They all together have gathered to create value to the direct and end customer and in the same time taking the business opportunity to their own company. The analogue and basis is in the ecosystems of the nature (Moore 1993). The business model is needed to define both the ecosystem and a single company business structure how they do the profitable business to themselves. The sustainable and well-being business ecosystem consist only if all can have their profit share from the value creation revenue. Even though the business ecosystem is dynamic and ever changing structure as the ecosystems in the nature, the

ecosystem nourishes when the network structure feeds the stakeholders and it is created as a complex partnership (Iansiti and Levien 2004). Every company needs to make a decision themselves about the investments, projects and new product development activities is it according the company goals and if it is profitable to them to join the ecosystem. The business case analysis comes into discussion at this point and is done to evaluate every product or project separately to go or not to go into that business. Decision making requires a careful analysis about the upcoming project and its possibilities. All these business activities are unique in the industrial context, in this case the side stream utilisation, which surrounds the specific business case, the companies and the business ecosystem.

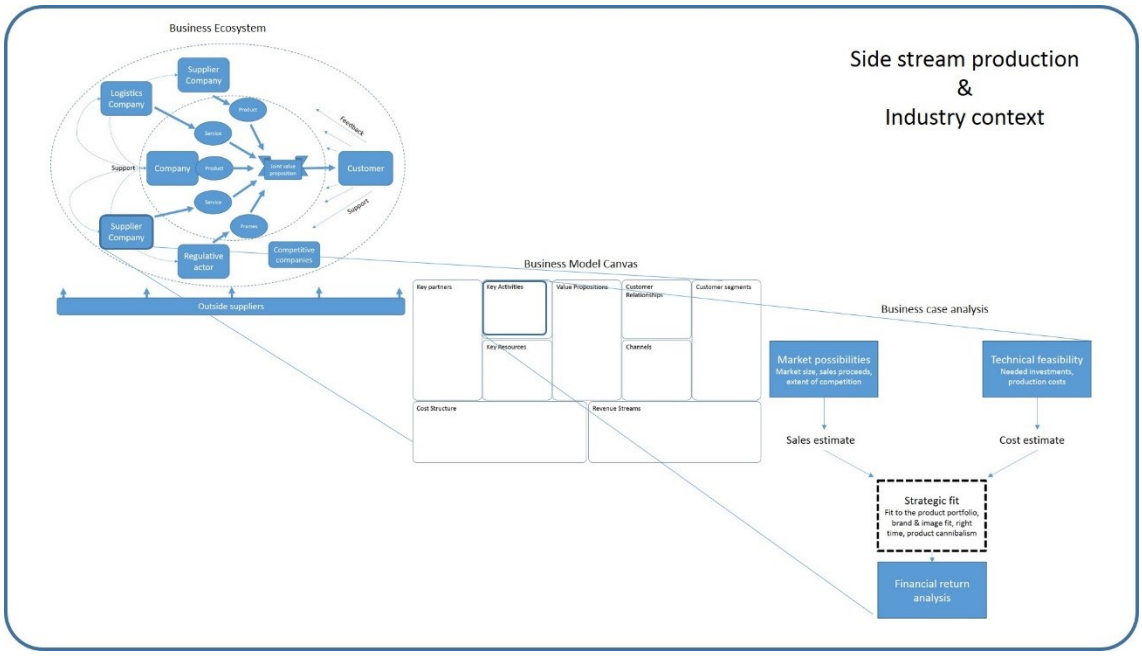


**Figure 9.** Theoretical synthesis of the business ecosystem, business model and business case analysis (modified from Kinnunen T. *et al*. 2011; Osterwalder 2009).

# 3 ECONOMICAL FEASIBILITY OF PETRIT-T

In this part of the thesis the practical implementation of the theoretical research is represented. The practical part includes the project, the research method, the project formation and the side stream material Petrit-T explained in detail. The empirical material and the material gathering methods are introduced and analysed. The material consists the Petrit-T substance introduction, business ecosystem knowledge gathering in this case study, value creation to the customer and the details to form a holistic view about the economic feasibility and business case proposition whether take or not to take the investment and technology into business implementation.

The research is a study for EU's EIT Raw Materials funded project MIN-PET which is led by a Swedish company Höganäs AB. EIT Raw Materials is one of the European Institute of Innovation & Technology consortia that has an ambition to help society use raw materials as efficiently as possible and make it as a strength for Europe via innovation and entrepreneurship. MIN-PET is a project which studies and pilots the raw material efficient utilisation from side stream to secondary raw material in the circular economy mind set through alkali-activation and hydration to end product as acoustic panels, cement binder and sustainable concrete. Project has started in 1.1.2016 and it has seven phases as known as work packages from feasibility studies to industrial scale-up. This thesis is the economic feasibility study of the side stream Petrit-T utilisation in the very beginning of the project. Other tasks in this phase includes technical feasibility studies which are made by Kinnunen P. and Illikainen (2016) from Fibre and Particle Engineering Research Unit in Oulu University and Kriskova *et al*. (2016) from Katholieke Universiteit Leuven. The environmental feasibility study is authored by Korat and Ducman (2016) from ZAG (The Slovenian National Building and Civil Engineering Institute). After the feasibility studies and continuation decision the project goal is to do the piloting of the business feasibility and the technologies with business partners Destamatic and Dansk jordstabilisering. The MIN-PET project formation is presented in the figure 10.

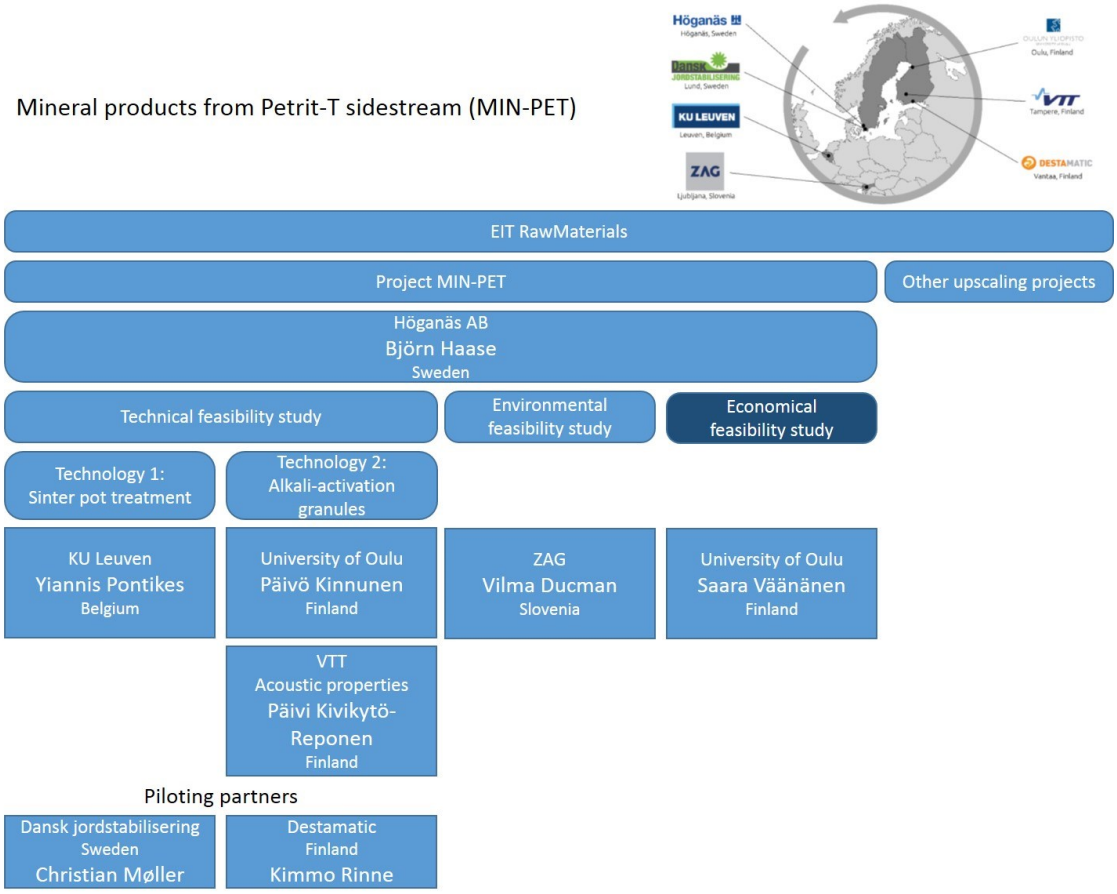


**Figure 10.** Project MIN-PET participants and formation.

## 3.1 Research Method

In this thesis the empirical findings have been studied with qualitative, descriptive research methods to investigate possible business ecosystems, value networks and business case analysis in the case of Petrit-T utilisation. Empirical research will answer to the research question two of what the value streams business model scenarios of the side stream of Höganäs are. In this chapter the methods for empirical study data gathering are explained (figure 11).

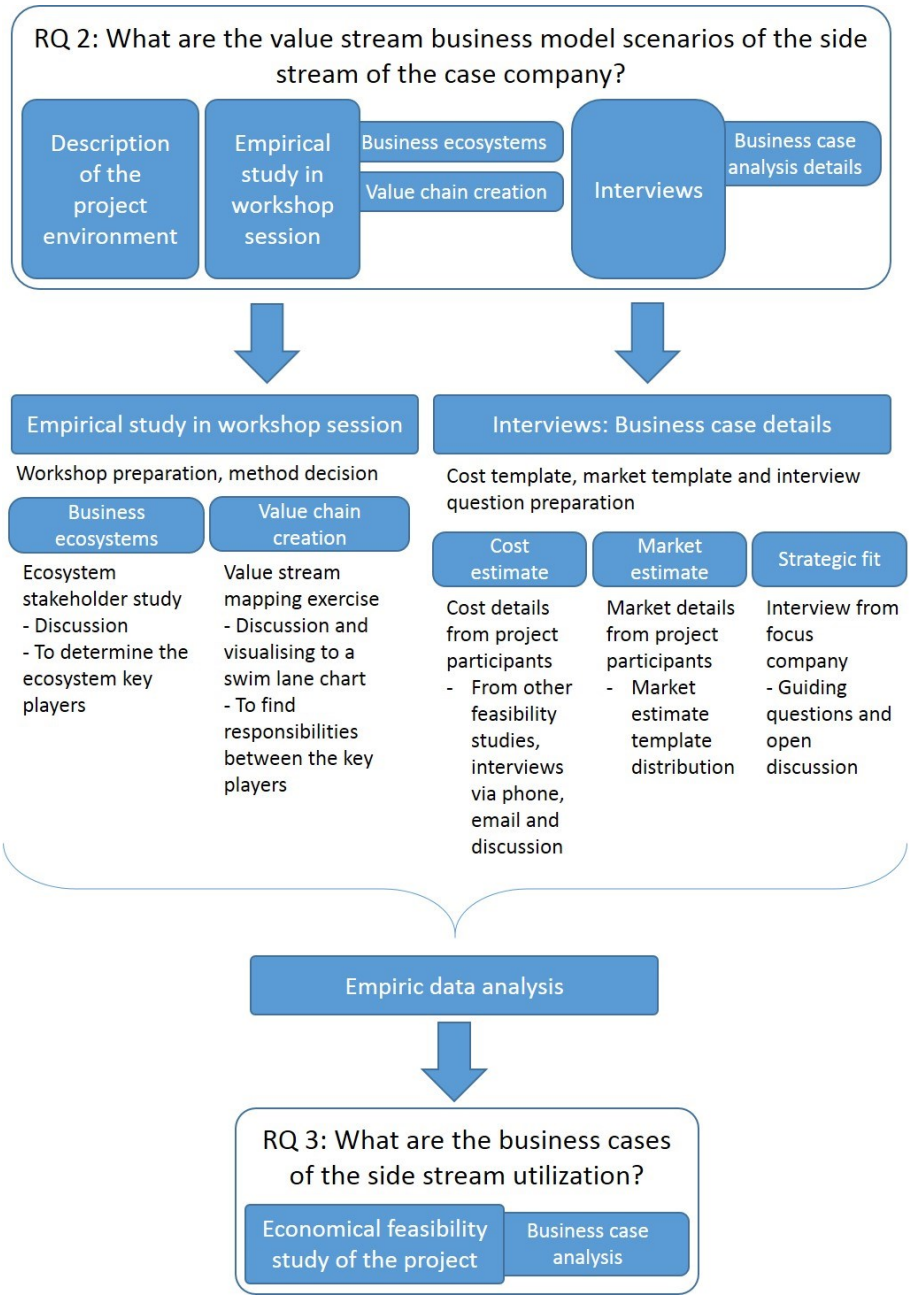


**Figure 11**. Research method.

To gain practical knowledge in this MIN-PET project, the workshop between all the project members and possible ecosystem members was needed to gather information that is good quality and wide enough to cover the research topic satisfyingly. The first step in the empirical research was to design the workshop where the empirical data was going to be gathered. The preparation included the information package creation to the participants and the workshop method design. The methods were selected to be suited to the nature of the event. Next step was to collect the data in the MIN-PET workshop. The workshop event was organised 27$^{th}$ of October in VTT Espoo premises by VTT participants and was

invited by the project leader Höganäs AB. The workshop participants were all the MIN-PET project members and they knew each other already via the project. Participants of the workshop are listed in the table 7. The methods used in the workshop were a group discussion, brainstorming and visual swim lane value chain mapping with sticky note exercise.

**Table 7**. MIN-PET workshop participants.

| Name | Title | Organisation | MIN-Pet project role | Other information |
|---|---|---|---|---|
| Björn Haase | Sponge Iron Production Manager | Höganäs AB | Leader of the project. | Strong knowledge in steel production, metallurgy and side stream utilization planning in Höganäs AB. |
| Eva Jacobsson | Global Process Development Manager | Höganäs AB | Representative of the company Höganäs AB, process development specialist. | Many year's experience in logistics, product transition and process development in Höganäs AB from 90's. |
| Päivö Kinnunen | Post doctoral researcher at University of Oulu | University of Oulu, Fibre and Particle Engineering | Author of technical feasibility study about geopolymer granules via alkali-activation. | Team leader in geopolymer research team. Has authored and co-authored many scientific articles to geopolymer and metallurgy journals. |
| Yiannis Pontikes | Senior researcher, associate professor | Katholieke Universiteit Leuven (KU Leuven) | Author of technical feasibility study about cementitious binders from sinter-treatment. | Several year's knowledge about metallurgy, especially steel slags and cement production in KU Leuven. |
| Lidija Korat | Assistant with doctorate | Slovenian National Building and Civil Engineering Institute (ZAG) | Author of environmental feasibility study. | Doctorate assistant and researcher in cement and ceramics materials. Strong experience about geopolymers. |
| Harri Haapasalo | Professor, head of IEM | University of Oulu, Industrial Engineering and Management | Supervisor of the economic feasibility study. | Many year's experience in research of production management, business ecosystems, business models and business case analysis. |
| Päivi Kivikytö-Reponen | Senior Scientist | VTT Technical Research Centre of Finland Ltd, Material modelling and Ecodesign team | Side stream utilisation researcher, premise coordinator. | Great knowledge in mineral processing and raw material in the industry and research. |
| Marjaana Karhu | Research Scientist | VTT Technical Research Centre of Finland Ltd, Material modelling and Ecodesign team | Side stream utilisation researcher, premise coordinator. | Experienced researcher in the field of material, physical and polymer chemistry. Has research materials for several years. |

The workshop was a big part of the empiric data gathering and it consisted of five steps that had specific goals (figure 12): Business ecosystem creation, value creation models through roles and responsibilities and business case analysis big picture details. Along these three main steps in the workshop also two other steps were in the agenda: end-product scenario selection and focus actor decision for the business case analysis. Workshop lasted one workday and the day went as planned. In the beginning there were short presentations from all the organisations present about their work in the project MIN-

PET. The business ecosystem creation exercise was about identifying the key actors in the decided end-product ecosystem, in value chain modelling phase the ecosystem key actors were connected to each other to form a value stream and the big picture details for the business case analysis were the initialisation to the interviews. The exercises were done by one group of nine persons as a group discussion in five steps.

| | | Time use suggestion |
|---|---|---|
| 1. | **End-product options** | All |
| | Is there any other end-product options from side stream technologies that needs to be evaluated?<br>Proposed: Concrete, cement, acoustic panels, noise barriers. | 20 min |
| | Result: Decision of the end-products | |
| 2. | **Ecosystem scenarios** | Groups |
| | What actors have to be present in the ecosystem in each end-product scenario? | 40 min |
| | Result: Max. 5 ecosystems per group | |
| 3. | **Value chain modelling** | Groups |
| | What are the roles and responsibilities of the actors?<br>What are the relationships between all the actors? | 1 h |
| | Result: Swim lane figure finished with roles and responsibilities | |
| 4. | **Decision of focus actor** | All |
| | To make case analysis the focus actor needs to be determined. | 30 min |
| | Result: Decision of a focus actor | |
| 5. | **Case Analysis details** | |
| | a. Technical feasibility → Cost estimates: needed investments, production costs<br>b. Market potential → Sales estimates: Market size, sales proceeds, extent of competition<br>c. Strategic fit (of the focus actor): From waste to secondary raw material, fit to the product portfolio, brand & image fit, right time. | 1 h |
| | Result: Big picture of the business case | |

**Figure 12.** MIN-PET workshop steps and goals.

The main exercise was the simplified value stream mapping exercise with sticky notes into a swim lane chart (figure 13). The tool is widely used Lean manufacturing tool in the new product development case studies and process mapping. The tool helps finding the value-adding process steps in the entity of different workers or in this case in the ecosystem. (Nauman *et al*. 2015). The tool was chosen to the research because it is clear and simply enough to the purpose and will bring the wanted outcome when figuring out the ecosystem participants, their responsibilities and the value stream flow.

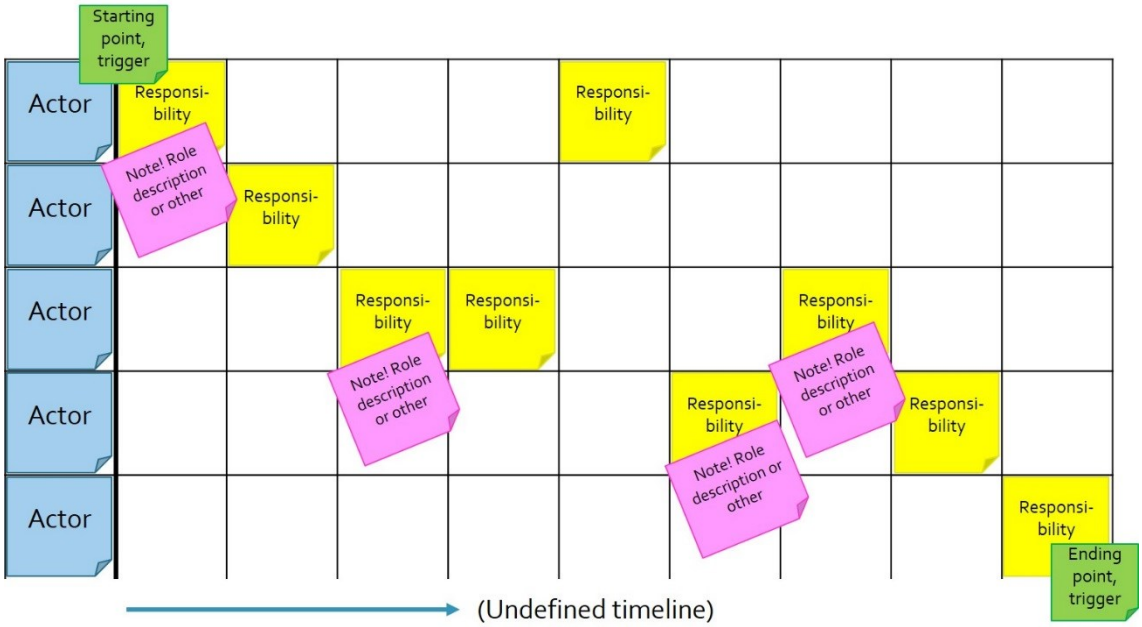


**Figure 13**. Value stream mapping tool used in the MIN-PET workshop.

After the workshop the case analysis data gathering continued via emails and phone calls. The surveys in different forms were sent between the interviews. All intended key stakeholders were contacted and interviewed directly or indirectly. The cost estimates were gathered via excel sheet, market potential interviewing and sending the EIT Raw Materials template to the project participants and company representatives, and strategic fit from the focus actor by interviewing via email and phone. The second step is interviewing the workshop participants further via skype, phone and emails. The methods used in an interview was fully open discussion about the details of the business case analysis and data filling to the templates of business case analysis. The questionnaire of the strategic fit is found in the appendixes. The template of the cost estimate is found later in the chapter 4.1. *E.g.* table 9 is filled to the cost estimate template. Market estimate template to sales estimate analysis is found in the chapter 3.5.1. Also during this research, other project activities took place. The technical and environmental feasibility studies were used in this research as the empiric material. Those feasibility studies are unpublished project studies which provide detailed information about the technologies, their costs and the feasibility of overall in the project.

After data collection analysis of the data to make appropriate calculations, statements and visual value stream maps takes place. Last in the fourth step the theoretical research of business ecosystems, business models and business case analysis is connected to the

empirical study to create side stream business ecosystem cases, evaluate the feasibility of the suggested models and answer to the research question three in the form of business case proposal in chapter 4.

## 3.2 MIN-PET Project and the Petrit-T Substance

In this research the main product which brings revenue to the business is the Petrit-T side product of the steel industry. Fibre and Particle Engineering Research Unit in University of Oulu investigated which end products the Petrit-T could be used through alkali-activation and granulation and they have found two applications – lightweight granules and acoustic panels made of the granules. Other research body is in Leuven Katholic University where they investigated the product possibilities using sinter-pot treatment. In the research they have developed the binder substance of cement from the Petrit-T side stream by-product.

Petrit-T is a stable by-product in the production of sponge iron. Yearly production is roughly 17 000- 20 000 metric tonnes but the exact amount depends on the sponge iron production. It comes from a sponge iron production from iron ore through solid state reaction and it is a mix of limestone and coke. (Haase 2015)

The production process of the sponge iron also results in the side product Petrit-T (figure 14). The Petrit-T is a refined substance from the tunnel kiln lime (TK lime). In the process coke, limestone and anthracite are blended together and the carbon reduces the ground iron ore in the high temperature tunnel kiln. The reaction is a solid phase reaction as the temperature is around 1200 °C and no melting is happening in this phase. Result is the sponge iron and the remaining reduction mix is the lime-rich TK lime. TK lime is separated and processed further to produce Petrit-T. (Haase 2015)

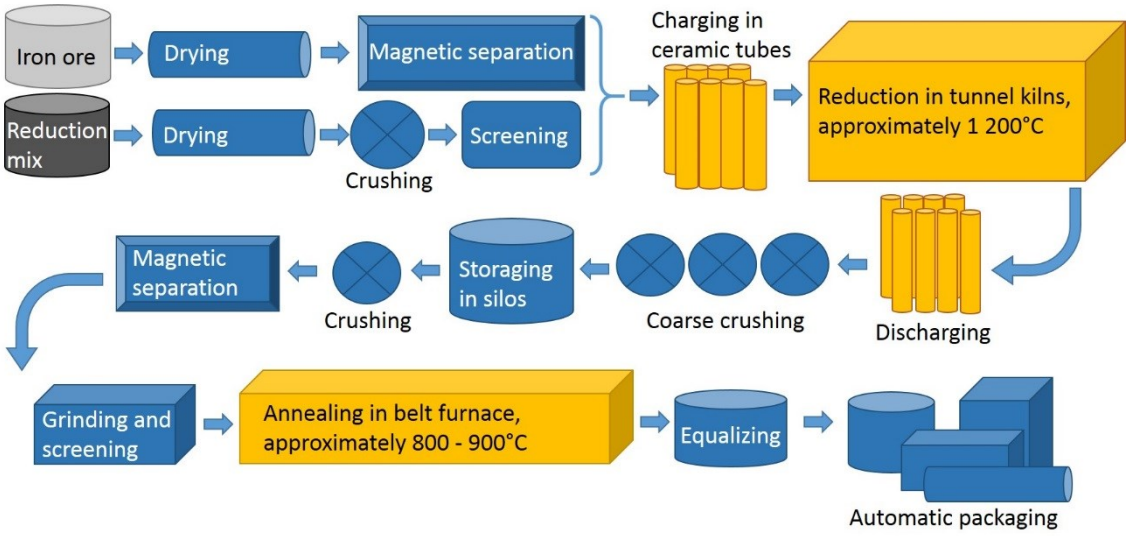


**Figure 14.** Höganäs sponge iron manufacturing process (modified from Korat and Ducman 2016).

A major challenge regarding Petrit-T utilisation is the handling and storage of the product. This is the one issue that will affect to the material handling in different states of the value chain. If it is handled dry it is a powder-like and must be handled with care since it contains lime. Inhalation of lime dust, or any other dust, should be avoided. However, product can be stored humid. In this case most of the lime reacts with water and forms Portlandite. Only difference to Petrit-T dusty form is that fine particles are bounded together and easier to handle, storage and transport. (Haase 2015) The humid form is also better for safety reasons since it does not cause irritation or burns when inhaled or in contact with skin or eyes (US Department of labor 1978).

### 3.2.1 End-Product Scenarios

The first step was to define all the end-product possibilities that are going to be developed and analysed in this part of the project. The mutual decision was to limit the end-product quantity to three and the selected products were acoustic panels, binder cement and concrete elements. These end-products are the offering that the ecosystem can offer to the customer. To analyse completely the acoustic panels, in this research also the lightweight granules that acoustic panels are made of are analysed. These products were selected to represent actual developed products that will most likely to have good markets and the best realistic business potential. The technology path from the source of the Petrit-T to these selected end-products is shown in the figure 15 below. As the figure shows, the

alkali-activation technology is required to make acoustic panels via granulation and the sinter pot treatment results in the binder substance of the cement. It is also possible to combine these two technologies into one product which is the third end-product, concrete element.

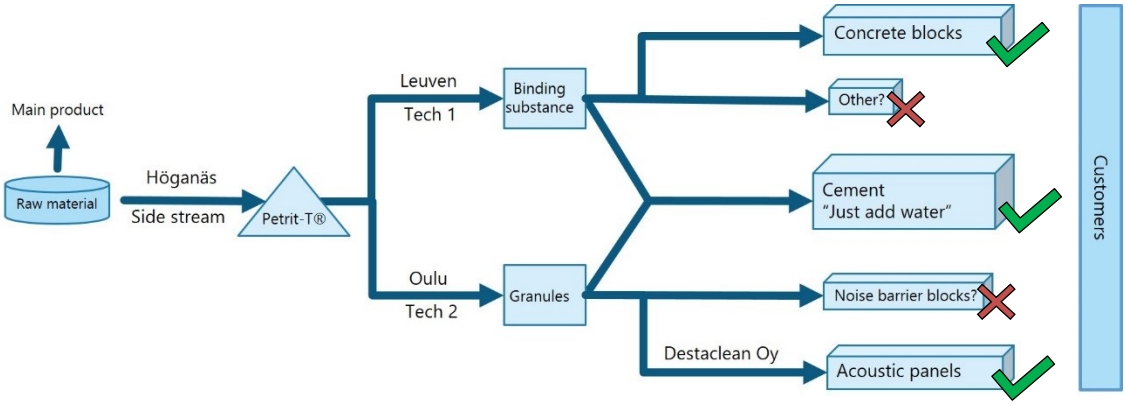


**Figure 15**. Technology path to selected end products.

### 3.2.2 Other MIN-PET Feasibility studies

In the MIN-PET project different end-products are made through two different processes and technologies. Acoustic panels are made through alkali-activation granulation and cement binder through sinter-pot treatment. The concrete blocks can utilise these both technologies in the production. Next paragraphs describe the technological feasibility study of these two technologies and the environmental feasibility study about environmental impact assessment. More detailed explanations can be found in the actual reports.

*Technical feasibility study, Geopolymerisation*

The technology of alkali activation (geopolymerization) is the responsibility of University of Oulu Fibre and Particle Engineering Research Unit. They have studied what different processes can be used granulating the dusty Petrit-T for further processing to end-product. They have come up into one feasible solution out of five different approaches that were considered. The Ca(OH) reaction and retarder use has given the best results and the most cost-energy-efficient reaction type. Also two other methods, calcination and grinding are feasible in technology-wise but they were deemed too costly to create sustainable

business from them as the first approximation (no actual calculations were made). Two remaining methods have been left out from the evaluation, the compatibiliser and retarder use combination and plain Ca(OH) reaction use. These alone doesn't give the favourable result in the material. The selected process to granulate the Petrit-T is a combination of these two latter methods. Together they are the most cost efficient and best performing method available. The successful process was found due to the screening of trial runs with different configurations. For sound absorption properties, the pore size distribution needs to be optimised. Optimisation to processes and properties will be conducted later in the project phases. There is still some properties that need more development but overall the granules are feasible and the product meets the requirements already with the technology and process. The Granulation technology research is presented in the figure 16. (Kinnunen P. and Illikainen 2016)

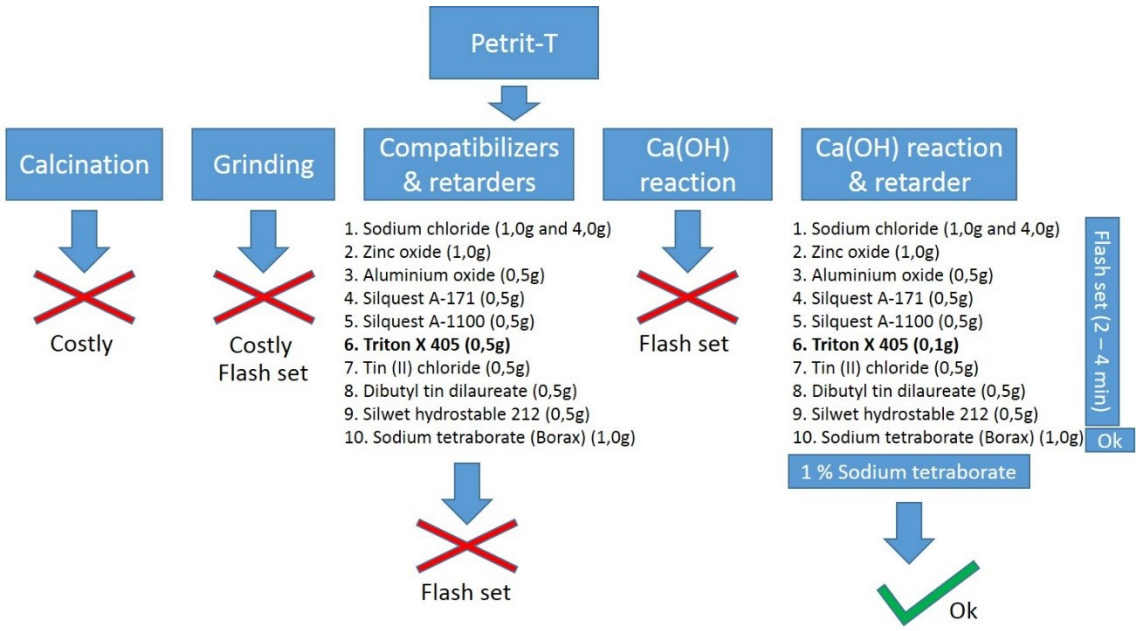


**Figure 16**. Granulation research (modified from Kinnunen P. and Illikainen 2016).

There is competition in the markets for lightweight aggregates, it being a commodity good that can be replaced with any other material with similar qualities as the granules. LECA and ceramsite are two similar products which is done via firing instead of alkali-activation. The competitors compete with low cost and low $CO_2$ emissions when producing the product. For the end-product, acoustic panels, the competition in the market is more scattered. As sound absorption solution there is for example inorganic or organic fibres, lightweight granule beds, textiles or foams. The cost-efficiency is also an

advantage in the acoustic panel markets. The advantage of the geopolymers made of Petrit-T is the process. All the high energy demanding process steps (crushing, grinding, firing and cooling) have been removed and left only granulation and screening. This brings cost savings in energy and in investments. The selected granulation process towards to the lightweight aggregates and finally acoustic panels is presented in figure 17 below. (Kinnunen P. and Illikainen 2016)

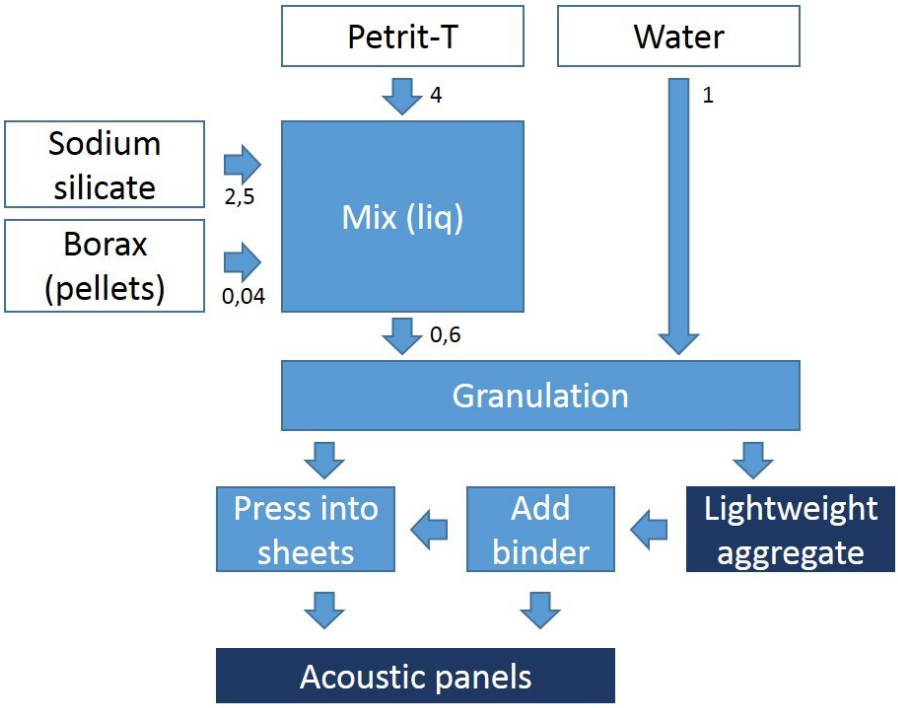


**Figure 17**. Granulation process (modified from Kinnunen P. and Illikainen 2016).

*Technical feasibility study, Cementious binders from sinter treatment*

Binder technology is been studied in KU-Leuven in Belgium in this MIN-PET project. They have studied the mixture design, chemistry, processes, substances and overall technology feasibility in sinter pot treatment for Petrit-T substance. The study starts with Petrit-T material analysis and reaction mixture design. The minerals or Petrit-T decide the mixture content and the treatment circumstances. After the substance design, the treatment mechanics are evaluated. The research process of the cementious binder to the MIN-PET project is represented in the figure 18. (Kriskova *et al*. 2016)

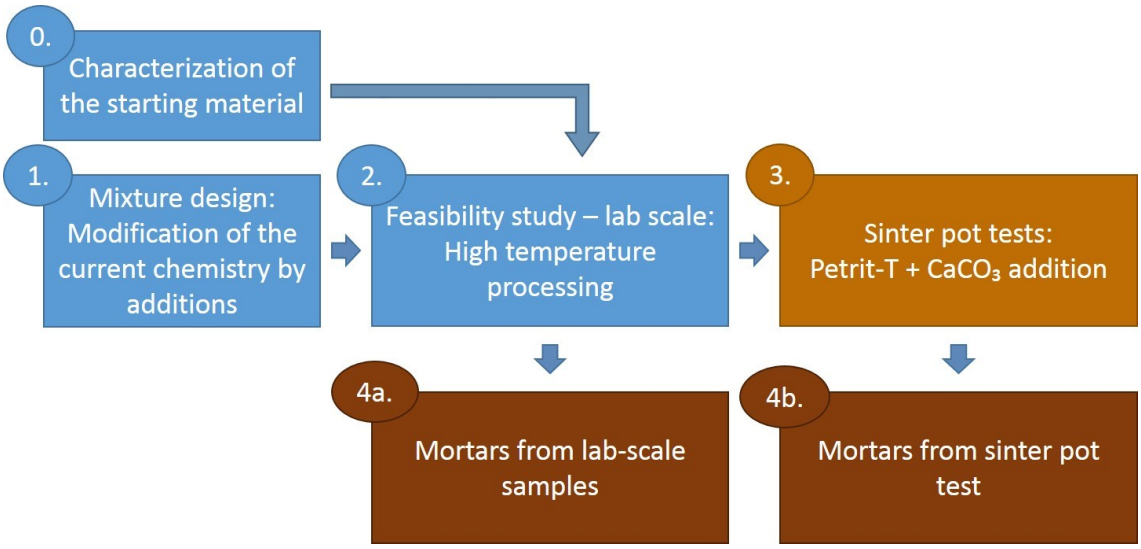


**Figure 18**. Sinter pot treatment research process (modified from Kriskova *et al*. 2016).

In the lab scale they tested the possible treatment temperatures in Agni bottom loading furnace. The temperatures tested ranged from 1350 °C to 1450 °C. After the lab scale experiments the sinter pot treatment was tried to process the Petrit-T. The sinter pot treatment process figure 19 below shows that before the sinter treatment the dusty-like Petrit-T needs to be pelletised. After the experiments with modified temperature, time and sintering method the result is that the process can be upscaled and used in several different applications fully replacing the most used Ordinary Portland Cement (OPC). (Kriskova *et al*. 2016)

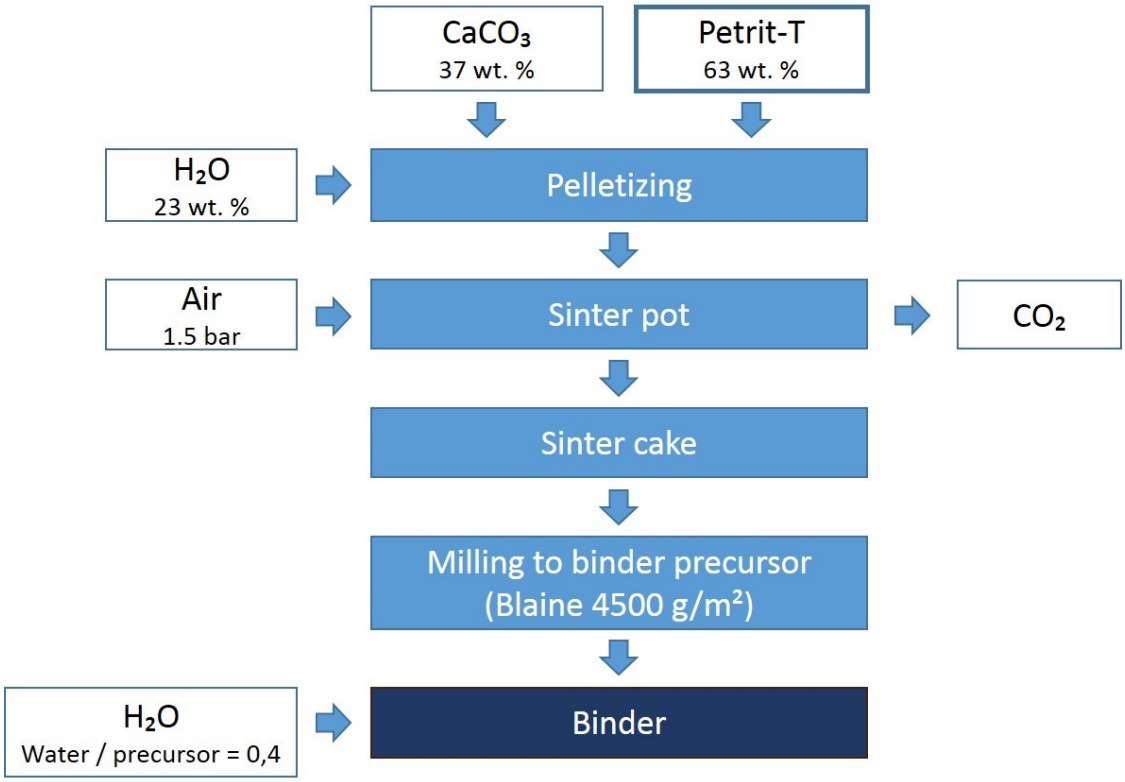


**Figure 19**. Sinter pot treatment process to binder (modified from Korat and Ducman 2016).

*Environmental feasibility study, Environmental impact assessment*

In the MIN-PET project in work package zero there is also the environmental feasibility study authored by researchers Korat and Ducman (2016) from ZAG in Slovenia. The environmental feasibility study contains assessment of the environmental impacts of the use of Petrit-T substance. The Environmental Impact Assessment include the significance of the environmental impacts of the substance, proposal of the mitigation actions and plan to avoid the harmful effects of the use of the Petrit-T in the future according to EU legislation. The environmental impact assessment has an influence to the economic feasibility through the waste treatment costs and financial benefits to the ecosystem and the independent companies. (Korat and Ducman 2016)

The environmental impacts need to be taken into account because all the harmful events and impacts to the environment due to the corporate actions brings costs to the company

and society. Also the prevention measures and actions of the negative impacts can bring operational costs or investments to the stakeholders. It is certain that the business ecosystem can realise cost savings when preventing harmful impacts to the environment. The environmentally friendly corporate image is beneficial not only in the name of brand but also financially.

The environment impact assessment made by Korat and Ducman (2016) has been conducted in the 5 scale classification according to ISO standard requirements. The likelihood (L) of the impact is evaluated by frequency (F), probability (P) with the equation of $L = \frac{F \times P}{2}$. The environmental significance (ES) is calculated with likelihood (L) and consequence (C) with equation of $ES = C \times L$. The significance ranges from low to high depending on the score that it can have from 1 to maximum 25. In this case the assessment results in the impacts are from low (score 1 – 4.9) to medium (score 10 – 14.99) significance for the environment. (Korat and Ducman 2016)

The early production and processing of Petrit-T is the responsibility of Höganäs. Also the monitoring of the quality and substance preparation of later processing are the main tasks for Höganäs. In this phase the environmental aspects that needs to be taken into account are the use of chemicals and emissions of heat and noise during production, emissions to soil and water during storage, emissions to air when handling the Petrit-T in its dust form and chemicals used in quality monitoring. After the Petrit-T transport to post-processing venue, the responsibility shifts forward. (Korat and Ducman 2016)

When producing the geopolymers, the granules through alkali-activation the noise, dust emissions, use of hazardous materials, accidents and waste disposal have an impact to the environment. Also the air emissions from the use of machines are considered. In the case of hydration and sinter pot treatment also the air emissions, accidents, use of hazardous materials and waste disposal are the main sources of the environmental impacts. This process has also the heat emissions to take into account. (Korat and Ducman 2016)

## 3.3 Business Ecosystems in the End-Product Scenarios

The second step in the workshop the goal was to determine the ecosystem actors in each end-product ecosystem. The base assumption is to have different ecosystem for each end-

product but later the similarities can be searched and ecosystem combined partially or entirely. The ecosystem participants in a high level were successfully determined in the workshop (figure 20). The ecosystem stakeholders were determined in the high level and ecosystem was simplified because there is no such ecosystem existing already and actors ready to be invited in the ecosystem. The results of the organised workshop were that three actors were the same in each three ecosystems: Höganäs, regulator and transport. Other actors were different depending on what product is been created. In the case of acoustic panels other ecosystem stakeholders were the sodium silicate provider, granulator, panel producer and finally the customer. When producing binder cement, stakeholders in this ecosystem are limestone provider and sinter pot treatment company and customer. Concrete element product requires the stakeholders from the both previous ecosystems, aggregate and filler material provider through granulation, sodium silicate provider, block producer and the customer. These ecosystems were mutually discussed and decided. The result of the ecosystem participant exercise is shown in the following value chain chapters for each end-product scenario.

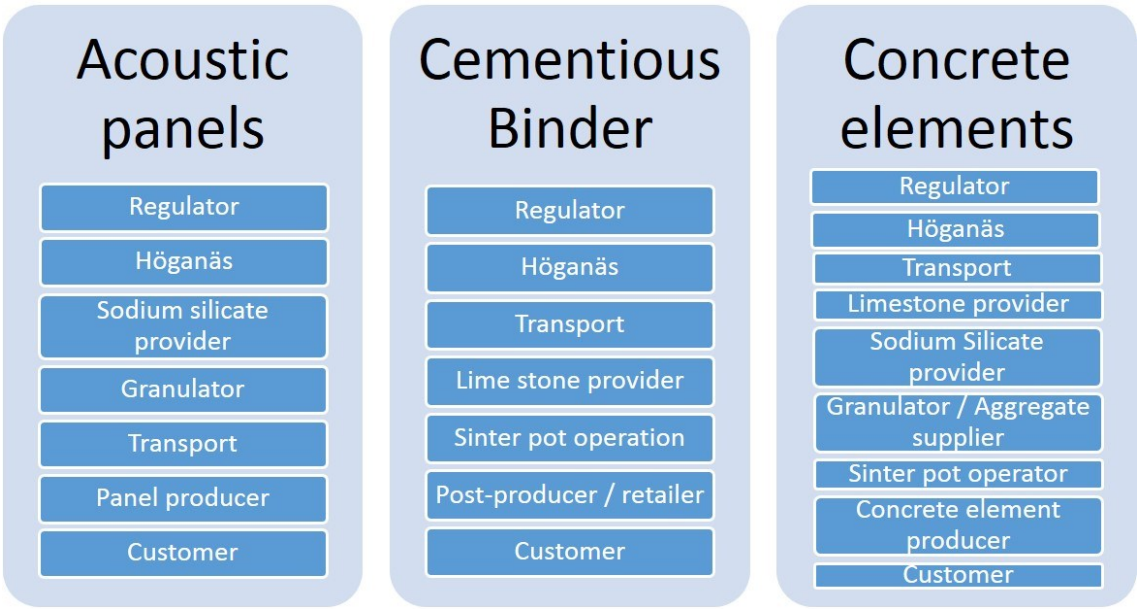


**Figure 20.** Ecosystem stakeholders in Petrit-T utilisation in different end-product scenarios.

## 3.4 Value Chains in the End-Product Scenarios

The third part of the workshop was to investigate the value chains to each ecosystem. The value chain modelling started with placing the stakeholders in a column in the order of the actions. The green sticky notes represent the stakeholders and the yellow ones the actions that the stakeholder is responsible of. The value chain modelling results seen in figure 21 below. To produce any end-product, the Petrit-T is assumed to get already the secondary raw material status from REACH evaluation. Other assumptions to the value chain modelling are the granulation recipes and design is excluded from the mapping because it is regular product development work in the stakeholder companies.

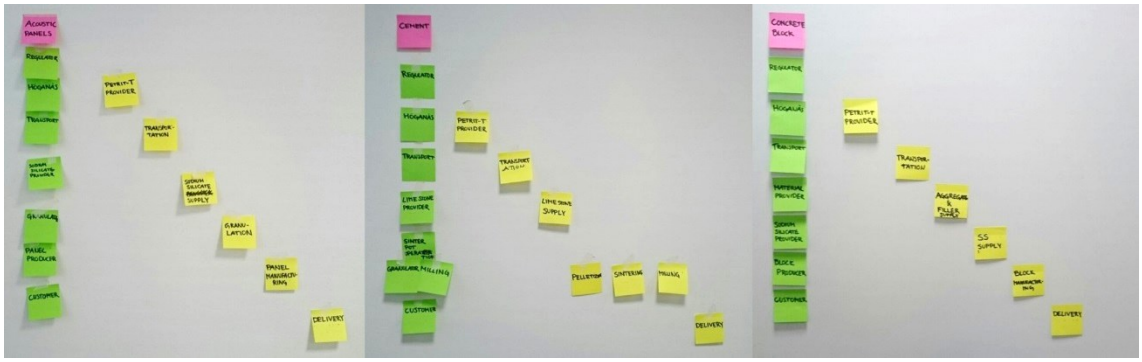


**Figure 21.** Value chain modelling exercise in the MIN-PET workshop.

The value chain figures show how the value flows in the ecosystem through the business model. There is an ecosystem to each selected end-product scenario and each ecosystem has its individual way to capture value to the customer. These business models represent mechanisms how the value is created and flowing towards the end customer.

### 3.4.1 Acoustic Panels

The first value chain is for acoustic panels. There in the ecosystem the initiative action comes from Höganäs as a Petrit-T provider. In the acoustic panel case, the granules are formed in some other company than Höganäs itself. The ideal situation would be that the granulation will be done in the same company as the acoustic panel production to avoid extra transportation and ensure the shorter lead times of the final product. This company solution is shown in the figure 22 by dashed circle. The granulation and panel production can also be separated from each other. The Petrit-T is changed into currency in every interface. To produce the granules and the panels, other material is needed and for

example, the sodium silicate provider is one supplier stakeholder in the business ecosystem. Suppliers are part of the ecosystem and value creation with their high quality materials to ensure the maximum value to the customer.

The panel producer can add the Petrit-T panels to its own business model and own product portfolio. Exploiting the existing structures of the business model makes the ecosystem more mature in shorter time and gains knowledge and expertise from the stakeholders. Transportation company is in the supportive role in the ecosystem but we assume that every company has existing contract with a transportation company. Also the regulatory stakeholder is existing in every step of the value chain in somehow to look after that the process from Petrit-T to the delivery the end-product to the customer is safe and just for all the stakeholders and the society.

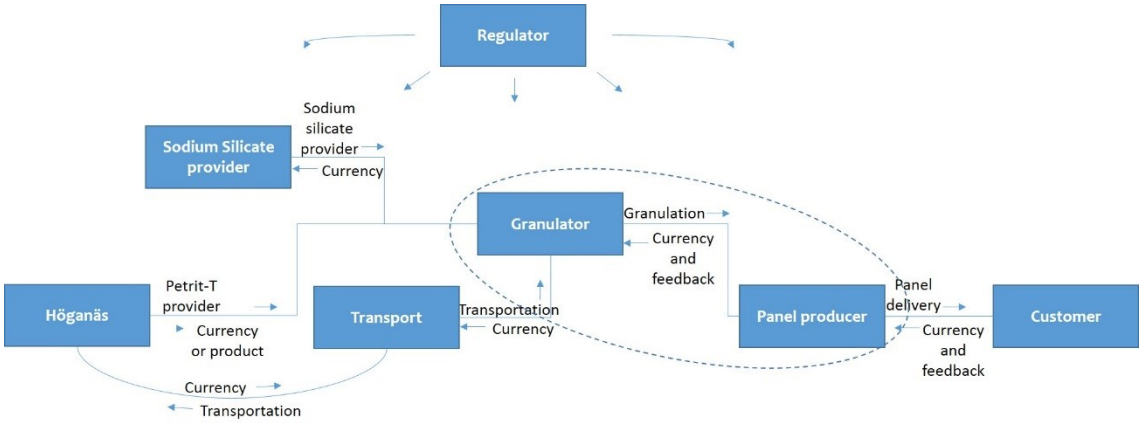


**Figure 22.** Acoustic panel business ecosystem and value chain.

### 3.4.2 Cementious binder

The value stream with the binder is constructed mainly with the same structure frame than the acoustic panels. Höganäs will provide the Petrit-T to the binder producer to operate the sinter pot. The binder producer handles the production and selling the product themselves through their own business. One recommended possibility to reduce extra work and transportation is to have the sinter pot operation and the post-production of the final product in the same company or at least in the mutual premises. This possibility is shown with dotted circle in the figure 23. This producer company will benefit themselves in the form of Petrit-T and the design work from the project and Höganäs and turn the material into binder and cement to be sold to the customer.

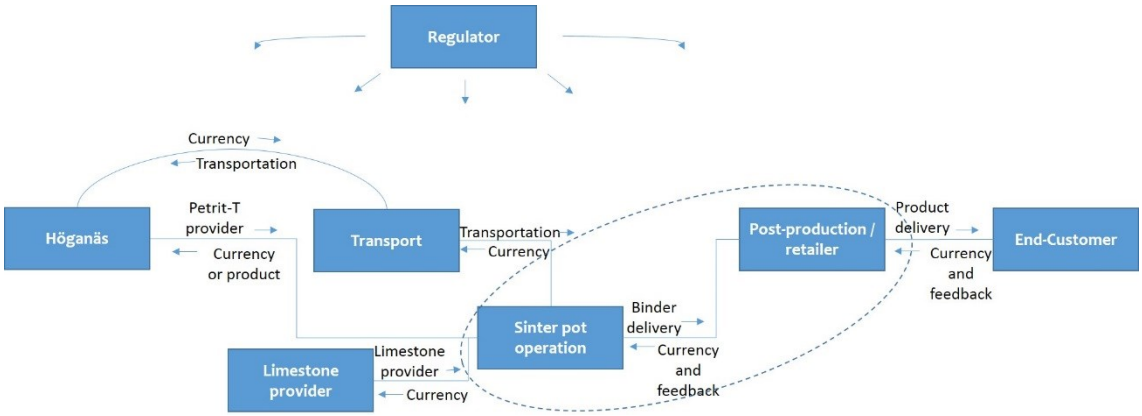


**Figure 23**. Cementious binder business ecosystem and value chain.

### 3.4.3 Concrete Elements

The concrete element value chain is the most complex and holds a lot of different possibilities to construct the ecosystem and the value chain (figure 24). In the first business model Höganäs is the provider of the Petrit-T to the producer of the concrete elements. The producer of the elements buys the Petrit-T and processes it into the elements, takes the product into its product portfolio and sells it to the retailer, customer or to Höganäs as a customer according to their business plan. One possibility is to combine the three main processing steps, granulation, sinter pot operation and concrete element production under the same company, as the dash circle shows, to avoid movement waste in the process.

Other solution would be that Höganäs holds the value of the Petrit-T substance throughout the production of end-product of other company. Höganäs orders the processing of Petrit-T and will pay for it, but owns the substance and the product. Höganäs will take the concrete element to itself, use it internally or sell it to the retailer or end-customer. The producer company of the elements has a decision to make the concrete elements only or do the required pre-processing of binder and granules also. If the producer refuses to invest to the whole process, the granulation phase could be a separate company in the value chain as well as binder producer. However, the more companies there are in the ecosystem, more it needs the profit as every company needs its share of the revenue to survive in the ecosystem. The best solution is to have the minimum but required amount of companies to ensure both the production and the business. In this case someone in the

ecosystem has to take the granulation and binder production and invest in those processes. This investment is worth to take as the calculations further below proves.

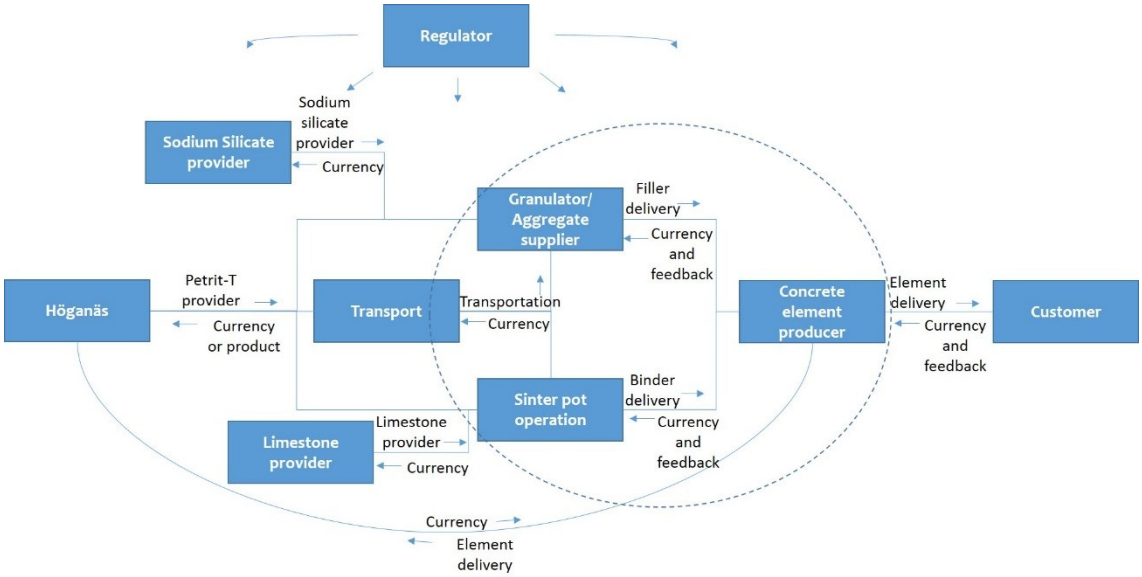


**Figure 24.** Concrete element business ecosystem and value chain.

## 3.5 Business Case Details

The decision of the focus actor for business case analysis is the fourth step. In the workshop it was decided to choose Höganäs as the focus actor. The business case is formed around the focus actor and all the costs and benefits are calculated in the Höganäs point of view. Even though Höganäs doesn't have interest to be the either end-product producer or retailer, the whole chain to the end-product delivery needs to be taken into account in the business case analysis also. That way the benefits and costs are seen in the calculations. Some assumptions have been made to take the end-products into account. For example we assume that with the project participant knowledge and estimations about the costs and benefits the calculations are done as if Höganäs is the producer of the end-product. In the ecosystem these responsibilities have divided to different companies. Realistically Höganäs will be only the Petrit-T provider and some other company in the ecosystem will take the responsibility of production of the end-product.

The final step in the workshop was to discuss and decide the business case details. In the case of acoustic panels the main costs from the technical point of view are the granulation,

alkali-activation, granule porosity and sound absorption properties technology development. The technology development costs are excluded from the research and the business case analysis since the costs of technology development have been taken into account elsewhere in the project. The operational costs and capital investments are mainly in the storing the dust-like or humified Petrit-T and after the alkali-activation the granules. Material costs comes mainly form the sodium silicate as it is big in volume of the total amount of granules. For the granulation the slag prices are according to alibaba.com internet site 24-57 $/ton. Borax costs 500 €/ton, sodium silicate 150 €/ton and it is 80 % of the materials used in granulation mixture. Water, processing and investments as storage, handling and granulation costs were collected afterwards to the excel sheet. If 50 mm thick panel is made, material costs are 1,7 €/$m^2$. Granulation investment in machine is 500 000 €, in panel making more equipment is needed, *e.g.* in moulding, curing and packing. Also a weighing station and other facilities are needed.

The binder cement costs are mainly the capital investment in the pelletising, sintering and milling equipment, material costs from limestone that are about 10 €/ton and operational costs from electricity to pelletising and milling. The concrete elements operational costs consists mainly of transportation since the weight of the concrete elements, mixing and moulding the elements and labour costs. There is no capital investments with an assumption that the producer stakeholder of the elements have already the equipment available. It was discussed that the binder production in the concrete elements would have the same costs as before mentioned in the binder section and the density and weight issues needs to be discussed further. The product design and features are out of scope at this point of the project. This means for instance that it is relevant if the concrete elements are made of light-weight aggregates or not.

Business case details were gathered in the workshop and with interviews with the technology researchers and Höganäs. After the workshop an excel template was send to the interviewees and they filled the details needed.

### 3.5.1 Sales Estimate

Market possibilities cannot be evaluated with certainty but the estimates are showing that there is real market for the products made of Petrit-T. The market potential is mapped to find the right market to introduce the right product.

Business models are different in different end-product scenarios. Business model for the ecosystem is the ordinary sell and buy business model in the cases of acoustic panels and binder and each stakeholder have their own business model and a way to sell the produced outcome. In all of these cases the business model would merge in the company's other products' business models. The exploitation strategy is to utilise the stakeholders' existing structures as well as possible to lower the extra effort that the new product introduction would bring and ensure the quick market penetration. The product will be a part of the product portfolio of the producing company.

Project of the implementing the business plans into use starts with gathering all the stakeholders. In the future action the stakeholders will form a business ecosystem and the ecosystem analysis tells who must include to the ecosystem. The Petrit-T will be Höganäs and the end-product producer at this point will be Destamatic to the acoustic panels and Dansk Jordstabilisering AB for the concrete elements. Other supporting ecosystem companies will form from the present stakeholders of these companies and those are utilised in this Petrit-T case products also. The next section will explain the market environment to the selected end-products. In the table 8 below it is described the markets of the all three selected end-products made of Petrit-T.

**Table 8.** Market potential analysis.

| | Market #1 | Market #2 | Market #3 |
|---|---|---|---|
| Market name | Acoustic panels | Cement binders | Concrete elements |
| Market description | Small markets, dependent on regulations (tightening noise suppression regulations in urban areas) | Large markets with many companies in the construction field. Cost efficiency leads in the market and it is achieved with huge volumes. | Market size is moderate. The main market of the big elements is the construction. Yard décor. Pavement stones, price driven. |
| Potential benefits | Low-cost material with medium noise suppression – not competing with high-end applications | Reduce raw material dependence and environmental impact of concrete products, integration of high waste volumes, lower material cost, better environmental performance / lower environmental impact end product, comparable or even improved compressive strength. | Low-cost material, CO2 footprint lower. Lighter material (lightweight aggregates) → transportation cost reduction, easier installation |
| Market interest | Sustainable material for infrastructural applications, such as railroad noise suppression in urban areas. | More environmental friendly option for cement binder with the same requirements. | Interest in the market in in cheaper material and recycled material content if the minimum requirements in properties are met. |
| Market requirements | Acoustic properties and durability need to be shown. | Durability, good binding properties, cost efficiency, affordability. | Lower price, eco friendliness is a benefit in B2C, CE marking needed, standard requirements for frost resistance, concrete properties, mechanical properties. |

### 3.5.2 Cost Estimate

To make various end-products from Petrit-T, the investments are needed to make before the production will start. In addition to three selected end-product scenarios, also the geopolymer granules have been taken into account in the business case analysis calculations because those are needed in acoustic panel production. In the calculations it

has been decided that the focus company is Höganäs who provides the Petrit-T supply. To take also into account the end-product in the calculations, it has been assumed that Höganäs will also produce the end-product in-house. In the real life the interest is not to produce in Höganäs but in the other stakeholders' premises.

Investments needed are mainly in storage premises and capacity for Petrit-T, its work-in-progress products and final products. The storage estimations varies from 50 000 – 400 000 €. Another big investments are the machines to process the Petrit-T into granules, acoustic panels, binder or concrete elements. In the case of acoustic panels, it is assumed that the panel producer that will come to the ecosystem, already has the similar products and required machines in use. In that case the investments are lower. In the granules, binder and concrete elements the machine investments varies from 200 000 – 400 000 €. Especially binder needs significant investments in pelletising, sintering and milling if those are not ready in producer's premises. Also the overhead for costs has been estimated to be 10 % of the variable costs in the calculations. Total investment costs are therefore 300 000 – 700 000 €. Business infrastructure, logistics, marketing, sales mechanics doesn't need special investments as the plan is to utilise also existing ecosystem's stakeholders' structures as well as possible. In the case of the binder, the milling could be outsourced from the other binder production so the investments for milling is not necessarily needed. The sinter pot and pelletising machines are quite specific and needs investments if the binder production is wanted to be commenced.

Other costs are variable costs that depends on the production annually. In the calculations the variable costs include material costs depending on the end-product, and other possible costs such as water, energy, labour and transportation. The biggest variable costs are in granule production with 350 000 €/year with use of all of the Petrit-T in a year which is 20 000 ton.

The profit for Höganäs comes from the landfilling cost savings and revenues from selling the Petrit-T. The cost to landfill the Petrit-T would be 300 000 €/year since the base of the landfilling cost is estimated to be 15 €/ton and the amount of Petrit-T is 20 000 ton annually. It is foreseen that the landfilling costs are going to rise even more in the future. If the annual Petrit-T is sold entirely at the price of 5 €/ton, the revenues are 100 000 €/year. In addition Höganäs' benefit is the costs savings from landfilling which are

previously mentioned 300 000 €/year. Total benefit from the Petrit-T for Höganäs is 400 000 €/year.

In the calculations afterwards it has been assumed that the annual production of Petrit-T is 20 000 tons and the whole amount is used only in each product. If it is decided to establish the ecosystem and business around several proposed end-products, then the Petrit-T annual amount will be split in certain shares. Possible taxes are not included in the calculations. The investments have been taken into account and assumed that the depreciation is for 7 years in straight-line method. The profit calculations have been done by subtracting the variable costs, annual payment of the investment and depreciation from the revenues and in end-product producer point of view. In the return on investment (ROI) calculations the same assumptions have been made. ROI has been calculated for every end-product scenario separately with one year details.

### 3.5.3 Strategic Fit

The strategic fit has been conducted in the Höganäs point of view as in the workshop it was agreed with all of the participants. Overall the Petrit-T and the post-processed products from it are a good fit to the strategy of Höganäs. Höganäs have other similar products that are from the side streams of the main products. The Petrit-T would not be one of the main products but it is sellable product, which need a special approval to sell the substance to each customer. This is one pieces of evidence that the Petrit-T is a good fit to the special product portfolio as the other side stream products in the company.

Petrit-T fits very well also to the corporate image and brand strategy. Höganäs has a zero waste corporate policy and the aim is to perish the landfill waste totally. This is implemented as the recycling the side stream into secondary raw material sustainably and the Petrit-T is one of these products that can be used instead landfilling it. This helps to increase the value of the corporate image and brand ‘Höganäs’. The production and post-processing into products are very well aligned with the Höganäs’ business strategy. There is no limited themes in the strategy or plans to make changes concerning the Petrit-T substance, production or any other matters that might change the output of Petrit-T in the future.

The development and the utilisation of the Petrit-T is a good fit to the technology roadmap and product portfolio in timeline-wise. In the markets the eco friendliness, sustainability, circular economy and corporate responsibility towards the nature is a rising and hopefully lasting trend and the products that are aligned with this strategy have demand if the requirements are met. In addition to the market situation, it is favourable time technologically. The technology to make Petrit-T, process it and make it into the products are available and viable. For the details, please look the technological feasibility studies.

In Höganäs point of view the Petrit-T is a food fit as it doesn't take shares from any other product in house. It is a competitive product to other companies' products in the market but now or in the future it doesn't cannibalise any of the revenues of other products. There is no products that are similarly used in same purposes so the market potential for Petrit-T is unique. Overall, Petrit-T is a good fit for the Höganäs's strategic fit and the production to various end-products is feasible in business sense to other stakeholders also. Höganäs is primarily a metal powder producer so the suggested end-products are not aligned with the corporate strategy to be produced in house. Höganäs will be a provider of Petrit-T and be one stakeholder in productising the end-products made of Petrit-T. Höganäs' main benefit from the Petrit-T utilisation project is to minimise the landfilling Petrit-T. The benefit from transforming waste into a usable goods is remarkable and even if the Petrit-T doesn't give a lot of revenues, the benefit from not landfilling the substance will satisfy Höganäs' needs.

# 4 BUSINESS CASE ANALYSIS OF PETRIT-T

In this chapter the results of the empirical research is connected to the theoretical knowledge about the business ecosystems, business models and finally the business case analysis. Business case analysis is the final analysis that leads to the business case proposal. This chapter answers to the research question 3 of what the business cases of Petrit-T are.

## 4.1 Business Case Analysis

Business case analysis includes previously presented cost estimate, sales estimate and strategic fit which are studied and analysed in the previous chapter in this case study. Based on the first two components of the analysis the detailed calculations to the business case analysis are conducted first in this chapter to study are the selected end-product scenarios profitable and worth invest in. Strategic fit is then added to the result of the calculations to give an overall view of the business case and comprise a proposal to decision making whether to take the opportunity to this new product and investments.

### 4.1.1 Granules

In the end-product scenarios the granules are needed in the acoustic panel production and in these calculations for evidence behind the acoustic panels. Business case analysis calculations of Petrit-T granules shows that granules can be one profitable product to be sold in the market as it is itself profitable product (table 9). The profit from the granules can generate approximately 551 000 € annually in the first years. After the investment has been paid, the profit per year is growing.

**Table 9**. Profitability of geopolymer granules.

GRANULES

| | Cost | Usage | Price |
|---|---|---|---|
| **Variable costs** | | | |
| Material Petrit-T | 100000 €/year | 20000 ton/year | 5 €/ton |
| Other production material | | | |
| Borax | 100000 €/year | 200 ton/year | 500 €/ton |
| Water | 28000 €/year | 8000 ton/year | 3,5 €/ton |
| Sodium silicate | 840000 €/year | 7000 ton/year | 120 €/ton |
| Labour | 150000 €/year | 3 | |
| Drying | 105600 €/year | 35200 ton/year | 3 €/ton |
| Electicity | 29920 €/year | 35200 ton/year | 0,85 €/ton |
| TOTAL VARIABLE COSTS | 1353520 €/year | | |
| **Investment costs** | | | |
| Machine investments | 400000 € | | |
| Storage investments/costs | 100000 € | | |
| TOTAL FIXED COSTS | 500000 € | | |
| Overhead/other (10 % of total variable costs) | 135352 €/year | | |
| Depreciation 7 years, straight-line | 71429 €/year | | |
| **Revenue** | | | |
| Market prices / expected price | 60 €/ton | | |
| Expected amount sold in year | 35200 ton/year | | |
| Revenues | 2112000 €/year | | |
| PROFIT | 551699 €/year | | |
| **Other** | | | |
| Savings from landfilling | 300000 €/year | 20000 ton/year | 15 €/ton |

### 4.1.2 Acoustic Panels

The acoustic panels are assumed to be made of the previously presented Petrit-T lightweight geopolymer granules. This is a reason to exclude the landfilling savings from the benefit calculations since that is covered in the granule calculations. That benefit is still mentioned in the calculation sheet. The calculations shows that with the present market value of the acoustic panels, it is possible to have around 1,3 million euros revenues with annual production and when considering the costs, the business is profitable with 850 000 euros in the first years (table 10).

The manufacturing can be done using a regular concrete product facility, and therefore the investment cost is estimated from a larger manufacturing facility. An automated factory with an output of 250 m2/h has an approximate investment of 3 000 000 €. Therefore, when only about a tenth of that is required to produce the planned amount of acoustic panels, approximately 32 000 m2/y and 20 m2/h, small investment is needed. However since the investment does not scale linearly to needed smaller factor, somewhat

larger investment need is assumed. This calculation method is likely to cause errors to the final outcome, and may partly explain the extremely high return on investment (70%), however it is believed to show the correct trend nevertheless.

**Table 10**. Profitability of acoustic panels.

| ACOUSTIC PANELS | For a concrete production unit with 250m2 per hour output | | |
|---|---|---|---|
| | Cost | Usage | Price |
| **Variable costs** | | | |
| Material Petrit-T granules | 120000 €/year | 2000 ton/year | 60 €/ton |
| Other production material | | | |
| Cement | 20000 €/year | 200 ton/year | 100 €/ton |
| Other supporting production material | | | |
| Water | 700 €/year | 200 ton/year | 3,5 €/ton |
| Electricity | 3200 €/year | 32000 m2/year | 0,1 €/m2 |
| Labour | 150000 €/year | 3 persons/shift | |
| Transportation (in, out, between) | 32000 €/year | 32000 m2/year | 1 €/m2 |
| TOTAL VARIABLE COSTS | 325900 €/year | | |
| **Investment costs** | | | |
| Machine investments | 400000 € | | |
| Storage investments/costs | 100000 € | | |
| TOTAL FIXED COSTS | 500000 € | | |
| Overhead/other (10 % of total variable costs) | 32590 €/year | | |
| Depreciation 7 years, straight-line | 71429 €/year | | |
| **Revenue** | | | |
| Market prices / expected price | 40 €/m2 | | |
| Expected amount sold in year | 32000 m2/year | | |
| Revenues | 1280000 €/year | | |
| PROFIT | 850081 €/year | | |
| **Other** | | | |
| Savings from landfilling taken into account in granule calculations | | 20000 ton/year | 15 €/ton |

### 4.1.3 Binder

The case of cement binder is more challenging than the other products. In the market the binder production straight from the raw material is profitable with large volumes. The annual production of Petrit-T is only 20 000 tons and with this volume it is not in the same level as with the traditional cement binder production. The investments are big compared to the output of cementious binder in these estimated volumes. The low volume brings a challenge to the profitability but still the business looks profitable. The profit will be 198 000 € annually the first years but if we compare the savings of 300 000 € in landfill costs, the total financial benefit would be in the first years 498 000 € (table 11).

**Table 11**. Profitability of cement binder.

BINDER CEMENT

| | Cost | Usage | Price |
|---|---|---|---|
| **Variable costs** | | | |
| Material Petrit-T | 100000 €/year | 20000 ton/year | 5 €/ton |
| Other production material | | | |
| Limestone | 117460 €/year | 11746 ton/year | 10 €/ton |
| Other production material costs (electricity, water) | 15334 €/year | 4381000 l/year | 0,0035 €/l |
| Labour | 250000 €/year | 5 persons | |
| Transportation | | | 0,10 €/t/km |
| Milling | 285720 €/year | 19048 ton/year | 15 €/ton |
| TOTAL VARIABLE COSTS | 768514 €/year | | |
| **Investment costs** | | | |
| Machine investments | | | |
| Pelletizing | 100000 € | | |
| Sintering | 200000 € | | |
| Storage investments/costs | 400000 € | | |
| TOTAL FIXED COSTS | 700000 € | | |
| Overhead / others (10% of total variable costs) | 76851 €/year | | |
| Depreciation 7 years, straight-line | 100000 €/year | | |
| **Revenue** | | | |
| Market prices / expected price | 60 €/ton | | |
| Expected amount sold in year | 19048 ton | | |
| Revenues | 1142880 € | | |
| PROFIT | 197515 € | | |
| **Other** | | | |
| Savings from landfilling | 300000 €/year | 20000 ton/year | 15 €/ton |

### 4.1.4 Concrete Elements

Concrete elements are assumed to be made partly of Petrit-T. To have enough volume to produce the concrete elements, it is necessary to add some other aggregates in addition to aggregates made of Petrit-T. The aggregates would be in this case small rocks and Petrit-T used also as the part of the binder substance. Total variable costs are with this end-product scenario over 812 000 € annually but with the market prices today the profit is nevertheless very good, about 575 000 € annually. Also the investments have been taken into account in the calculations. Here investment estimations are depreciated figures. Overall the business case analysis calculations of concrete elements show that it is possible to have profitable business of it with nearly 600 000 M€ in addition to benefit of landfilling cost savings worth of 15 000 € (table 12).

**Table 12.** Profitability of concrete elements

| CONCRETE ELEMENTS | Based on a production of 10 000 blocks (á 2,4 ton) per year | | |
|---|---|---|---|
| | Cost | Usage | Price |
| **Variable costs** | | | |
| Material Petrit-T | 5 000 €/year | 1 000 ton/year | 5 €/ton |
| Other production material | | | |
| Borax + others | 50 000 €/year | 100 ton/year | 500 €/ton |
| Aggregates/ballast mtrl | 200 000 €/year | 20 000 ton/year | 10 €/ton |
| Limestone/cement | 200 000 €/year | 2 000 ton/year | 100 €/ton |
| Other production material costs (electricity, water) | 7 500 €/year | | |
| Labour | 250 000 €/year | 5 persons | |
| Transportation | 0 €/year | | |
| Handling | 100 000 €/year | | |
| TOTAL VARIABLE COSTS | 812 500 €/year | | |
| **Investment costs** | | | |
| Machine investments | 200 000 € | | |
| Molds etc. | | | |
| Storage investments/costs | 50 000 € | | |
| Other various costs | 50 000 € | | |
| TOTAL FIXED COSTS | 300 000 €/year | | |
| Overhead / others (10% of total variable costs) | 81250 €/year | | |
| Depreciation 7 years, straight-line | 42857 €/year | | |
| **Revenue** | | | |
| Market prices / expected price | 63 €/ton | | |
| Expected amount sold in year | 24 000 ton | | |
| Revenues | 1 512 000 € | | |
| PROFIT | 575 393 €/year | | |
| **Other** | | | |
| Savings from landfilling | 15 000 €/year | 1 000 ton/year | 15 €/ton |

## 4.2 Business Case Proposition

The research question 3 is answered in the following chapter explaining what the business cases are for the Petrit-T utilisation. Business case analysis leads to the business case proposal through evaluation of the analysis and the feasibility assessment.

### 4.2.1 Return on Investment

The return on investment is calculated to gain visibility of the benefit to the investments. If investments are made, the investor expects returns from it. The return of investment for end-product producer stakeholder is calculated with the formula of

$$\text{ROI} = \frac{Gain\ from\ investment - Cost\ of\ investment}{Cost\ of\ investment} \times 100\ \%$$

Where the gain from investment is calculated to be the revenues from sales plus the benefit from landfilling the Petrit-T. Cost of investment is accumulated investment costs, also mentioned total fixed costs. With this formula, the investment cost for each end-product is calculated for this upscaling project regarding the Petrit-T utilisation possibilities in various end-products in producer point of view. The gain of the investment can be estimated to be the total profit from the business possibilities and the landfilling savings. The total benefit and investment costs from every end-product scenario are calculated in the calculations in the previous sections. ROI is calculated for the first year and separately for every end-product scenario since it has been assumed that all the annual Petrit-T goes into one end-product.

$$\text{Geopolymer granules ROI} = \frac{(0{,}852\ M€ - 0{,}5\ M€)}{0{,}5\ M€} = 0{,}7 = 70\ \%$$

When investments are 500 000 € and total benefit 852 000 € as the calculations in section 3.4.1 shows, taking into account the savings from reduced landfilling of Petrit-T.

$$\text{Acoustic panels ROI} = \frac{(0{,}85\ M€ - 0{,}5\ M€)}{0{,}5\ M€} = 0{,}7 = 70\ \%.$$

When investments are 500 000 € and total benefit 850 000 € in the production of acoustic panels.

$$\text{Binder ROI} = \frac{(0{,}498\ M€ - 0{,}7\ M€)}{0{,}7\ M€} = -0{,}29 = -29\ \%.$$

When investments in binder manufacturing are 700 000 € and total benefit from landfilling savings and business profit 498 000 €. Although negative value for the first year, the ROI calculated for 2 years is 42%.

$$\text{Binder ROI 2y} = \frac{(0{,}996\ M€ - 0{,}7\ M€)}{0{,}7\ M€} = 0{,}42 = 42\ \%.$$

$$\text{Concrete elements ROI} = \frac{(0{,}59\ M€ - 0{,}3\ M€)}{0{,}3\ M€} = 0{,}97 = 97\ \%.$$

When the investments are 300 000 € and total benefit from landfilling savings and business profit 590 000 € in the case of concrete elements.

We can see that the best return on investment for the first years of the production is for the concrete elements, even though the best revenues comes from the acoustic panels. In the binder case, the return on investment is negative with in the first year but the return will accumulate along the years being on a positive side in the second year.

### 4.2.2 Case Proposition

The waste policies are becoming stricter and regulations are tightening in the raw material sector. Presented technologies and end-products from the side stream Petrit-T can be used as a secondary raw material according to circular economy mind-set.

To achieve a profitable business from side stream Petrit-T the business infrastructure has to be created. According to the Moore's (1993) studies the business ecosystem around the Petrit-T is in the planning phase of the ecosystem birth. The birth phase challenge is to have a common accepted decision about the new value proposition to the customer between all the ecosystem stakeholders. The competitive challenge in this phase is to protect the innovation and also the supply and sales channels from the competitors. Höganäs is one of the key players in forming ecosystem around the main innovation, the side stream substance Petrit-T. As the Iansiti and Levien (2004) have studied, the Höganäs fulfills the criteria for being the keystone in the ecosystem that is the very core of the ecosystem. As the keystone, Höganäs is in the key role to ease the ecosystem's ability to create new products in the ecosystem, give technologies to create new and simplify the tasks and processes in the network. By doing this it will itself nourish and ensure own business also. In this Petrit-T case and in general, the business ecosystem brings the knowledge, assets and resources from all the included stakeholders and with suitable business models the ecosystem will be formed sustainably but dynamic. Value is added in every stakeholder of the value network to ensure the best possible quality products in best price.

Business models in the Petrit-T utilisation ensure that the right thing is done in every company of the ecosystem. As Osterwalder (2005) has stated, the business model need to be planned in every company separately and in larger scale in the whole ecosystem. The Petrit-T value stream analysis shows the mechanics that provide the value to the customer through financial, commercial and industrial aspects in simplified process representation.

Every value stream ecosystem has its own business model structure but it seems that the mechanics doesn't vary a lot. All companies separately has their own business model to their products and services in this case and the focus is on the ecosystem business model. The ecosystem business model here is to create a new product using every company's strengths and use their present business channels and contacts. The business model inspection supports the business case analysis and vice versa since business model is strongly linked to the capabilities of the companies, strategy and organisational aspects as well as the monetary perspective as the Al-Debei *et al*. (2008) also have stated.

As a summary, to produce acoustic panels, binder and concrete elements from Petrit-T is profitable business in the ecosystem stakeholder model and value creation business models. Even though there is big investment, there is a market potential for all of these end-products if the product meets requirements in the properties and the price is competitive. The calculations show that the acoustic panels and concrete elements are significantly profitable business with present market prices. Only the concrete binder shows that with the investments the business is not in the beginning a huge business but in time it accumulates good profit and the benefit is greater when landfilling savings are taken into account. Figure 25 shows from the profitability calculations that all the end-product scenarios from the Petrit-T are profitable business. Acoustic panels show the total benefit that combines the profit and savings from landfilling with over 850 000 € annually and granules 852 000 € with the estimations mentioned. Also the binder shows reasonable benefit but is lower due to the low annual production volume. Even though the revenue expectations are lower, about 198 000 €, the benefit from landfilling savings are remarkable and total benefit is 498 000 €. The benefit of concrete elements seems to be stable 590 000 € in total with 5 % of annual Petrit-T output quantity. Concrete element business would have more potential as there is a lot more Petrit-T available.

Total benefits are more than just the revenues from the business. In the figure 25 below it is shown the total benefit from the business potential and also the cost savings from the landfilling. All the calculations assume that the Petrit-T is used only in one selected end-product. If it is decided to produce two or more different end-products, the split calculations needs to be done and the production share optimised. In the case of acoustic panels, the landfill savings are excluded since those are already taken into account in the granule scenario.

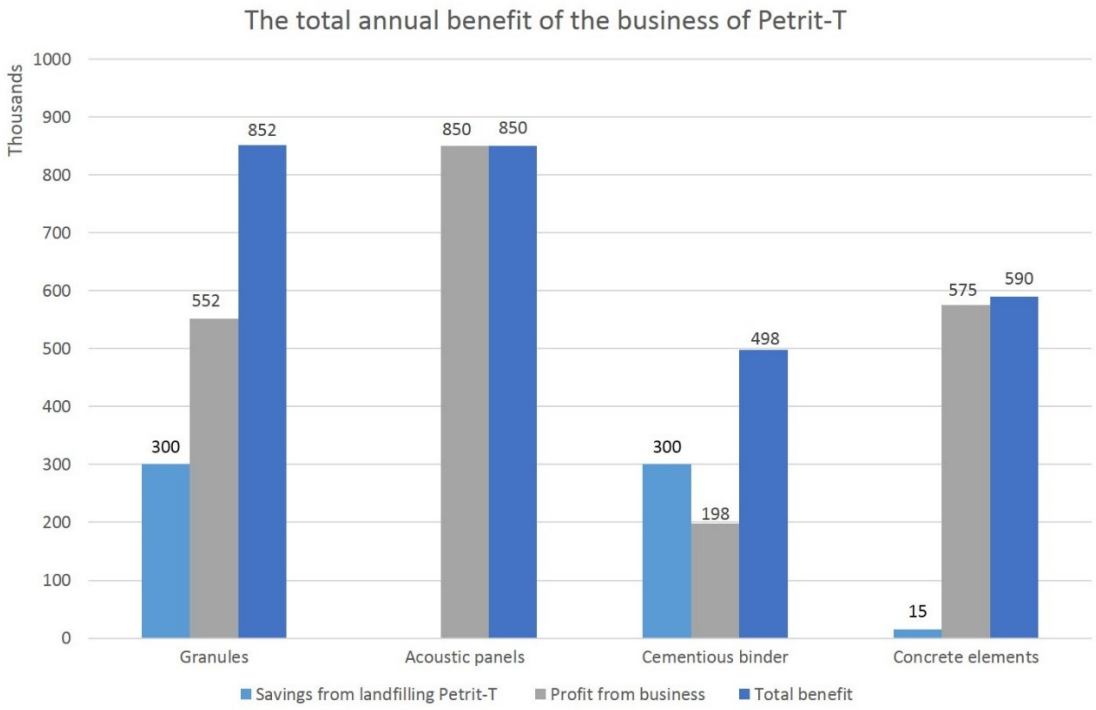


**Figure 25.** Total annual benefit of the Petrit-T.

The second summarising profit and loss from the business figure 26 is here to show how the profit accumulates over the years with 7 year investment depreciation. The profit figure is based completely on the calculations presented in section 3.4 and is made in the end-product producer point of view. The profit and loss statement does not take the cost savings from landfilling into account but is here to show the profitability of the different end-product scenarios. Profit for every scenario is expected to accumulate from the first year onwards with same market demand and material availability. The best accumulated profit is expected to come from acoustic panels. It is seen that the granules can be very profitable product itself and concrete element trend in profit is in the same level with very good expectations. Binder is also profitable product with these assumptions above, and with the savings taken into account, it is worth the investments.


**Figure 26.** Profit and loss over 8 years, without taking into account the savings from landfilling.

These results are made with the assumption that only the single end-product scenario is implemented to the practice. With sensitivity analysis it is possible to evaluate the robustness of the solutions in the uncertainty. One uncertain aspect is the market evaluations. In the sales estimate in chapter 3.5.1 the market evaluation shows the estimations about the customer acceptance. These estimations can vary in the practice and in time. It is important to notice that if one of these end-products is not a success, the other one could be more successful than estimated. Nevertheless these risks needs to be evaluated in detail whether to split the processing the Petrit-T in many different end-products or just only one. Calculations in the chapter 4.1 shows that all the evaluated end-products are feasible and profitable. So at least in one of these products it is worth invest. However the investment need is great in all of these cases. If it is decided to split the processing the Petrit-T in different products, investment costs can be multiplied and compared to the annual output of Petrit-T which is 10 000 tons, return on investment will fall and the expected benefit and value would realise after several years. In the business

operations point of view it is more convenient to split the Petrit-T into different products to ensure the maximum usability of Petrit-T in case of one of the products' demand would drop. In this phase where the project is in feasibility study phase, it is justified to examine the business benefits in the investor point of view. So according to the calculations, it is advisable to focus on the one most promising end-product to ensure the best benefit to the investor.

All in all, with the market interest, selected end-products are worth the investments and can give remarkable financial benefits to the business ecosystem built around the Petrit-T side stream. The profitability combined with the benefit of the brand and corporate image will increase the success possibilities in the markets.

The most important conclusions from this study can be summarised in:

- It is a profitable business to produce acoustic panels, binder and concrete elements including granules.
- It is necessary to create a business ecosystem from different stakeholders to achieve the most profitable business, have the maximum benefit and deliver value to the customer.
- The most profitable business from this study is to produce the acoustic panels that also includes, as the first processing step, the production of granules.

Therefore business case proposition with the present knowledge is to go for in any of these selected end-products made of Petrit-T in the MIN-PET project separately.

# 5 CONCLUSIONS

In this chapter the conclusions about the research success, validity and reliability are evaluated. Also the goal achievement is examined through the research progression. The last paragraph suggests the next possible themes that could be studied in the future around this subject.

## 5.1 Contribution of the Study

The main goal of this research is to evaluate the economic feasibility of the utilisation of Petrit-T substance by answering the research questions. The first research question of how the industrial side streams can be analysed in the economical point of view, is answered in the first chapter by literature review. The literature review explains how the economic consortium formation is done around the innovations effectively. This is explained via business ecosystem concept where all the participants form an ecosystem based on the model from the living nature. Also it was examined what the economics of the side stream business models are and how they are formed. Finally in the literature review the business part demands the review about the side stream context as an environment description. In the side stream analysis review the legislation in the EU has been investigated and the side stream analysis effects to the business environment. The theoretical synthesis explains the entity of business ecosystems, business models and business case analysis interfaces.

The empirical part of the study gives the answer to the second research question of what the value streams business model scenarios of the side stream of Höganäs are. In the practical part the end-product scenarios, business ecosystems with its stakeholders and the business models are created with the MIN-PET project participants. The results are flow charts for every end-product scenario. The business models found in literature are applied in this research very shallowly. The focus is in the ecosystem creation and the value proposition planning through the process flow in the ecosystem.

The final research question was what the business cases of Petrit-T utilisation are and the research has gathered all the information and knowledge about the business ecosystem

and business model basic concepts and implementation in this case. Also the business case analysis details were gathered to achieve the desirable goal in form of the analysis, economic feasibility of Petrit-T utilisation and finally the business case proposition.

The business ecosystem is needed to model in this side stream utilisation case since this kind of consortium is not been created before or the topic been researched on this industry and this kind of side stream. To be able to form a business case proposal of the technology or investment all the costs and market potential need to be found, evaluated and analysed. And these can be achieved only if the whole process, value stream and network are modelled. The key partners in the ecosystem need to be visible and the responsibilities between them planned even in the rough level. Therefore the research starts with the ecosystem participation mapping and ecosystem formation. Value stream modelling between these participants will follow.

Value chain modelling is important part of the new business creation since the main goal of doing business is to create value to the customer and get enough revenues from it to keep business alive. When the value creation structures are clear, the details as the costs are possible to evaluate according to the structure and responsibilities in the ecosystem.

All the end-product scenarios are feasible for the business. Even though the demand drops from one end-product, the other ones are still strongly beneficial to the ecosystem actors. In the calculations it has been assumed that all the annual Petrit-T goes into one product. It is also possible to split the Petrit-T into different shares in the end-product scenarios. In these cases the risks for success is split between different products but investment costs will rise if more technologies and processes are created. Then also the return on investments are going to change as the revenues change but the investments are still the same.

## 5.2 Evaluation of the Study

The research is evaluated in terms of reliability and validity. Reliability tells if the research is repeatable by other people and if similar results could be found and applied in some other similar research in the future. Also how the results are found from the data is one aspect of the reliability. Validity will reveal does the research study the right subject

with right methods and does the research study what it is meant to study. (Saunders *et al.* 2009) The business ecosystem analysis results overall are reliable and outlast the time. The details to the ecosystem structure have been collected from the project workshop from different participants in the project who are experts in their field of technology. The ecosystem formation is planned in the high level and gives the basis that the project team and the company participants can build up the Petrit-T business in the future.

The visual ecosystem mapping method was a swimming lane chart exercise and it gives a good frame to fill the details in. (Tangpong 2011) The methods used are more qualitative and certain scientifically proved tools have not been used in this research. Nevertheless the material gathering method here is not completely according to LEAN value stream mapping principles. In this study it was not intention to map and improve one process completely but the main target was to create a guidelines for the value stream around the innovation. Therefore the value stream mapping method was modified lightweight version combined to process mapping in this research to serve the intentions and goals better.

The empirical data has been collected to the real purpose and need of the project to reflect the real state of the business environment. The empirical information is as reliable as possible with the today's knowledge of the participants but few parts in the research brings unreliability. In the workshop there was nine persons present from the MIN-PET project. Unfortunately all the invited stakeholders could not make it to the workshop. Two companies and their representatives were absent from the workshop and this brings a little distortion to the empiric material and analysis about the ecosystem structures and value stream analysis. There is probably missing some key opinions and perspective from the companies in the project. The project and the case is in its first phases and only the planning of the possibilities takes place in this phase of the project. The interviews have not been planned to be closed-ended but more open-ended and unstructured discussion via phone, email and in person and therefore the questions were not strictly specified. The open discussion is unreliable data gathering method in very specific studies but in this research it brought more space to innovation and inventing new ideas and that is why this method has taken into the research. Workshop participants knew each other beforehand and this has brought trust and openness to the innovation in the workshop. Results are validated since they are checked with the project participants and thesis supervisors. The

workshop was also audio-recorded which reliability to the research with the access to the discussion afterwards in the analysis phase. Transparency still is missing in the audio-recording since the workshop audio was never transcribed.

The business case analysis details for the profitability calculations are gathered from the company representatives also and they have commented to the calculation details so the profitability calculations are truly the best available estimations available at this moment. The numbers in the business case analysis of the study contains a lot of estimations about the costs and revenues since this kind of ecosystem and business does not exist yet and therefore the calculations are not the most reliable or exact but they are the best estimations of the present knowledge of the participants. When the market setup and prices change, the calculation results are no longer usable and applicable or up to date. Calculations are in method-wise reliable and done as carefully as possible but they could be more reliable if the study has been done to the existing business. Nevertheless the methods have been selected to suit to the purpose. The calculations are based on assumptions and estimates about the costs and market situations at the moment of research. More detailed and certain numbers were difficult to find out for the business case analysis because the planning and ecosystem formation is only in feasibility phase. Further in the future in the project it is possible to have more specific plans and numbers. These results are reliable to give an overall view about the feasibility for the project continuation but not for the practical implementation and these calculation results cannot be used directly in the specific business planning of the Petrit-T productisation.

The results can be applied in the field of business ecosystem research in side stream utilisation also in different industries. Although the detailed calculation results are applicable only in this case study. The methods and results are valid in the research of the similar side stream product business ecosystem and business case analysis. In this case, later in the project implementation phase more specific calculations need to be done to have clearer view about the success of the ecosystem. Altogether, the results can be used generally in business ecosystem creation in side stream utilization in the future.

## 5.3 Further Research

Further research is needed around these themes and the project. One future theme could be the profitability follow-up for the selected end-products later in the project phases before the practical implementation and comparison to the initial estimations in this research. Another theme could be to study the business risks of the utilisation of Petrit-T to these end-products. The risk assessment including the detailed sensitivity analysis is not covered in this research. Annual Petrit-T split into different products needs also more attention and research and could be one of new research subjects around this theme. It would be interesting also to see how the research of business ecosystem, business models and business case analysis would apply to some other side stream substances. Therefore the similar research could be done in other case studies. The themes presented here are suitable for example for other master thesis subjects or in smaller scale to the bachelor thesis subject.

# 6 REFERENCES

Allee, V., 1999. The art and practice of being a revolutionary. Journal of Knowledge Management, 3, 2, p. 121–131.

Al-Debei, M., El-Haddadeh, R., Avison, D., 2008. Defining the Business Model in the New World of Digital Business. Proceedings of the Fourteenth Americas Conference on Information Systems. Toronto, Canada, August 14th–17th.

Amit, R., Zott, C., 2001. Value Creation in eBusiness, Strategic Management Journal, 6–7, 22, 493–520.

Andersson, B., Bergholtz, M., Edirisuriya, A., Ilayperuma, I., Johannesson, P., Grégoire, B., Schmitt, M., Dubois, E., Abels, S., Hahn, A., Gordijn, J., Weigand, H., Wangler, B., 2006. Towards a Reference Ontology for Business Models. International Conference on Conceptual Modeling (ER2006).

Boardman, A. E., Greenberg, D. H., Vining, A.R., Weimer, D. L., 2006. Cost-benefit Analysis: Concepts and Practice. Third edition. New Jersey, Pearson Education. ISBN 0-13-143583-3.

Bocken, N. M. P., Short, S. W., Rana, P., Evans, S., 2013. A literature and practice review to develop sustainable business model archetypes. Journal of Cleaner Production, 65, p. 42–56.

Bouwman, H., 2002. The sense and nonsense of Business Models. International Workshop on Business Models, HEC Lausanne.

Business Case Pro, 2010. The Business Case Checklist: Everything You Need to Review a Business Case, Avoid Failed Projects and Turn Technology into ROI. ISBN 978-0-9823761-9-5.

Campanovo, G., Pigneur, Y., 2003. Business model analysis applied to mobile business. Proceedings of the 5th International Conference on Enterprise Information Systems, April 23–26.

De los Rios, I. C., Charnley, F. J. S., 2016. Skills and capabilities for a sustainable and circular economy: The changing role of design. Journal of Cleaner Production, xxx (article in press), p. 1–14.

Diao, J., Zhou, W., Ke, Z., Qiao, Y., Zhang, T., Liu, X., Xie, B., 2016. System assessment of recycling of steel slag in converter steelmaking. Journal of Cleaner Production, 125, p. 159–167.

European Chemicals Agency (ECHA), 2010. Guidance on waste and recovered substances, 2, p. 30.

European Commission (EC), 2006. Regulation (EC) No 1907/2006 of the European parliament and of the council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC. Available: https://echa.europa.eu/regulations/reach/legislation [cited 19.1.2017]

European Commission (EC), 2008. Waste Framework Directive. Directive 2008/98/EC of the European parliament and of the council of waste and repealing. Official Journal of the European Union.

European Commission (EC), 2014. Towards a circular economy: A zero waste programme for Europe. Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions, Brussels.

Fan, Y. 2005. Ethical branding and corporate reputation. Corporate Communications, 10, 4, p. 341–350.

Frosch, R.A., Gallopoulos, N., 1989. Strategies for manufacturing. Scientific American, 261, 3, p. 144–152.

Galanteau, E., Avasilcai, S., 2013. Business Ecosystems Architecture. Fascicle of Management and Technological Engineering, 1, p. 79–84.

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., Hultink, E. J., 2017. The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production, 143, p. 757–768.

Gossain, G.K.S., 1998. Reinventing value: The new business ecosystem. Strategy & Leadership, 26, 5, p. 28–33.

Haaker, T., Faber, E., Bouwman, H., 2004. Balancing strategic interests and technological requirements for mobile services. Proceedings of 6th International Conference on E-commerce, ICEC04, Delft, The Netherlands.

Haaker, T., Faber, E., Bouwman, H., 2006. Balancing customer and network value in business models for mobile services, International Journal of Mobile Communication, 4, 6, p. 645–661.

Haase, B., 2015. General information about Petrit®-T. Internal product document of Höganäs AB.

Hadley, D., 2011. Sensitivity analysis within cost benefit analysis. Spicosa Project Report, University of East Anglia CSERGE, Norwich.

Hamel, G., 2000. Leading the Revolution. Boston: Harvard Business School Press.

Hearn, G., Pace C., 2006. Value-creating ecologies: understanding next generation business systems. Foresight, 8, 1, p. 55–65.

Hirschnitz-Garbers, M., Tan, A. R., Gradmann, A., Srebotnjak, T., 2016. Key drivers for unsustainable resource use – categories, effects and policy pointers. Journal of Cleaner Production, 132, p. 13–31.

Hoover, Jr. W. E., Eloranta, E., Holmström, J., Huttunen, K., 2001. Managing the Demand-Supply Chain: Value Innovations for Customer Satisfaction, New York: John Wiley & Sons, Inc.

Husgafvel, R., Karjalainen, E., Linkosalmi, L., Dahl, O., 2016. Recycling industrial residue streams into a potential new symbiosis product – The case of soil amelioration granules. Journal of Cleaner Production, 135, p. 90–96.

Iansiti, M., Levien, R., 2004. Strategy as Ecology. Harvard Business Review.

Jovanović, P., 1999. Application of sensitivity analysis in investment project evaluation under uncertainty and risk. International Journal of Project Management, 17, 4, p. 217–222.

Kallio, J., Tinnila, M., Tseng, A., 2006. An international comparison of operator-driven business models, Business Process Management Journal, 12, 3, 281–298.

Keller, K. L., 2003. Strategic Brand Management: Building, Measuring, and Managing Brand Equity. Second Edition. New Jersey: Pearson Education Inc. ISBN 0-13-110583-3,

Kinnunen, P., Illikainen, M., 2016. Technological Feasibility Study Report – Petrit-T Geopolymerization. Unpublished Project Feasibility Study Report, MIN-PET. University of Oulu.

Kinnunen, T., Pekuri, A., Haapasalo, H., Kuvaja, P., 2011. Business case analysis in new product development. Global Journal of Management and Business Research, 11, 2.

Kinnunen, T., Hänninen, K., Haapasalo, H., Kropsu-Vehkaperä, H., 2013. Business case analysis for rapid productisation. Proceedings of 2013 International Conference on Technology Innovation and Industrial Management, p. 342–354.

Koivisto, T., Lehto, T., Poikkimäki, J., Valkokari, K., Hyötyläinen, R., 2004. Metallin ja koneenrakennuksen liiketoimintayhteisöt Pirkanmaalla. VTT tiedotteita 2257, VTT, Espoo. ISBN 951–38–6490–1.

Korat, L., Ducman, V., 2016. Environmental Feasibility Study – Environmental Impact Assessment. Unpublished Project Feasibility Study Report, MIN-PET. Slovenian National Building and Civil Engineering Institute.

Kotler, P., 1997. Marketing Management: Analysis, Planning, Implementation, and Control, 9th ed., Upper Saddle River: Prentice-Hall International, Inc.

Kriskova, L., Pandelaers, L., Pontikes, Y., 2016. Technological Feasibility Study Report – Cementitious Binders from Sinter-treatment of Petrit-T. Unpublished Project Feasibility Study Report, MIN-PET. Katholieke Universiteit Leuven.

Kuhn, K-A. L., Alpert, F., Pope, N. K., 2008. An application of Keller's brand equity model in a B2B context. Qualitative Market Research: An International Journal, 11, 1, p. 40–58.

Leek, S., Christodoulides, G., 2012. A framework of brand value in B2B markets: The contributing role of functional and emotional components. Industrial Marketing Management, 41, p. 106–114.

Leem, C. S., Suh, H. S., Kim, D. S., 2004. A classification of mobile business models and its applications. Industrial Management and Data systems, 104, 1, 78–87.

Linder, J., Cantrell, S., 2000. Changing Business Models: Surveying the Landscape. Accenture Institute for Strategic Change.

Ma, S., Wen, Z., Chen, J., Wen, Z., 2014. Mode of circular economy in China's iron and steel industry: a case study in Wu'an city. Journal of Cleaner Production, 64, p. 505–512.

Magretta, J., 1998. The Power of Virtual Integration: An Interview with Dell Computer's Michael Dell, Harvard Business Review, 76, 2, 73–84.

Magretta, J., 2002. Why business models matter, Harvard Business Review, 80, 5, p.86–92.

Menshov, P., Khulpin, Y., Nalesnik, O., Makarovskikh, A., 2014. Ash and Slag Waste as a Secondary Raw Material. Procedia Chemistry, 10, p. 184–191.

Monosi, S., Ruello, M. L., Sani, D., 2016. Electric arc furnace slag as natural aggregate replacement in concrete production. Cement and Concrete Composites, 66, p. 66–72.

Moore, J., 1993. Predator and Prey: A New Ecology of Competition. Harvard Business Review.

Morris, M., Schindehutte, M., Allen, J., 2005. The entrepreneur's business model: toward a unified perspective. Journal of Business Research, 58, 6, 726–735.

Nauman, B. A., Petersen, K., de França, B. B. N., 2015. Evaluation of simulation-assisted value stream mapping for software product development: Two industrial cases. Information and Software Technology, 68, p. 45–61.

Nguyen, N., Leblanc, G., 2001. Corporate image and corporate reputation in customers' retention decisions in services. Journal of Retailing and Consumer Services, 8, p. 227–236.

OECD, 2006. Cost-Benefit Analysis and the Environment: Recent Developments. ISBN 92-64-01004-1.

Osterwalder, A., Pigneur, Y., Tucci, C. L., 2005. Clarifying Business Models: Origins, Present, and Future of the Concept. Communications of the Association for Information Systems, 16, 1.

Osterwalder, A., Pigneur, Y., 2009. Business Model Generation. p. 281, (ISBN 978-2-8399-0580-0.

Otto, K. N., Wood, K. L., 2001. Product Design: Techniques in Reverse Engineering and New Product Development. New Jersey: Prentice-Hall, Inc., p. 1071, ISBN 0-13-021271-7.

Petrovic, O., Kittl, C., and Teksten, D., 2001. Developing Business Models for eBusiness, Proceedings of the International conference on Electronic Commerce.

Popp, K. M., 2011. Hybrid revenue models of software companies and their relationship to hybrid business models. CEUR Workshop Proceedings, 746, p. 77–88.

Porter, M. E., 1985. Competitive Advantage: Creating and Sustaining Superior Performance, New York: The Free Press.

Porter, M. E., 2001. Strategy and the internet, Harvard Business Review, 79, 3, p.62–78.

Rajala, R., Rossi, M., Tuunainen, V., Rautiainen, K., Korri, S., 2001. Software business models: a framework for analyzing software industry, Technology Review 108/2001, TEKES, Helsinki.

Rajala, R., Westerlund, M., 2005. Business Models: A new perspective on knowledge-intensive services in the software industry. 18th Bled eCommerce Conference eIntegration in Action, Bled, Slovenia, 1–15.

Randall, W. S., Brady, S. P., Nowicki, D. R., 2012. Business Case Analysis and the Confounds of Innovation Driven by Performance-Based Postproduction Support Strategies. Transportation Journal, 51, 1, p. 33–58.

Rappa, M., 2000. Managing the Digital Enterprise. North Carolina State University. Online: http://digitalenterprise.org/index.html [cited 19.1.2017].

Saunders, M., Lewis, P., Thornhill, A., 2007. Research methods for Business Students. Fifth edition. Prentice Hall.

Schulte, U. G., 2013. New business models for a radical change in resource efficiency. Environmental Innovation and Societal Transitions, 9, p. 43–47.

Slywotzky, A. J., 1996. Value Migration: How to Think Several Moves Ahead of Competition. Boston: Harvard Business School Press.

Stähler, P., 2002. Business Models as a unit of analysis for strategizing, Proceedings of 1st International Workshop on Business Models, Lausanne, Switzerland. Online: http://www.business-model-innovation.com/english/definitions.html [cited 19.1.2017].

Suikki, R. M., Goman, A. M., Haapasalo, H. J., 2006. A framework for creating business models – a challenge in convergence of high clock speed industry. International Journal of Business Environment, 1, 2. p. 211–233.

Tangpong, C., 2010. Content analytic approach to measuring constructs in operations and supply chain management. Journal of Operations Management, 29. p. 627–638.

Teece, D. J., 2010. Business Models, Business Strategy and Innovation. Long Range Planning, 43, p. 172–194.

Tikkanen, H., Lamberg, J. A., Parvinen, P., and Kallunki, J. P., 2005. Managerial Cognition, Action and the Business Model of the Firm. Management Decision, 43, 6, 789–809.

Timmers, P., 1998. Business Models for Electronic Markets. Journal on Electronic Markets, 8, 2, p. 3–8.

Torbay, M. D., Osterwalder, A., Pigneur, Y., 2001. eBusiness Model Design, Classification and Measurements. Thunderbird International Business Review, 44, 1, p. 5–23.

Tsvetkova, A., Gustafsson, M., 2012. Business models for industrial ecosystems: a modular approach. Journal of Cleaner Production, 29–30, p. 246–254.

Venkatraman, N., Henderson, J. C., 1998. Real Strategies for Virtual Organizing. Sloan Management Review, 40, 3, p. 33–48.

Winans, K., Kendall, A., Deng, H., 2017. The history and current applications of the circular economy concept. Renewable and Sustainable Energy Reviews 68, p. 825–833.

Zahra, S. A., Nambisan, S., 2012. Entrepreneurship and strategic thinking in business ecosystems. Business Horizons, 55, p. 219–229.

# APPENDIX

Appendix 1. Questionnaire about the strategic fit to the representative of Höganäs AB.

- What is the fit to the product portfolio of Höganäs AB? (How remarkable product this would be for the company, expectations, compared to other products, what is the position?)
- What is the brand and corporate image fit to Höganäs AB? (Eco-friendliness? The corporate values *e.g.* "no waste policy")
- What is the right time for introducing the product? (Why now is the best time to develop? Is the market ready for this product?)
- Could there be other product cannibalism if the selected end-products are sold? (Does Petrit-T or its end-products eat the revenues from some other product now or in the future?)
- Is the product/investment for the product aligned with the corporate strategy or enterprise architecture?