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INNOVATION PROCESS AND ORGANIZATIONAL ADOPTION OF DISRUPTIVE INNOVATIONS: EMPIRICAL EVIDENCE FROM FINNISH BIO-ECONOMY COMPANIES.

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ABSTRACT

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The thesis aims to build a coherent view and understanding of the innovation process and organizational technology adoption in Finnish bio-economy companies with a focus on innovations of a disruptive nature. Disruptive innovations are exceptional hence in order to create generalizations and a unified view of the subject the perspective is also on less radical innovations. Other interests of the thesis are how ideas are discovered and generated and how the nature of the innovation and size of the company affect the technology adoption and innovation process. The data was collected by interviewing six small and six large Finnish bio-economy companies. The results suggest companies regardless of size consider innovation as a core asset in the competitive markets. Organizations want to be considered innovators and early adopters yet these qualities are limited by certain, mainly resource-based factors. In addition the industry, scalability and Finland’s geographical location when seeking funding provide certain challenges. The innovation process may be considered relatively similar whether the idea or technology stems from an internal or external source suggesting the technology adoption process can in fact be linked to the innovation process theories. Thus the thesis introduces a new theoretical model which based on the results of the study and the theories of technology adoption and innovation process aims on characterizing how ideas and technology from both external and internal sources generate into innovations. The innovation process is in large bio-economy companies most often similar to or a modified version of the stage-gate model, while small companies generally have less structured processes. Nevertheless the more disruptive the innovation, the less it fits in the structured processes. This implies disruptive innovation cannot be put in a certain mould but it is rather processed case-by-case.

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Tutkielman tavoitteena on hahmottaa ja syvemmin ymmärtää biotalousyritysten innovaatioprosessia sekä teknologian omaksumista etenkin disruptiivisten innovaatioiden kohdalla. Disruptiivisten innovaatioiden harvinaisuuden vuoksi tutkielma keskittyy luomaan yleisen ja yhtenäisen kuvan aihealueesta tarkastelemalla myös vähemmän radikaaleja innovaatioita. Keskeisiä aihealueita ovat ideoiden kerääminen, arvioiminen ja prosessoiminen sekä yrityksen koon ja innovaation luonteen vaikutus innovaatioprosessiin ja teknologian omaksumiseen. Aineisto kerättiin haastattelemalla kuutta pientä ja kuutta suurta suomalaista biotalousyritystä. Tulosten ja aiemman kirjallisuuden pohjalta luotiin teoreettinen malli kuvastamaan ideoiden ja teknologian omaksumista sekä niiden kehittymistä organisaatioiden sisällä. Tulokset osoittavat yritysten koosta riippumatta pitävän innovaatioita ja innovointia keskeisinä kilpailutekijöinä. Organisaatiot tahtovat tulla mielletyksi innovatiivisina ja aikaisina omaksujina joskin todellisuudessa näitä ominaisuuksia rajoittaa tietyt tekijät, jotka ovat enimmäkseen resurssipohjaisia. Tiettyjä haasteita luovat myös toimiala, skaalautuvuus sekä ulkopuolisten rahoittajien etsinnässä Suomen maantieteellinen sijainti. Huolimatta siitä onko idea tai teknologia sisäisistä vai ulkoisista lähteistä, innovaatioprosessi voidaan nähdä jokseenkin samankaltaisena, sillä myös ulkoa omaksutut teknologiat vaativat useimmiten muokkaamista organisaatioon sopivaksi. Innovaatioprosessi on suurissa biotalousyrityksissä yleensä jonkinlainen sovellus stage-gate –mallista kun taas pienissä yrityksissä innovaatioprosessi on harvemmin yhtä strukturoitu. Mitä radikaalimpi innovaatio, sitä huonommin se näyttäisi sopivan mihinkään tiettyyn malliin. Tämä viittaa siihen, että disruptiivisia innovaatiota ei voi asettaa tiettyyn muottiin, vaan ne käsitellään tapauskohtaisesti.

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"Life isn't about waiting for the storm to pass; it's about learning to dance in the rain." –Vivian Greene

It is suddenly dawning on me that by giving in this thesis I am finishing one chapter of my life. The five years at LUT have been … Oh well, something I can't even find the words to describe without understating the experience. I want to thank everyone who has been there to make my student years memorable, full of laughter and worth every single struggle. A special thanks to the very special girls who have been beside me from the very first days at Lappeenranta.

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To conclude I must say, reaching this goal feels pretty great but this trip has been all about the journey.

Helsinki, 11.6.2015

Ella Laurila

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1. INTRODUCTION

1.1. Background of the study

“If a man can write a better book, preach a better sermon, or make a better mousetrap than his neighbour, though he builds his house in the woods, the world will make a beaten path to his door.”

Ralph Waldo Emerson (1803-1882)

If Emerson had lived today, his perception of innovativeness could have been different; without successful commercialization and diffusion even the greatest of innovations would never be adopted by the large audience in the common competitive markets. Nevertheless, the number of technological innovations has grown exponentially throughout the years. Partly this is due to the major ground-breaking innovations such as the World Wide Web, which has lowered the barriers of information flow and thus market entry (Hagel et al. 2013). Furthermore the technological growth is ever more rapid; while 25 years ago the thought of a small and portable mobile phone with the functions of a computer seemed impossible, today they are a standard. Correspondingly it is found likely that high technology such as the 3D-printer will be a regular household object in the near future.

Exponential growth is also found to be visible in the quantity of innovations: it is predicted that the amount of technological change and innovation that took 2.5 years in 2011 will take one year in 2060. Especially in mobile, computing, bio and other fields of high technology, new innovations are continuously disrupting old industries and standards with an exponentially growing rate. (Sheffield 2014) Therefore it is no wonder the innovation research has in the past decades put a significant emphasis on the way technological innovations are diffused to the social system and on the other hand, adopted. Researchers have been interested through time about the factors which cause some innovations to diffuse with a great speed while others fail to ever reach the markets.

This research nevertheless takes one step back from consumer adoption and tackles the concept of organizational innovation adoption with a focus on disruptive technology and synthetic biology as a specific example. Synthetic biology is one of these disruptive modern technologies which enable the creation of new organisms and life forms. This arising breakthrough technology is seen to have a great impact on the future of the world. (Hyytiäinen 2014) As a form of biology it is a rapidly growing field in which biologists view life forms and DNA in a similar manner technology 'wizards' once viewed basic electronics, transistors and circuits (Garrett 2013). Synthetic biology offers solutions to for instance medical and environmental issues and is seen as a potential way to fight serious diseases and build more sustainable environmental solutions. The technology tackles the problems of the common world and is one instrument in reducing oil dependency, greenhouse gases and pollution issues (Keasling 2013). While the new technology possesses great potential, it has yet to have reached commercial success in Finland due to its extent of novelty.

1.2. Literature review

Innovation has been an ever increasingly popular subject of research for decades. Researchers commonly agree that innovation is a necessity and requisite in the modern world (Assink 2006; Rothwell 1994), yet there still is a lack of cohesion in determining innovation types (i.e. Garcia & Calantone 2002). Schumpeter (1950) was one of the first researchers to discuss disruptive innovation, yet naming it "creative destruction". Later, Christensen (1997) introduced the theory of disruptive technology focusing on technological innovations and how they come to surpass other previously superior technologies and hence dominate the markets.

The innovation process has also been broadly researched. The first models on innovation were linear, focusing on three to four phases from scientific discovery to technological development to diffusion to the marketplace. Thus the first models had a strong focus on R&D and "technology push", of which a popular example is the one by Rogers (1962), introduced further in the study. Later, the theories evolved towards the "market pull" –perspective. The linearity of the models received criticism which lead to the wave of unlinear innovation models (i.e. Kline & Roosenberg 1986; Rothwell & Zegveld 1985; Assink 2006) The innovation process concerning strictly technology and high-technology companies has also been researched to a great extent (For instance Bianchi, Chiesa & Frattini, 2011;

Narvekar & Jain, 2006) There is also an endless amount of other literature discussing the subject of innovation (i.e. Elite, 2006; Pulkkinen, 2003; Hautamäki, 2008; Palmberg, 2002).

Innovation adoption and diffusion may be approached from both the organizational and individual adopter's level (Frambach & Schillewärt 2002) The studies on innovation adoption and diffusion have commonly had an emphasis on the way individuals absorb and adopt new innovations (Rogers & Eveland 1978). Consumer innovation adoption has been the main perspective for the adoption and diffusion studies in the late 1960s and early 1970s, when a large number of studies were conducted on the subject (i.e. Robertson 1971; Rogers 1976; Ostlund 1974). The theory of reasoned action (TRA) (Fishbein & Ajzen 1975) is a model which aims to predict individuals' behavior and decision-making. The model has been the basis for many further researches and models. Of these an example is the theory of planned behavior (TPB), which is an improved version of the TRA-model including perceived behavioral control (Ajzen 1985). Another popular model is Davis's (1989) technology acceptance model (TAM), which has been developed to predict an individual's intentions in accepting and using information systems. These models have also been evaluated and compared by many researchers (i.e. Chuttur 2009; Mathieson 1991). However, in this research the individual level of adoption has consciously been left without further scrutinizing, for the main emphasis is on the organizational absorber's perspective.

While there are various models describing the individual's decision-making process, organizational innovation adoption has been a less researched subject (i.e. Frambach & Schillewärt 2002; Dewar & Dutton 1986; Daft 1978). Rogers (i.e. 1962, 1985, 2003) has formed many of the organizational adoption and diffusion theories which several researchers have benchmarked, discussed and based their research on in the past years (i.e. Easingwood & Harrington 2002; Wright & Charlett 1995; Boutellier & Heinzen 2014). Furthermore Damanpour (i.e. 1987) has been one of the active researchers of organizational factors in the adoption of innovation. Damanpour and Gopalakrishnan (1991) state a problem in the organizational innovation adoption research is the way research commonly focuses on only one dimension of innovation at a time. These are dimensions such as type, radicalness or stage of innovation. Therefore they strived upon developing a more complex model for structure-innovation relationships. The effect of radicalness in the innovation process has been researched to some extent (i.e. Waarts, Everginden & Hillegersberg 2002; Abetti 2000; Dewar & Dutton 1986) but according to Damanpour, Szabat and Evan (1989) the impact of the adoption of an innovation on another over time has never been researched.

The concept of bio-economy is relatively new yet emphasized to a great extent in the modern world. Bio-economy is a growing and innovative field and it is seen to have great potential in the Finnish markets. Furthermore the Finnish government has acknowledged the growth potential and emphasizes sustainable factors in the national plans. The visualized potential may also been seen through how bio-economy is one of the governmental strategic focuses for the upcoming ten years and thus also financially emphasized on. (Valtioneuvosto 2015) The research around the subject has mostly been around gene modifications, regulatory issues, national implementation and policies (i.e. Chapotin & Wolt 2007; Schmid, Padel & Levidow 2012; Carlson 2007). Nevertheless there is little research on how companies of this nature innovate, manage innovations or adopt new technology.

1.3. Objectives and research problems

The key aim of this research is to scrutinize the organizational innovation process and discover the technological innovation adoption and implementation strategies Finnish bio-economy companies have. It is of interest to link together the technology adoption and innovation process and determine the extent to which the innovation process is similar whether the idea or technology is internally or externally developed. Furthermore it is expected to understand how organizations gather, evaluate and process both external and internal ideas and how large and small companies' processes differ. This research is conducted for VTT technical research center of Finland and is part of a larger Tekes-funded large strategic opening for synthetic biology. The main focus is on disruptive innovations and although the approach is theoretical, the hope is to discover information which could help approach companies with new disruptive technology: applications in synthetic biology. The technology is new to the market in Finland thus there is very little research on its implementation. In addition to identifying certain innovation adoption strategies, this research thrives to determine to what extent the technology companies at hand see synthetic biology as an opportunity and whether they could potentially utilize it in the future. Moreover it is important to identify the challenges and future prospective of the new technology and its adoption.

These factors lead to the main research question:

"How do Finnish bio-economy companies generate, adopt and process disruptive technology/innovations?"

The main research question as such is so broad it has been further divided into five sub-questions to clarify the main objectives of the thesis:

-How do companies collect, evaluate and generate ideas/innovations?

-How can the technology adoption process be linked to the innovation process?

-How does the nature of the innovation affect the technology adoption and innovation process?

-How does the size of the company affect the technology adoption and innovation process?

-What are the bottlenecks and challenges concerning the technology adoption and innovation process?

The research is conducted by interviewing 12 Finnish bio-economy companies which include both small and large enterprises. A common factor for all of the companies is that they could potentially be able to utilize synthetic biology at some point in the future. One interest of this study is to find a distinction between the small and large enterprises in their way of planning and managing the innovation process and moreover absorbing new innovations.

1.4. Theoretical framework

The theoretical framework expresses the structure and theoretical key concepts of the study (See Figure 1). The model shows how although the technology may be from internal or external sources it goes through the relatively similar innovation process. Certain organizational factors, which this study thrives to determine, affect the discovery of the external and the generation of the internal idea. The framework emphasizes the technology adoption, yet the study aims on determining also the phases for the innovation process thus unifying the two concepts. The organizational technological innovation adoption is influenced by both external and internal factors and may be divided into the initiation and implementation phase. The framework illustrates how technology diffusion and adoption may be seen as the same phenomena, just viewed from different perspectives. To which phase of the innovation process the innovation is adopted depends on the variables which are adoption timing, the readiness of the adopted innovation and the extent to which the innovation needs to be re-invented to fit the organization.

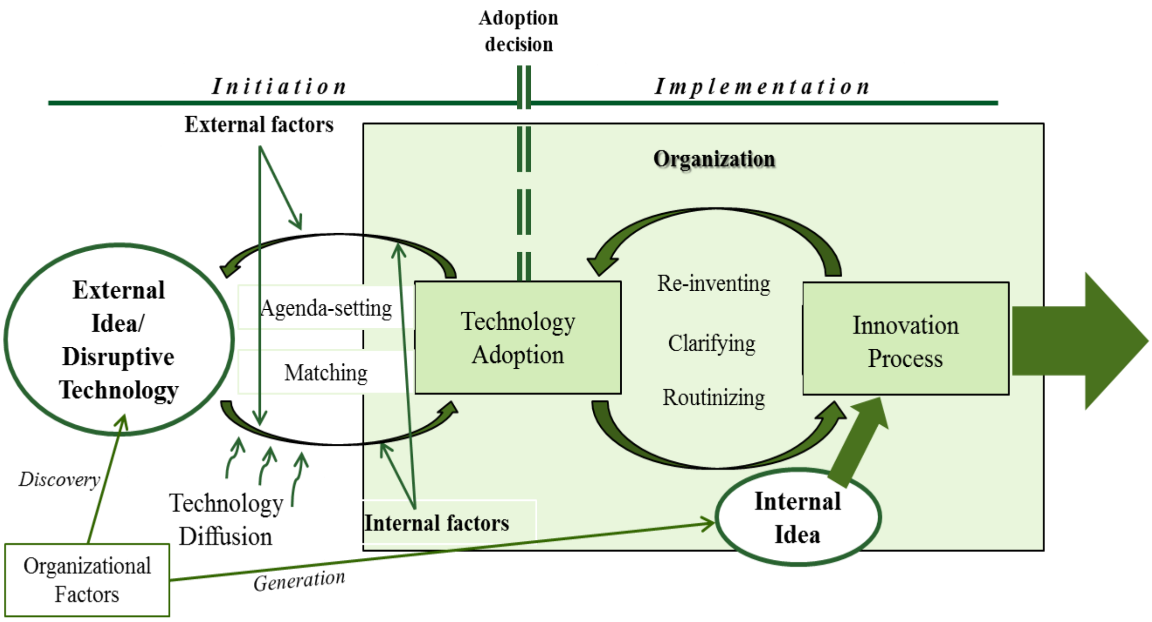

Figure 1. The theoretical framework of the study: The phases of the organizational idea/innovation development when the idea is adopted.

1.5. Key concept definitions

The thesis includes some concepts which may either be commonly unestablished or differ in conceptualizations. Thus the few concepts are shortly defined in this part to help the reader understand what the concepts stand for in this study. The concepts are further opened and discussed in the upcoming parts of the study.

Bio-economy: A generalization to describe companies of which the operations are in some way linked to natural sciences and the used methods are focusing on sustainable solutions; central goals are the reduction of the CO_2 footprint and dependency on fossil-based carbon sources.

Technology adoption: The procedure of individuals/organizations absorbing new technology such as ideas, processes, inventions and innovations to be part of their new functions.

Technology diffusion: The process of new technology spreading into cultures. The diffusion theory explains the rate and time for new technology to spread; the time it takes for a certain group to absorb the technology.

Innovation: A new idea, practice or object that brings added value to the company.

Disruptive innovation: An innovation with the element of radicalness; technology that produces new ways of functioning and even new business fields and customer bases.

Innovation process: A set of actions and phases through which an innovation develops in an organization from an idea to a commercialized product, implemented process or other technology with utility.

Synthetic biology: A branch of biotechnology which uses raw materials to create novel synthetic biological systems.

1.6. Delimitations

This study focuses on the organizational perspective of the innovation process and technology adoption. The research aims on determining the strategies and methods in which technology, both absorbed from the outside and in-house developed are transferred into innovations which bring utility to the organization. The main focus of the study is on disruptive innovations, yet in order to create valid data and possibilities for comparison on the subject, also incremental innovations and innovations without strict segmenting are viewed to some extent. Furthermore it was interpreted disruptive innovations are so rare in companies regardless of size that the research is more thorough if also innovations are discussed also in a more general manner. The utility may either be commercial success or more efficient processes or other enhancements to the company's procedures. In this context the term 'technology' refers to both unprocessed ideas and more ready, actually concrete inventions or processes. Since the thesis focuses on technology, for instance administrative and other innovation types are left out of the examination. Furthermore the individual perspective to technology adoption is left without further scrutinizing in order to create a more unified and compact research.

The essential meaning of this thesis is to create a coherent view of how companies absorb and process innovations. The motivation behind this is to develop knowledge on how the market could be approached with synthetic biology in the future, thus the interviews are limited to twelve bio-economy companies. Furthermore the research is limited to Finnish companies although some of the large organizations have functions also abroad.

1.7. Structure of the thesis

The thesis consists of two main sections, the theoretical and empirical part. The theoretical part is formed of three chapters while the empirical section contains two chapters. The first chapter of the study familiarizes the reader to the subject at hand, first introducing the research background and most important prior literature. After these factors the research problems and theoretical framework are presented. Furthermore the key concepts, delimitations and thesis' structure are discussed.

The second and third chapters introduce the main theoretical construct of the study thus familiarizing the reader with the concepts of innovation and technology adoption. The concepts are scrutinized based on previous literature and most relevant models are introduced to create a coherent view of the subject and tie the theory to the empirical part. The fourth chapter introduces the concept of synthetic biology and discusses the main phenomena on the field. Thereafter the LiF-project of which this thesis is a part of is presented in a short manner.

The fifth chapter begins the empirical part of the study by introducing the research methodology thus explaining in detail how the study has been conducted. The chapter begins with a short insight to qualitative methods after which the data gathering and analysis of this study are discussed in detail.

The sixth chapter introduces and discusses the results of the qualitative research through the themes discussed in the theory. The findings are mirrored through the introduced models and distinctions and similarities are discussed and scrutinized. Finally the final chapter concludes the thesis, summarizes the findings, acknowledges the limitations of the research and brings forward thoughts of further research on the subject.

2. THE NATURE OF DISRUPTIVE INNOVATION

This chapter introduces the concept of innovation at first on a common level after which the subject is scrutinized more thoroughly through the existing models and literature. The distinction between incremental and radical innovations is made and the concept of radical or disruptive innovation is opened and discussed on a deeper level. Thereafter the sources, drivers and challenges of innovation are scrutinized. Finally the conversation moves towards the innovation process and three innovation process models are introduced and discussed: the innovation-decision process, the radical innovation process and the stage-gate model of innovation.

2.1. The concept and definition of innovation

In all its simplicity, an innovation is an element of novelty which adds commercial value (Narvekar & Jain, 2006). Innovation is often defined as “an idea, practice or object that is perceived as new by an individual or other unit of adoption” (Rogers 2003, 12). Innovations may be totally new products or processes, but just as well they may be substitutes, improvements, reorganized production or better support for a given product (Kline & Rosenberg 1986). Innovation enables industrial development, productivity growth and has raised the standard of living through time (Abernathy & Clark 1984). OECD (2010) defines innovation as “an iterative process initiated by the perception of a new market and/or new service opportunity for a technology based invention which leads to the development, production, and marketing aiming at the commercial success of the invention.”

Innovations are often categorized into technical, administrative, process or product depending on their type (Van de Ven 1986). Nevertheless technology is strongly combined to the whole concept of innovation (OECD 2010, 35) and the term “technology” is still often used as a synonym for it (Rogers 2003, 139). Technology may refer to for instance know-how, techniques, patented or otherwise proprietary processes, materials, equipment or systems (Siegel et al. 1995). The value creation through technical innovations does not happen directly, but rather through the changes in functionality, utility or processes (Assink 2006).

The capability to innovate is seen as a requisite for survival in the modern, dynamic, changing and complex markets (Assink 2006). By definition the term innovation possesses the qualities of creating and marketing an element of novelty (Kline & Rosenberg 1986), which crystallizes the two main factors of innovation: commercialization and novelty. Rogers (1962) emphasizes the element of “newness” in determining an innovation; it may be expressed through persuasion, knowledge or the potential decision to adopt. Also Teece (1986) acknowledges newness by characterizing innovations as technical knowledge which exceeds the old state of the art way of doing things. Assink (2006) defines the term as “The process of successfully creating something new that has significant value to the relevant unit of adoption.”

2.2. The nature of innovation

Innovations are seldom well-behaved, simple or linear, but rather complex, disorderly and difficult to measure and manage (Kline & Rosenberg 1986). Schön (1967) was one of the first researchers to acknowledge the important distinction between an innovation and invention. Most commonly in research the clearest difference between the two concepts is the commercialization aspect: an innovation is an invention with proven market demand and success. Inventions and creative ideas must be implemented or institutionalized in order to become innovations. (Van de Ven 1986) Rogers (2003) noted that there is at times a difficulty in cutting a line between the two terms, for the innovation changes as it diffuses through the social system. He therefore suggested the use of the term “re-invention”, which refers to the actions the absorber goes through in adopting and implementing the innovation. (Rogers 2003, 180-181)

An innovation provides economic value and is successfully diffused outside the organization it has been developed in (Garcia & Calantone 2002). Innovation may be seen as the key competitive advantage in the uncertain and fast paced markets (Assink 2006). Horn (2005) describes innovation to be “introducing” combined with “inventing” – the key is in bringing new ideas to the market place and driving through new ways of handling matters. Therefore innovation is closely tied with the concept of change of which the extent is defined by the innovation’s nature or in other words, level of destructiveness (Abernathy & Clark 1984). Successful outcomes require the management of both the commercial and technological areas (Kline & Rosenberg 1986).

Innovations behave in different ways: some refine and improve while others disrupt, destroy and create new markets and competence (Abernathy & Clark 1984). There is no single dimensionality for innovation but rather several dimensions covering a variety of activities (Kline & Rosenberg 1986). Thus innovations are divided into groups depending on their nature. Commonly the categorization is made between radical and incremental innovations, but Green, Gavin and Aiman-Smith (1995) argue innovations should not be so strictly classified due to the restriction of the radicalness construct it produces. Christensen (1997) added the categories of disruptive and its opposite sustaining or in other words revolutionary and evolutionary to the innovation research. It is said disruptive and sustaining innovations describe the performance and market-related parameters while radical and incremental characterize the improvement and change in technology or other factors. Garcia and Calantone (2001) added the concept of ‘really new’ into the mix. They categorized the innovations based on the amount of marketing and technological discontinuities both on macro and micro level. Radical innovations cause both marketing and technological discontinuities on both macro and micro level whereas incremental innovations are seen to cause either marketing or technological discontinuities on only the micro level. Really new innovations are a combination of these two extremes.

In the effort to map together and visualize the terminology of the innovation literature, Thomond and Lettice (2002) developed a framework (See Figure 2). The framework visualizes how market uncertainty and environmental turbulence are the key determinants in categorizing innovations and furthermore, how the terms function together. When market uncertainty and environmental turbulence are high, the mainstream value networks and new business models are altered; revolutionary, competences destroying disruptive innovations are born. Conversely, while these elements are low, business models are improved and mainstream value networks maintained. This characterizes evolutionary, incremental innovations.

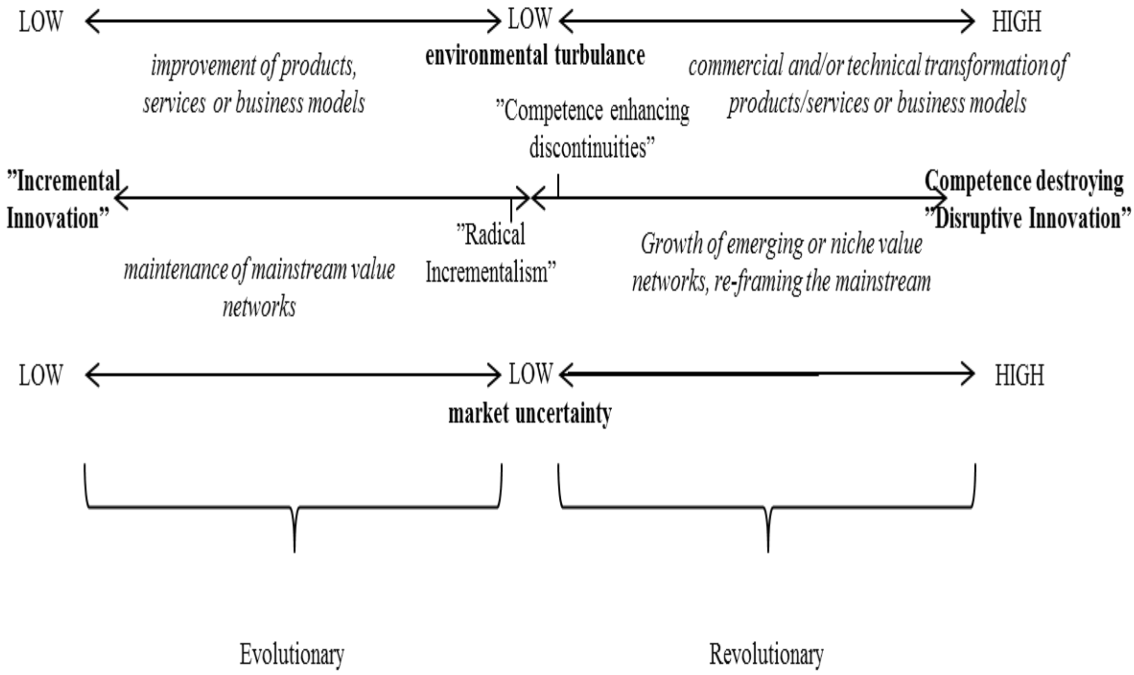

Figure 2. The Innovation Continuum. (Thomond & Lettice 2002)

While it is generally clear there is a distinction between innovation types, researchers often collide with the missing consistency in defining the nature of innovations. The innovation types lack a standardized definition which leads to problems with the terms overlapping and implying different matters depending on the individual or organization communicating. (Garcia & Calantone 2002) Abernathy and Clark (1984) categorize innovations based on their capacity to influence the established systems of marketing and production in order to visualize their competitive significance (See Figure 3). The four given categories are regular, niche creation, architectural and revolutionary innovations. Both the architectural and revolutionary innovations disrupt existing competence. Nevertheless, architectural innovations are considered even more modifying, for they disrupt existing and create new markets, while revolutionary innovations disrupt and render in the existing ones. Still the competitive impact is strictly tied with the innovation’s ability to meet the market needs; the market success is the crucial measure for even the most unique and unduplicative innovation.

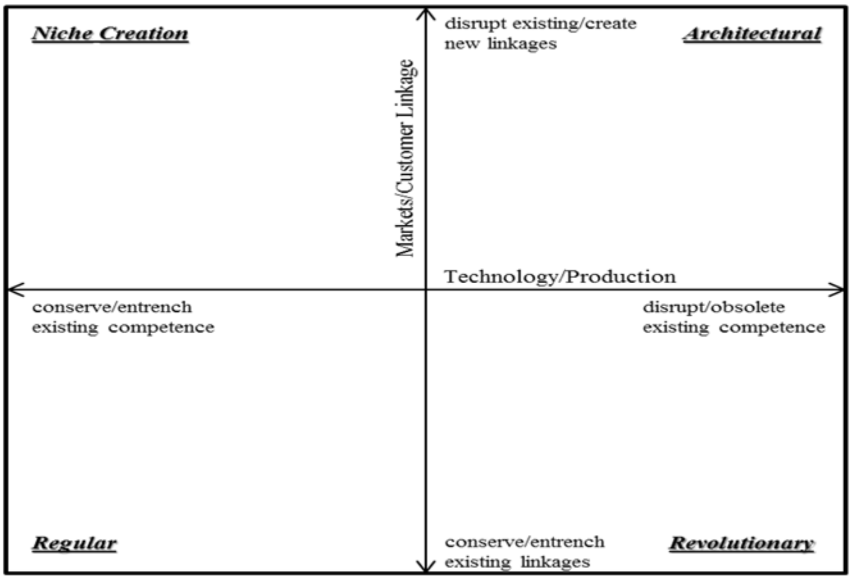

Figure 3. The map of Transilience. Adapted from Abernathy & Clark (1984)

On the other side of the diagram are the niche creation and regular innovations. Regular innovations may be the most invisible but nonetheless significant in cutting product costs and enhancing performance. They often develop through existing innovation processes, are less risky and easier to plan. These innovations may but enhance competence in production, also strengthen linkages to the markets and customers. Continuous improvements and quality management such as performance improvement or product differentiation typically lead to this kind of innovation (Boutellier & Heinzen 2014, 151-152). The niche creation innovations on the other hand open new market opportunities by utilizing existing technology. The existing technology is refined, improved or otherwise changed to a form which supports and improves its applicability in old and new market segments. (Abernathy & Clark 1984)

2.3. Radical and disruptive innovations

The dear child has many names. The literature reveals terms such as “disruptive”, “radical”, “non-linear”, “discontinuous”, “breakthrough”, “paradigm-shifting” and “revolutionary” all to be used to describe the opposite of a sustaining innovation (Thomond & Lettice 2002). Yet according to Yu and Hang (2009) disruptive should not be mixed or used as a synonym with destructive, for not all radical innovations destruct the existing markets, business models or technology. Nevertheless Thomond & Lettice (2002) described disruptive innovation as “A successfully exploited product, service or business model that significantly transforms the demand and needs of an existing market and disrupts its former key players". Also Assink (2006) defined disruptive innovation as "successfully exploited radical new product, process or concept that significantly transforms the demand and needs of an existing market or industry, disrupts its former key players and creates new business practices or markets". As is clear from the given definitions, what combines most of the previous innovation literature is the certain challenges in categorizing innovations, for there are no commonly accepted definitions or measures. This is particularly clear when discussing radical, disruptive and destructive innovations, which are, depending on the author, synonyms or have a different nuance.

Christensen (1997) first introduced the theory of disruptive technology focusing on technological innovations and how they come to surpass other previously superior technologies and hence dominate the markets. Christensen's definition of disruptive innovation has received critique in the way it groups disruptive technological, business-model and product innovations together. Markides (2006) argues whilst all of them being disruptive innovations, they produce versatile challenges to companies and management and thus should not be handled as one.

Green et al. (1995) determine radical innovations through four dimensions of radicalness which are technological uncertainty, business inexperience, technical inexperience and technology cost. Govindarajan and Kopalle (2006) also give four qualities for disruptive innovations. According to their research, disruptive innovations should (1) be inferior to the mainstream's attributes, (2) offer new value propositions to attract new customer segments, (3) be sold with a lower price and finally (4) penetrate the market from niche to mainstream. It is seen that the radicalness of an innovation is not an objective measure, but rather depends on the innovating company's qualities concerning the mentioned four dimensions (Green et al. 1995). Also Yu and Hang (2009) argue that disruption is a relative phenomenon depending on the adopting company. Furthermore the innovation project management and encountered challenges vary depending on whether the accessed market is new or requires development (McDermott & O'Connor 2002).

Radical innovations are associated with greater change in organizations through their business and technical knowledge demand (Green et al. 1995); they disrupt and destroy by imposing requirements that existing resources and skills satisfy poorly (Abernathy & Clark 1984). Radical innovations are risky due to the uncertainty combined in moving to new undeveloped knowledge areas (Green et al. 1995). Disruptive innovations are deep, extensive and create new industries while simultaneously making former technology useless (Abernathy & Clark 1984). However it should be acknowledged that although radical innovation is different from routine or incremental innovation, it is not necessarily better (Boutellier & Heinzen 2014, 153).

McDermott and O’Connor (2002) discuss the importance of different management styles according to the level of radicalness of the innovation. While incremental innovations do not necessarily require significant changes in action from the management, radical innovations demand strong, persistent individuals as drivers of the process. These individuals are described but by depth of experience, also breadth. The management studies concerning disruptive innovations have proven that the incompetence of managers may often be the main obstacle to disruptive innovations on the verge of breakthrough (Yu & Hang 2009). Also Stringer (2000) sees the management’s lack of courage and culture based on control rather than trust an issue for the breakthrough of innovations. Abernathy and Clark (1984) emphasize how companies may simultaneously have to manage product lines with innovations of versatile nature although they have a certain dominant orientation. Therefore they also emphasize the importance of different kinds of organizational and managerial skills for the successful management of versatile innovations. Also Christensen and Overdorf (2000) recognize the managers’ potential haste to adopt new disruptive businesses due to old models working effortlessly. Nevertheless they suggest managers must function two product lines in tandem; the other focusing on the existing while the new is gearing towards adopting the new model.

2.4. The drivers and sources of innovation

Schumpeter (1950) formed the term “creative destruction” to characterize the procedure in capitalistic markets of new inventions destroying the old economic structure from within and continually creating new ones. Capitalism consists of change, which has been falsely interpreted by mainstream economics. According to the author's theory some systems, which have utilized all their possibilities to the greatest may be overcome in the long run by inferior systems that never do so. This, he states is a condition of the new system's level or speed of the long-run performance. (Schumpeter 1950, 81-85)

The importance of research in the innovation process is often stressed and defined as the ground for successful innovation. It is also the first stage of the generally accepted linear model of innovation, of which the inventor is rarely documented. Although the importance of research should not be underestimated, Kline & Rosenberg (1986) argue that most innovations stem from already existing and available knowledge in the heads of individuals. Especially radical innovations could be characterized as a novel mixture of slightly adapted, existing knowledge (Boutellier & Heinzen 2014, 154). It is common for companies to base their launch of radical new projects and processes on already existing internal market and technological knowledge. (McDermott & O'Connor 2002) The main driver for some innovations especially relating to cost-cutting may be necessity, but it is a weak justification for handling uncertainty and risks (Boutellier & Heinzen 2014, 158). However, disruptive opportunities are often outside the company's current market base and technology (Assink 2006).

To a smaller extent, another important source of innovation is the other accessible information in the company. The main discovery in this acknowledgement is that a significant amount of innovations are not initiated by research. In other words important, although often more incremental, innovations have been created even when the science is inadequate or lacking. (Kline & Rosenberg 1986) Even though new-product innovations are often emphasized, from the commercial perspective process and incremental innovations may have equal or even greater importance (Abernathy & Utterback 1978).

Boutelier and Hendsen (2014) identify four forces to drive innovation (see Figure 4). These forces are *lower costs, improved performance, new performance features and new competitive basis*. Often the first two forces are associated with incremental or "routine" innovations, whereas the latter two commonly describe radical innovation. Nevertheless radical innovations may also be based on the first mentioned drivers. The chart (see Figure 4) demonstrates how the market uncertainty and risk grows exponentially the more radical the innovation's aspects are.

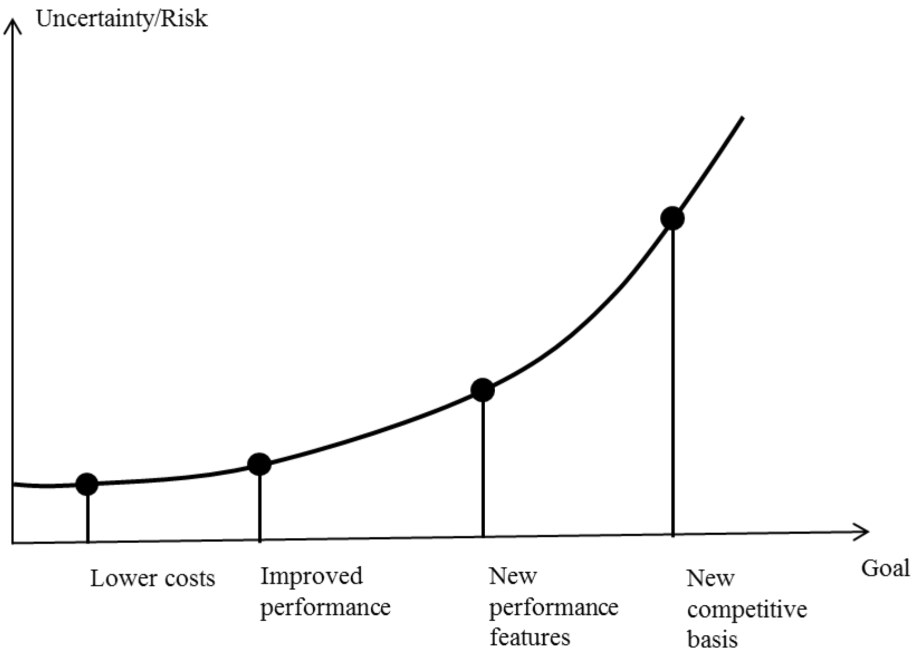

Figure 4. Drivers of radical and incremental innovations. (Boutellier & Hendsen 2014, 157)

Schumpeter (1950) stated that the key stimulus to entrepreneurial activity is relative, rather than absolute, size or market power. New industries often possess more new product innovations than matured industries. In new industries entry is high, market shares change rapidly and companies compete with a versatile selection of diversifications of the industry's product. When the industries mature, exit overtakes entry, the amount of producers decreases and increasing value is put on enhancing the production process; the market stabilizes and the companies do not have the similar need to innovate radically. (Klepper 1996) Furthermore the previous research shows that it is commonly found that large companies are responsible for a more significant amount of inventive activity and thus introduce a larger relative percentage of innovations than small companies (Mueller & Tilton, 1969). According to Abernathy & Utterback (1978), also certain natures of innovation are often typical for certain industries. When the company produces established, high-volume products such as paper, steel or standard chemicals to a well-defined market, the innovations are often incremental. This is due to the typically low profit margins of the products combined with price-based competition; there is not financially much room for uncertainty and these highly integrated systems imply costly alteration.

Major innovations seldom appear from large companies' R&D laboratories (Mueller & Tilton 1969). Christensen and Overdorf (2000) state industry leaders are more likely to produce sustaining than disruptive innovations in order to provide their existing customers with incremental yet on the other hand risk minimized elements of newness. Disruptive innovations are not as attractive to a company's best customers and furthermore most often offer a lower profit margin per unit sold. Industry leaders are organized for incremental innovation and thus often surrender growth markets to smaller, disruptive companies with fewer resources but better capability to proceed in a more turbulent environment. These qualities include the possibility for more dynamic and intuitive managerial decisions and cost structures that can manage low margins. Large risks in development also require decisions from the higher level management, which is in bigger companies often far away from the R&D laboratories to see the potential of potentially disruptive ideas (Mueller & Tilton 1969).

Smaller, more easily adaptable organizations that possess a flexible technical approach are more likely to manage the uncertainty and diversity of new products (Abernathy & Utterback 1978). Moreover, entrants have less to lose and may be faced with the reality that disruptive technology may be the only way to gain a foothold in the markets (Danneels 2004). Also Tushman and Anderson (1986) found that new companies are more likely to produce competence-destroying technological discontinuities while existing firms focus on competence-enhancing discontinuities. The most radical technological innovations commonly stem from R&D projects which are absorbed to and developed in internal ventures and finally change the corporate strategic focus of the firm (Abetti 2000) Christensen and Bower (1996) claim disruptive innovations are most likely to stem from frustrated engineering teams coming from established companies. One way for incumbents to prevent this brain drain of talents would be to establish spin-offs. Nevertheless, Yu and Hang (2009) note that disruptive innovation does not always mean that the entrant completely replaces the incumbents business and the winner takes it all.

When discussing successful technology implementation and innovation success, the role of a champion inside an organization is often emphasized in the literature (i.e. Schön 1963; Rothwell et al. 1974; Burgelman 1983; Ettlie, Bridges & O'Keefe 1984; Howell & Higgins 1990). A champion is an energetic and driven individual inside the organization who makes "a decisive contribution to the innovation by actively and enthusiastically promoting its progress through the critical stages" (Achilladelis, Jervis & Robertson 1971: 14) Schön (1963) was the one to first identify the importance of a champion and find the role a crucial success factor for taking through new ideas inside organizations. Champions are most often innovative and risk-taking, which is often associated with an entrepreneurial mind-set. These characteristics imply that some individuals are more likely to emerge as champions than others. The champion's capacity is based on the skills to articulate a compelling vision to the organization, get others to participate effectively in the initiative and display innovative actions to achieve goals. (Howell & Higgins 1990)

2.5 The innovation-decision process model

The development of technology and economy has led to trends modifying the innovation process models through time. This has derived to the need of diverse innovations in different time periods. (Elite 2006, 24-25) The concept of innovation is a continuously researched, popular and important subject, mainly due to the developments in competition, globalization and technology (McAdam 2005). Porter (1990) argues that a company which stops improving and innovating will inevitably be overtaken by competitors. Technology develops and changes rapidly which may be seen as a challenge for technological companies (Narvekar & Jain 2006). Rothwell (1994) divides the innovation processes into five generations beginning from the 1950's putting emphasis on the societal and economical happenings on each decade. The early innovation models were linear whereas later, more emphasis was put on the market-pull technology-push concept (Narvekar & Jain, 2006)

The model introduced in this section (see Figure 5) was first developed by Rogers in the year 1962 and it is one of the most traditional theories in the field. As previously mentioned, the early innovation process models were linear.

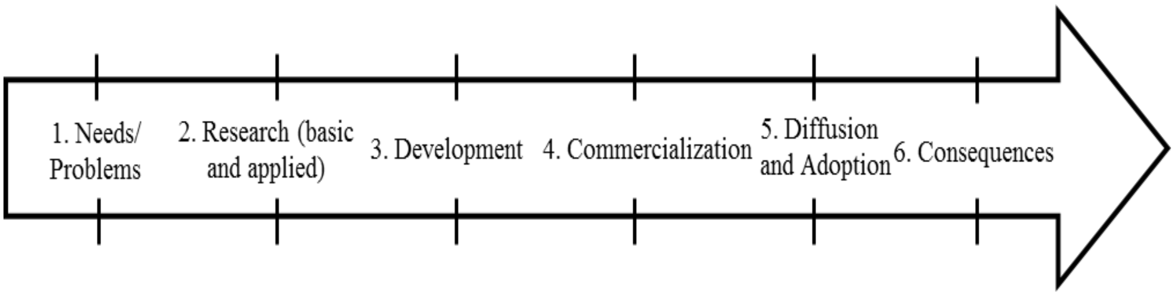

Figure 5. Six main stages of the Innovation-Decision Process. (Rogers 2003, 138)

The innovation-development process describes the whole set of actions a company goes through when producing an innovation; from the recognition of a need or problem, to the consequences of the innovation. It is important to acknowledge that the stages do not always occur in this particular order and in some scenarios certain stages may be skipped. In addition, not all innovations arise through research and development. (Rogers 2003, 138-139)

The first stage of the process is the recognition of a problem or need. The significance of defining the customers’ needs and listening to them is often emphasized in literature and studies (i.e. Pulkkinen 2002; Simula et al. 2009; Hjelt et al. 2006). The recognition of problems and needs often stimulate the beginning of research activities or in other words, recognition activates the innovation process. The second stage is basic and applied research. Basic research refers to original investigations that do not have part in any particular problem solving. Applied research on the other hand is initiated for some specified reason. (Rogers 2003, 137-140) According to the current innovation research, the difference between basic research and applied research is often hard to identify from the innovation function perspective (Hjelt et al. 2006, 5). Rogers (2003) claims that an invention is often a result of a sequence of basic research, followed by applied research and leading to development.

In this model, research and development have been separated for it is argued that research always precedes development in the innovation-development process. Therefore they may at least conceptually be considered as different phases. The third stage, development, is the processing of the idea into a form in which it is thought to attract possible adopters. The ability to control product development speed is generally an important core competence, for being timely and fast compared to competitors is most often seen advantageous from the profitability point of view (Rothwell 1994, 13). Commercialization follows this stage. It is the conversion of an idea into the form of a product or service in order to be sold at a marketplace (Rogers 2003, 146-152). Chiesa and Frattini (2011) claim that commercialization is the most critical stage of the technological innovation process mainly due to the high risks and costs required.

The fifth stage in the model is diffusion and adoption. Diffusion is a special type of communication process in which a specific innovation is transmitted through certain channels to the members of a social system in a certain time period. The point at which the innovation is diffused to possible adopters is according to Rogers (2003) one of the most crucial parts of the whole process. There is often pressure to diffuse as soon as possible, whereas in some cases it is more efficient to wait and not rush in the process. The final phase of the process is the consequences of an innovation. These are the changes that individuals or social systems discover or go through after the adoption or rejection of the new innovation. (Rogers 2003, 152-157)

2.6. The disruptive innovation process model

Assink (2006) developed a conceptual model to describe the dynamic disruptive innovation process (See Figure 6). Although the model is based on the four basic development steps of innovation (identify – develop – plan – implement) it strives to characterize the complexity and interactivity of the process. The earlier innovation process models did not put emphasis on the communication happening inside the organization. Rather than being linear, it is seen that the disruptive innovation process is closer to a “spiral or circular development process of continuous fast feed-forward and feed-back loops”. The model emphasizes interaction in all of the phases, acknowledging also the way information flows backward in the process. The internal factors such as resources, competencies and strategy are seen to influence the problem identification while the external factors such as competition and customers affect the implementation of the innovation to the markets.

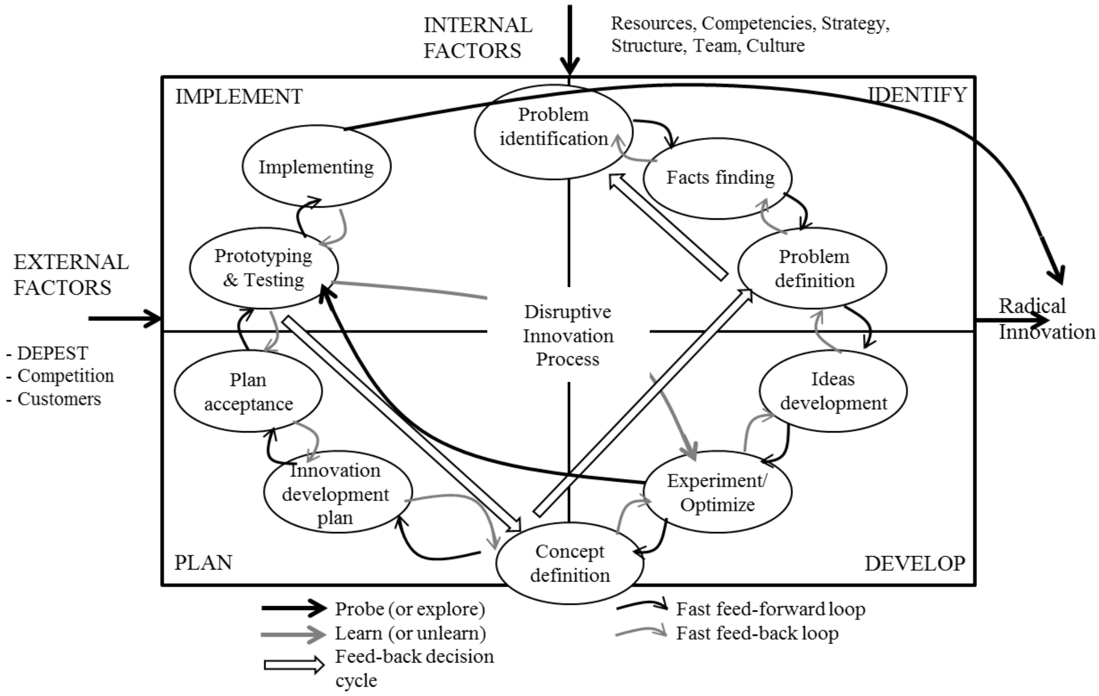

Figure 6. The dynamic disruptive innovation process model. (Adapted from Assink 2006)

2.7. The stage-gate model of innovation

The stage-gate model of innovation is one created by Cooper (1990) to describe the organizational innovation process (See Figure 6). The model is characterized as "both a conceptual and an operational model for moving a new product from idea to launch", which separates it from the other given models in its less academic and theoretical approach. The model is based on the perception that innovation can and should be managed as a process similarly to any other. Hence the system merely combines process-management methodologies with the innovation process.

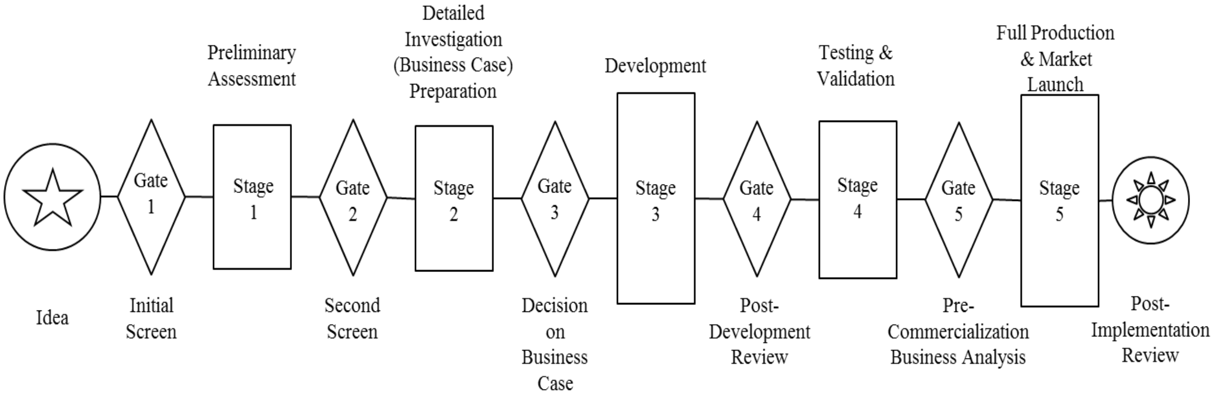

Figure 7. The Stage-Gate model of innovation. (Cooper 1990)

The basic principle of the model is that the innovation process is divided into a certain amount of stages or workstations and gates or quality checkpoints. The idea proceeds through the workstations and in order to qualify for the next stage, it must fill the certain criteria set for each gate. The outputs at each gate are most often clear Go/Kill/Hold/Recycle –decisions based on objective measures. The gates are monitored by senior managers who decide on both the decision of going forward and the future action plan. Furthermore the project requires a team and a project leader, who drives the projects through the stages. (Cooper 1990)

Cooper (i.e. 2008) has further developed the Stage-Gate model to match the constantly developing markets and trends. The newest development of the model acknowledges the concept of open innovation thus recognizing the possibility of idea collection from the outside throughout the process. The term open innovation refers to the innovation process moving from strictly in-house procedures to utilizing outer facets in the phases of the process from idea creation to commercialization; the concept is based on the point that not all knowledge lies within one organization (Chesbrough & Crowther 2006). Controversially, the open innovation Stage-Gate model focuses on transparency during the course of the whole process from ideation to development and finally commercialization thus focusing on the possibility of information exchange throughout. One aspect to the open innovation process is that the knowledge flows not only inside the company, but also to the outside in a controlled manner through for instance out-licensing. In the ideation stage organizations focus not only on finding solutions to external needs, but also on seeking ideas and technologies from other facets and perhaps finding partners for joint development. In the development stage the openness of the process is reflected by the possibility of seeking external sources to solve technology problems or out-licensing technologies not seen as core competence for the company. In the final stage the company may sell or out-license or controversially in-license ready technologies. (Cooper 2008)

2.8. Challenges concerning disruptive innovation

Due to their nature, disruptive innovations hold within an element of uncertainty, which results as difficulties in predicting monetary return on investment. This may pose as a barrier to innovation for companies. (Harper & Becker 2004) Neely and

Hill (1999) list factors such as high and difficult to manage innovation costs, long pay-back time, fear of imitation, lack of adequate financial resources and high-risk expectation as inhibitors for innovation activities. Both Kline & Rosenberg (1986) and Chiesa & Frattini (2011) continue in the same theme pointing out the high development costs of high technology products or processes. These factors raise the financial risk involved, which may be seen as a threat for a company's ability to overtake future innovation processes. The development costs correlate with the development time, which in high technology is often very long. (Kline & Rosenberg 1986) Bianchi et al. (2011) found the keep-or-sell decision and its timing to be very risky and challenging especially for large companies; improper exploitation could be harmful. Other challenges concerned for instance the choice of partners, potential revenue and control of the process.

3. INNOVATION ADOPTION AND DIFFUSION

This chapter introduces the terms of technology adoption and diffusion and further clarifies the difference between the terms. Thereafter the concept of innovativeness is scrutinized through the innovation adoption timing model. The methods of innovation adoption and the important factors concerning the choice of adoption are further discussed. Finally an innovation adoption model is introduced and the topic of when an innovation is successfully adopted to an organization is scrutinized.

3.1. The relationship between diffusion and adoption

New technologies are spread and on the other hand accepted by individuals and organizations because they solve problems and thus create the feeling of perceived utility (Boutellier & Heinzen 2014, 59). Diffusion is characterized as the process of an innovation being spread by communication through versatile chosen channels over time among individuals in a social system. The important elements of determining diffusion are *innovation*, *communication through channels*, the *time period* and the *social system*. (Rogers 2003, 23-24) Typically the diffusion models consist of sequential adoption and implementation stages (Lyytinen & Damsgaard 2001). Innovation adoption, on the other hand, is looking at the phenomenon from the absorbers perspective; how is the innovation adopted by the social system? Most innovations follow the S-shaped curve of rate of adoption, which refers to innovations at first diffusing to the innovators, later to the larger population and finally reaching its maturity stage and being overcome by the next innovation (see Figure 8).

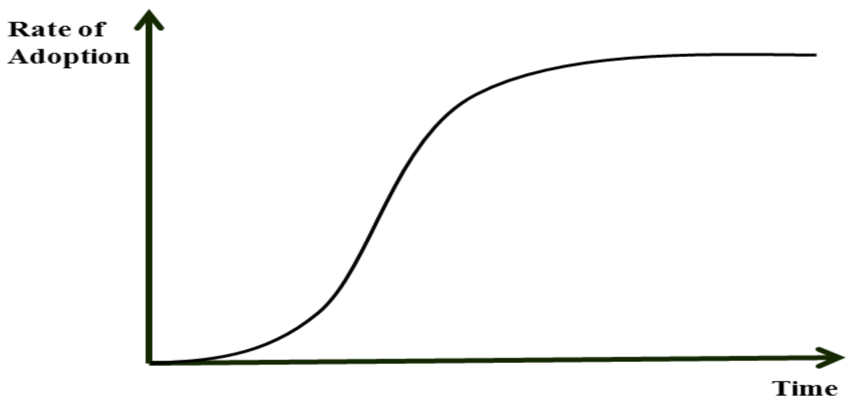

Figure 8. The S-curve. (Adapted from Rogers 1983, 11)

The slope of the S-curve varies according to the innovation and its rate of adoption – some innovations diffuse significantly faster than others. (Rogers 2003, 23-38) This study focuses on innovation adoption thus studying the organizations that absorb the new technology.

3.2. Innovation adoption

The studies on innovation adoption and diffusion have commonly concentrated on how innovations are communicated to individuals through a social system rather than the organizational adoption perspective (Rogers & Eveland 1978). Consumer innovation adoption has been the main perspective for the adoption and diffusion studies in the late 1960s and early 1970s, when a large number of studies were conducted on the subject (i.e. Robertson 1971; Rogers 1976; Ostlund 1974). Nevertheless in order to be adopted by individuals, innovations must often be first adopted by organizations (Damanpour & Evan 1984). Since innovation is a complex and disorderly construct, its adoption is affected by several individual, organizational and contextual factors (Damanpour, Szabat & Evan 1989). The oldest diffusion theory research has focused on innovation adoption as an act of imitation of how the innovation has been used by earlier adopters. Through the years diffusion researchers have discovered that in fact the adopter should not be considered only as passive but surprisingly often as an active modifier of the idea. This act is defined as “re-inventing”, which refers in other words to the adopter’s way of moulding the innovation as it is adopted and implemented. Most often the re-inventing happens in the implementation stage of the innovation. Correspondingly it was previously thought that an adopting organization would merely absorb the technological innovation from an external source and implement it to its processes. This would imply that the innovation would behave similarly independent from the company it is adopted to. Re-invention is likely to occur in situations such as when the absorbed innovation is complex, the absorber does not have sufficient knowledge or understanding of the innovation, the innovation is a general tool or concept or if the innovation must be adapted to fit the structure of the organization. (Rogers 2003, 180-183)

3.3. Innovation adoption timing

While adopting innovations most often indirectly increases a company's profit flow, it is more costly for companies to adopt the newer the innovation is (Fudenberg & Tirole 1985). Rogers (1983) categorizes innovation adopters through their level of innovativeness (See Figure 9). The six groups of innovation adopters are: *innovators, early adopters, early majority, late majority and laggards*. The first two groups are called the visionaries while the rest are characterized as the optimizers. The curve of the model is the regular "bell-shaped" distribution curve, which if changed into scrutinizing the cumulative amount of adopters would resemble the S-shaped curve. Innovativeness is a relative concept which describes an individual's or other facet's timing to adopt an innovation in a social system. The adopter types are conceptualizations and cannot in reality be grouped so tightly. Furthermore innovativeness is a continuous variable and the lines between the different adopter categories are thus difficult to form in reality.

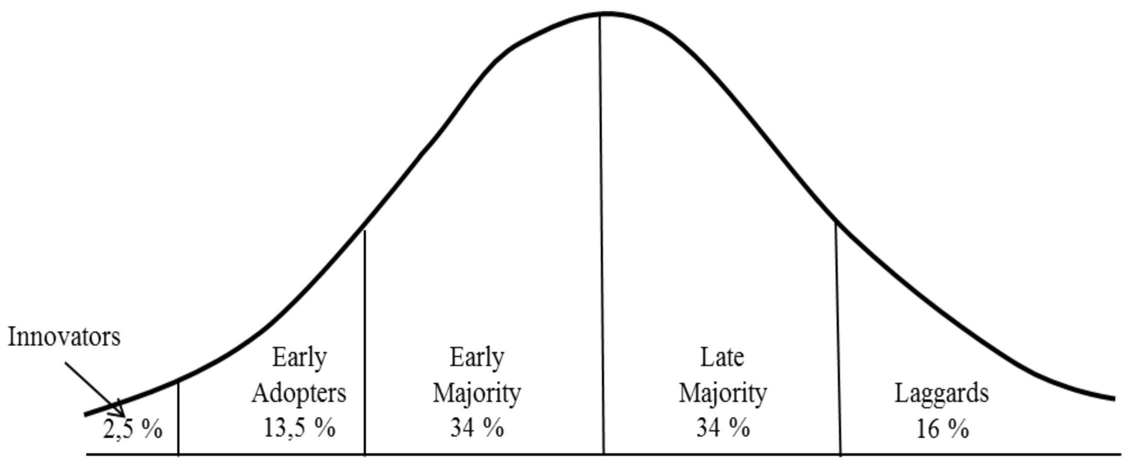

Figure 9. Innovation adopter categorization on the basis of innovativeness. (Rogers 1983, 247)

Innovators are the rarest category of adopters; they represent the venturesome individuals or organizations who are almost obsessed about finding and trying new ideas. The innovators bare the largest risk concerning innovation adoption due to the uncertainty and newness aspects; the risk may be divided into implementation, financial and operational risk (Frambach & Schillewärt 2002). Innovators must be able to both cope with the uncertainty of new innovations and also possess the financial resources to manage if the innovation would not succeed. The innovator plays the role of introducing the new innovation to a larger crowd of absorbers and may hence be thought of as the gatekeeper of the social system. (Rogers 1983, 246-248)

The next adopter group, early adopters, represent a more integrated group of the social system than the previously mentioned. This group is sought opinions from regarding the innovation adoption. Furthermore the early adopters are close to the largest categories of adopters and thus their actions and adoption decisions are followed with interest. (Rogers 1983, 248-249) Boutellier and Heinzen (2014) argue that innovators and early adopters are most often small and medium enterprises in which the owner makes the decision and bears the risk thus not needing several employees to calculate payback time. Owners of SME's are said to be chance takers who do not need to justify their decisions concerning the adoption decision to financial analysts. This, however contradicts with Rogers's (1983) research, which generalizes earlier adopters to have larger sized units than later adopters.

Between the early adopters and the early majority there is at times a decrease in sales called 'the chasm' (see Moore 1998). The chasm is a consequence of moving from small to big markets which results from the overlay between the early and late markets (Boutellier & Heinzen 2014, 65; Easingwood & Harrington 2002). The other of the two largest groups, the early majority, adopts the innovation just a bit before the average adopter. This group is relatively slower in the adoption decision than the visionaries and furthermore is not as willing to bare risks. Nevertheless this group is eager to adopt innovations but does not want to take the lead. The next group of adopters differs from this group in the sense that they do not possess such a desire to adopt new innovations. The late majority makes the decision to adopt when the social system's norms truly favour the innovation and often need persuasion in order to make the decision. (Rogers 1983, 249-250)

The final group, laggards, represents a group which adopts ideas last; often at the point when there are also newer innovations which the innovators have adopted. This group has relatively traditional values, are suspicious of change and innovations and moreover reflect to the past when asked to make decisions. This grouping has been criticized from its naming, for "laggard" has a relatively negative distinction to it. Nevertheless it was seen regardless what the given name were, it would begin to possess a negative vibe. (Rogers 1983, 250-251) According to Boutellier and Heinzen (2014) the optimizers are most often large companies which want predictability and stable products with a decent service.

In their research Fudenberg and Tirole (1985) found that the adoption timing has also a lot to do with external factors, especially the competitors and the knowledge of their movements. Furthermore it was found that different variables affect the early and late adopter; organizations that adopt at an early phase put most emphasis on the internal drivers such as the firm’s attitude towards the innovation and its strategic importance. Other influencers were external forces such as the parent company, industry competitiveness and supplier activities. (Waarts et al. 2002) This is to say, if the competitor’s adoption dates are fixed and known to the company, it will adopt pre-emptively to prevent or delay the rival’s adoption. Moreover, the choice of market affects the adoption timing; if the market is new and moving first may prove profitable, companies are more likely to adopt earlier. (Fudenberg & Tirole 1985) For the later adopter more practical factors such as implementation issues and the standard available budget seem to have a greater influence. Infrastructure compatibility and supply-side activities were the only two factors found to affect both early and late adoption. (Waarts et al. 2002)

Rogers’s model (see Figure 9) is popular and widely recognized even though it has been criticized for its lack of predictive validity and guidelines for marketing strategy. Rogers uses innovativeness as the categorizing factor, whereas research has proven that there are no consistent links between innovativeness and other personality characteristics. Furthermore it is claimed innovativeness is not a general personality trait but rather that individuals are innovative in some areas and laggards in others. Another critiqued area of Rogers’s model is that it does not give the marketer tools to predict who the innovators in the field are and thus provides predominantly a theoretical tool with limited utilization possibilities. (Wright & Charlett 1995)

3.4. Factors influencing the rate of innovation adoption

There are several variables affecting the innovation adoption decision. According to Waarts, Everdingen and Hillegersberg (2002), factors such as the innovation’s characteristics, the company and the internal and external environment all influence the decision to adopt. Damanpour (1987) conversely determines the levels as individual, organizational and environmental. Frambach and Schillewärt (2002) sum the factors which affect the decision to adopt innovations into one conceptual framework (See Figure 10). They found that suppliers and social networks affect the way the organization perceives the innovation's characteristics, which together with the adopting organization's characteristics are the main influencers of the decision to adopt. The environmental influences are seen to affect both the perceived innovation characteristics and the decision to adopt.

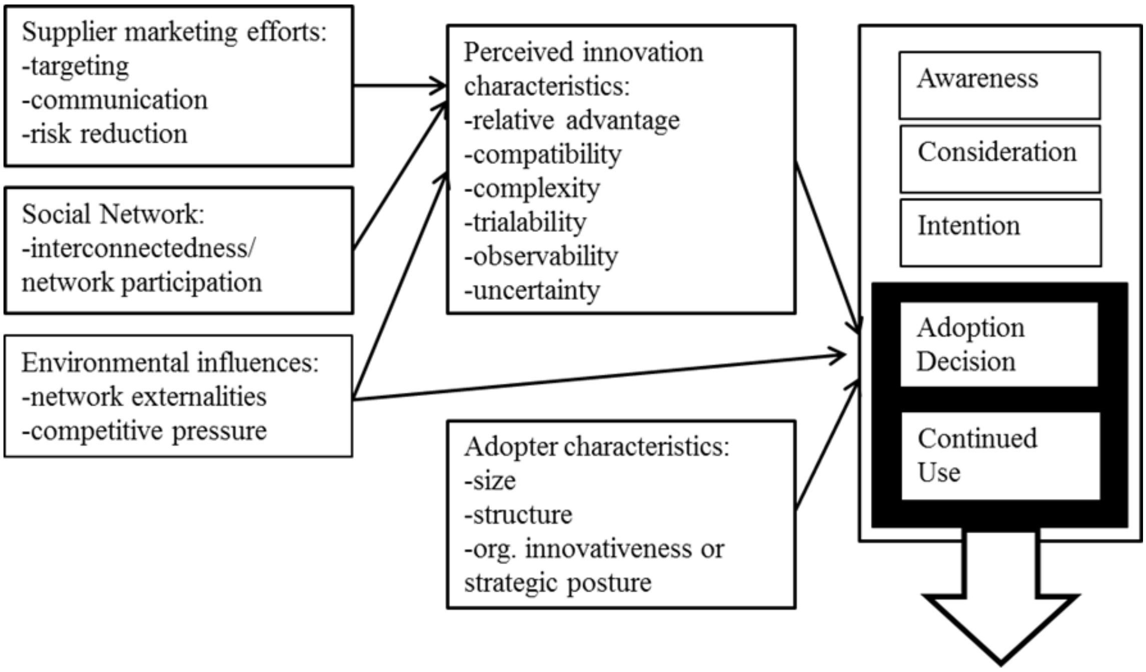

Figure 10. Factors affecting innovation adoption. (Frambach & Schillewärt 2002)

3.4.1. Supplier marketing efforts, social network and environmental influences

Marketing actions of the supplier, especially targeting, communication and perceived actions towards risk reduction affect the way in which the innovation is viewed by the adopter (Easingwood & Beard 1989). Carefully chosen and targeted organizations are often more receptive towards the innovation than a more loosely identified crowd. Furthermore the communication actions of the supplier and decreasing the innovation's early adoption risks for the adopter both influence the way the adopter perceives the innovation. (Frambach & Schillewärt 2002)

Interconnectedness influences the way the innovation is perceived due to the social network system; when the adoption rate passes a certain threshold, the self-generated network pressure towards adopting the innovation increases (Rogers 1983, 235). In addition to competitive pressure and interconnectedness, technology adoption decisions in the organization’s business environment may positively affect the adoption decision; a company is more likely to adopt a new technology if a partner has adopted it. Moreover members of an organization that are interactive both inside and outside the organization facilitate the spreading of information concerning innovations (Frambach & Schillewärt 2002). Controversially it may be seen that until the organization has a certain minimum level of peer influence and information about the adoptable technology, they are less likely to adopt. The higher the level of innovation sharing is, the more likely organizations are exposed to new ideas and innovations. (Rogers 1983, 235-236) Competitiveness is seen to influence positively the decision to adopt; in highly competitive markets adopting innovations is a way to stay on top of the competition or on the contrary, the decision to not adopt may result in competitive disadvantage (Frambach & Schillewärt 2002).

3.4.2. The adopter characteristics

Organization size is commonly seen to relate positively with the amount of innovation adoption. Dewar and Dutton (1986) found that the typical profile for an organization adopting radical innovations is a large company which can afford a significant amount of engineers experimenting on and absorbing innovations with substantial new knowledge components. One explanation for this could be that large companies feel a more urgent need to support and improve their performance through adopting new innovations. On the other hand, large companies more likely possess the financial readiness to bare the risk of failure. Moreover large companies often have diverse and complex facilities which enable the adoption of a larger amount of innovations (Damanpour 1987). Nevertheless also small companies often possess qualities which support innovation adoption, for they are often more flexible and innovative, resulting in enhanced receptiveness towards new products. (Frambach & Schillewärt 2002; Dewar & Dutton 1986) The more complex or specialized the organization is, the higher the rate of radical innovation adoption. In contrast, when adopting incremental innovations, the complexity and knowledge depth was not seen as equally important. (Dewar & Dutton 1986)

Organizational innovativeness and more specifically managerial skills are emphasized by Damanpour (1987). The author states that managers should introduce mechanisms to the organization which enhance the adoption of a needed type of innovation. This could be for instance the recruitment of personnel who are very familiar with the organization's technology and may thus increase the intensity of knowledge in the organization therefore easing the introduction of new technological innovations.

3.4.3. Perceived innovation characteristics

It would be a false interpretation to regard all innovations equivalent in the eyes of the adopting individual or system. Innovations are not perceived similarly by the adopter thus the focus should rather be on perceived characteristics of using an innovation than the primary attributes which are intrinsic regardless the adopter. Therefore what determines the successful diffusion of an innovation is not the adopter's perceptions of the innovation but rather of using it. (Moore & Benbasat 1991) It has been one goal of innovation research to recognize the factors behind why some innovations diffuse in a significant speed whilst others are never adopted by the large audience. Therefore Rogers (2003) distinguishes five attributes of innovation which influence the individual's or organization's will to adopt. These perceived attributes are: (1) Relative advantage, (2) Compatibility, (3) Complexity, (4) Trialability and (5) Observability. These attributes have been seen to explain up to half of the variance in the adoption rates of innovations. The challenge with these characteristics is in expecting the adopter's perceptions to be objective and thus focusing on the technology itself. (Tornatzky & Klein 1982) There is a lack of unified standards concerning for instance when an innovation may be considered complex (Tornatzky & Klein 1982); the listed factors are not innate attributes of the system but subjectively perceived qualities by different individuals and organizations (Agarwal & Prasad 1997).

Relative advantage may be seen as one of the strongest influencers in the decision to adopt an innovation (Agarwal & Prasad 1997). The term refers to the amount of added value the adopter believes to experience compared to the supersedes. It is seen the more the adopter perceives relative advantage the more likely they are to adopt. In fact one of the main influencers for organizations passing through the innovation-decision process (see Figure 6) is to overcome the uncertainty concerning relative advantage; the companies want to discover the extent to which the new practice is better than the old one. (Rogers 2003, 219-233)

Compatibility refers to the degree the innovation is seen to fit the adopter's existing values, needs and past experiences. The more compatible the idea, the less uncertain and simultaneously more familiar it will seem for the adopter. Thus the compatibility of the innovation is positively related to its adoption. Compatibility is affected by for instance sociocultural values and beliefs, previously introduced ideas and client needs for the innovation. (Rogers 2003, 240-256) Furthermore the amount of 'positive externalities' or users of the innovation among the organization's value chain (such as customers, suppliers or other organizations) enhance the adoption probability depending on the nature of the innovation (Frambach & Schillewärt 2002).

Complexity is the third attribute affecting innovation adoption. It describes the amount an individual or organization finds the introduced idea or innovation difficult to understand and use. Complexity is not seen as important an attribute as compatibility and relative advantage but nevertheless it is found that complexity has a negative relation to the adoption of new innovations. Less complex and easier to use innovations are considered more likely to be accepted by the adopter (Agarwal & Prasad 1997) The fourth attribute is Trialability, which refers to the degree to which an innovation may be experimented with prior adoption. Some innovations are easier to divide for trial than others. Trialability is seen to influence positively the adoption decision and to be especially important for early adopters. (Rogers 2003, 257-258)

Finally, the fifth attribute Observability is the level in which the results are visible to others. The nature of innovations varies, implying that some are more easily communicated, observed and described to others. Observability is seen to have a positive relation to the innovation adoption process. (Rogers 2003, 258)

In addition to these five attributes, Tornatzky and Klein (1982) identified five additional characteristics which are cost, divisibility, profitability, communicability and social approval. They found communicability to be closely related with observability and correspondingly divisibility with trialability. The authors found that out of the innovation characteristics compatibility, relative advantage and complexity had the greatest influence on innovation adoption.

3.5. Organizational innovation adoption

The adoption process may be characterized as a set of stages the potential innovation adopter goes through before accepting the new product, service or idea and having it as part of the organization functions (Frambach & Schillewärt 2002). The organizational innovation adoption process may be seen to consist of two comprehensive phases: initiation and implementation (See Figure 11)(i.e. Zaltman et al. 1973).

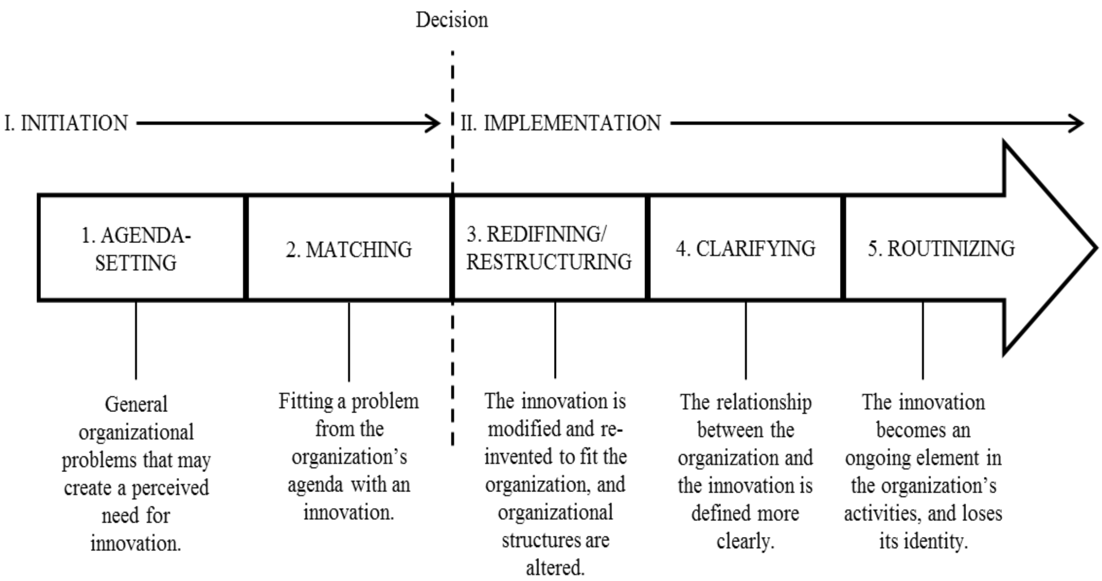

Figure 11. Innovation adoption in organizations. (Rogers 2003, 421)

The initiation phase consists of all the pre-work regarding the adoption of an innovation, such as information gathering, conceptualization and planning. These actions lead to the decision to adopt an innovation, which is followed by the implementation phase, which includes all the actions needed to make the innovation part of the organization's activities. Frambach and Schillewärt (2002) emphasize that organizational adoption occurs both on the organizational level and the individual within the organization or “intra-organizational” level. Tornatzky and Klein (1982) discuss in their study that adoption and implementation should be treated as dependent variables rather than simply yes/no adoption decisions. Adoption is argued to be an insensitive measure of innovation because the level of adoption varies within organizations according to perceived characteristics of the individual. In the following chapter these two stages of initiation and three stages of implementation are introduced and scrutinized. (Rogers 2003, 417-421)

The first stage of the initiation phase is agenda-setting, which consists of prioritizing and identifying needs and problems and searching for potential solutions (innovations) from the organization’s environment. In other words, agenda-setting refers to the stage where the organizational problem is defined and thus a need for an innovation is perceived. The second stage is matching, which refers to the organization finding, planning and designing an innovation’s fit to their activities. This stage focuses on the organization’s members attempting to determine the extent to which the potentially adoptable innovation could solve the company’s problems. If these individuals inside the organization do not see enough potential in the innovation, the innovation adoption process will end to this phase, prior implementation. (Rogers 2003, 422-423)

If the innovation is found to be a match for the company, the decision to adopt is made. The decision may be the direct result of a managerial choice or imposed by external conditions such as an acknowledged performance gap in the organization (Damanpour & Schneider 2006). This is followed by the stage of redefining and restructuring the innovation to fit the company’s practices. The innovation must be adapted to match the organization’s existing environment in order to be utilized most effectively (Iansiti 1994). This stage may also be called “re-inventing” the innovation (Rogers 2003, 431) or technology integration (Iansiti 1994). The adaptation stage moulds but the innovation to fit the organization, also the organization structure to accommodate the innovation. It is found that the radicalness of the innovation or in other words the amount of knowledge individuals have to adopt raises uncertainty and thus complicates the implementation of the innovation. (Rogers 2003, 424-427)

The fourth stage of the innovation adoption process is clarifying, which refers to spreading the innovation inside the organization in order to make it clearer to the organization's members. In this stage, innovation champions, individuals inside the organization who believe in the innovation and are ready to spread it, play an important role. The fifth stage is routinizing, which occurs when the organization has lost its separate identity and thus the innovation has become part of the regular activities. The final stage is closely linked to sustainability, which refers to the degree in which the innovation will continue to be used. There is always also the risk of discontinuance, which may also be a relevant option in some cases, if the innovation fails to solve the problem it was accustomed for. (Rogers 2003, 427-435)

Damanpour and Schneider (2006) found that there were several factors affecting organizational innovation adoption. Furthermore their finding was that while some variables affected all of the phases, there were also factors which affected only the initiation, adoption decision or implementation phase separately. The size of the organization was seen to affect all phases positively while organizational complexity only affected the initiation phase positively. Male and female executives were found to behave similarly concerning innovation adoption and organizational economic health influenced the adoption decision. Organizational factors were found to be more influential on the positive adoption decision than environmental or individual demographic factors. Moreover organizational factors were found to apply on all three phases of the adoption process. The same applies for managerial attitudes towards innovation adoption, which were found to be almost as strong an influencer as organizational factors.

3.6. Measuring success

There exists a unified view in the previous literature that an innovation is merely an invention without successful market activities. Nevertheless, there are also other aspects to measure the success or failure of radical innovation projects. There are three degrees in which success may be measured: technical, commercial and financial. The technical success refers to the innovation meeting its technical specifications, the commercial to the way it is accepted by the markets and the financial aspect refers to the return on investment. In order for the innovation to be considered prosper, it must fulfil all three attributes. The markets possess examples of products that have fulfilled only one or two out of the three, and thus have not succeeded in the long run. (Abetti 2000)

However, measuring an innovations success is relatively complex and difficult. The problem is that if calculated only through for instance financial key ratios such as the market percent of the product, revenue and sales volume, no feedback occurs concerning the factors that lead to the results. Indicators such as those concerning customer satisfaction and the markets should also be acknowledged and utilized. These could be for instance response and satisfaction concerning the product, quality and performance. Therefore the amount of indicators could be broadened to encase for instance the combination of customer satisfaction, profitability, profits and product performance. (Simula et al., 2009, 98-100)

According to Abetti (2000) there are four most critical characteristics successful radical innovations or the company behind it possess. Firstly, they possess a unique advantage, which separates them from competitors. Secondly, the company is well coupled with the marketplace or in other words has existing and potential customers. The third characteristic is technology gatekeepers, which refers to the company having experts of specific technologies who stay on top of newest developments and thus are able to evaluate upcoming technologies. The fourth prerequisites for success are free communication channels; the flow of knowledge both inside and especially outside the firm is crucial for successful radical innovations.

Disruptive innovation adoption often influences the company culture and may thus cause organizational resistance. Hence good and committed change management is important. The innovation should not be adopted unless the management is prepared to fully commit and accept the phase between adopting the innovation and crossing the motivation threshold. Successful implementation further requires focus on achieving the motivation threshold rather than merely generating fast results at any cost. Focus on generating fast and early results in one area of implementation may draw resources from other, weaker areas in the long term thus in fact affecting negatively the larger picture. (Repenning 2002)

4. SYNTHETIC BIOLOGY: STATE OF THE ART

Synthetic biology is a new-to-the-industry technology in Finland which has yet to be commercialized. The concept is shortly defined and the application areas are further introduced to the reader. Furthermore the challenges and ethical factors related to synthetic biology are scrutinized. Finally the LiF – Living Factories project at VTT is discussed.

4.1. The definition of synthetic biology

The approach of synthetic biology is arising due to the collision between science and engineering (Haseloff & Ajioka 2009). The term was first expressed by Waclaw Szybalski in the year 1975 (Liang, Luo & Zhao 2011), but the roots of the field can be traced back to the year 1961, when Francois Jacob and Jacques Monod first discovered regulator circuits which endorse the way cells respond to their environment (Cameron, Bashor & Collins 2014). If expressed in a simplified manner, synthetic biology refers to modifying living organisms into a form in which they can be utilized to address current and important problems in energy, environment and health (Benner & Sismour 2005); using raw materials to create novel synthetic biological systems (Bhutkar 2005). From this perspective, synthetic biology is very synonymous to the term “bioengineering” (Benner & Sismour 2005). Nevertheless, the scope of synthetic biology is in no way simple, but rather as complex as life itself. (Liang, Luo & Zhao 2011)

Synthetic biology is a new engineering approach for conducting biotechnology (Heinemann & Panke 2006), but there is still a consensus to be reached concerning the strict definition of synthetic biology. Nevertheless the use of molecular biology tools and techniques in order to forward-engineering cellular behaviour has become a general determination for the field. (Cameron et al. 2014) Liang, Luo and Zhao’s (2011) thoughts support this view, for they define synthetic biology as “deliberate design of improved or novel biological systems that draws on principles elucidated by biologists, chemists, physicists and engineers”. Furthermore Heinemann and Panke (2006) simplify their definition to be “the engineering-driven building of increasingly complex biological entities for novel applications”.

Synthetic biology may be used to engineer complex biological systems in order to enhance the production of chemicals, foods, fuels, drugs and polymers (Haseloff & Ajioka 2009). Synthetic biology is not a unified concept but rather varies depending on the researcher. Synthetic biology strives to develop cost-effective and efficient tools to synthesize and modify biological entities such as DNA, proteins, organelles, viruses, pathways and genomes (Liang et al. 2011). The primary objective of the technology is to create a programmable organism from scratch, which explains the need for cross functional industry expertise requiring biologists, engineers and systems specialists among others to co-operate (Bhutkar 2005).

4.2. The application areas of synthetic biology

Synthetic biology lies in the interface of many different biological research areas such as protein and metabolic engineering, chemical and systems biology, functional genomics and bioinformatics (Liang et al. 2011). The application areas of the field vary from medicines and vaccines to biofuels, industrial enzymes and life sciences (Thermo Fisher 2015), or more specifically from creating systems for environmental clean-up tasks, medical diagnosis and treatment to economical generation of hydrogen fuel (Bhutkar 2005). In the health industry, with the methods of synthetic biology it has already been possible to generate diagnostic tools for treating infectious diseases. Moreover the developed micro-organisms may for instance detect toxic chemicals, break down pollutants, repair defective genes, generate hydrogen and destroy cancer cells.

Synthetic biology should not be confused with genetic engineering, which refers to the transfer of individual genes from one species to another. This technology is a key enabler of the formerly mentioned but differs in details. (Tucker & Zilinskas 2006) Synthetic biology may be distinguished from other biotechnological ways of modifying living forms through four specified attributes, of which the first two are mandatory: *raw materials, no natural counterpart, programmable and synthetic whole genome.* The first attribute refers to the synthetic elements being constructed from basic elements in laboratory facilities and not as a part of a natural cellular process. Secondly, these synthetic elements or networks should not have an identical copy in natural cells. Thirdly, synthetic elements should be controllable externally in a deterministic way. The fourth and final attribute is that when starting with synthetic oligonucleotides (short strands of synthetic DNA) as raw materials, the end product is an artificially assembled or minimal genome. (Bhutkar 2005)

4.3. Research on synthetic biology

The progress of the field has been non-linear through its few decades of existence; there have been periods of major progress followed by setbacks due to the complexity and unpredictability of engineering inside living cells (Cameron et al. 2014). Synthetic biologists aim to develop altered, thus synthetic components that support Darwinian evolution or in other words, adapt biologically (Benner & Sismour 2005). This design-based approach to biological engineering is to a great extent based on accomplishments in systems biology, which has provided biological knowledge needed for understanding cellular systems in a deeper manner (Clay & Fong 2013, 47-48). A major breakthrough with this emerging and developing technology was in the beginning of the year 2014, when scientists were able to successfully alter the DNA-code of a yeast cell's chromosome without destroying its ability to divide and function. Previously this has been successful only with bacteria, of which the genetics are simpler. This is significant progress because it is a step towards being able to synthesize ever longer chains of DNA and thus modify cells into more efficient and superior forms to serve their purpose even better. (Paukku 2014) The ultimate goal is to wholesale reprogramming of biological systems and create whole novel synthetic organisms, but the field is still far behind in the biological knowledge and mechanistic insights needed for this. Nevertheless the technical and cost barriers for the creation of whole genomes are seen to diminish in the near future. (Cameron et al. 2014; Haseloff & Ajioka 2009)

The outlook for synthetic biology is that in the future it will be less dependent on the analogies to the theory and practice of other engineering disciplines and rather continue to strengthen and build its own identity and culture (Cameron et al. 2014). The studies in basic sciences combined with the numeric tools developed for the study of natural system provide a conceptual and practical framework for the systematic engineering of biological systems (Haseloff & Ajioka 2009). Today, almost any proposed genetic design may be directly implemented with genetic engineering methodologies (Clay & Fong 2013, 48).

4.4. The limitations and challenges of synthetic biology

The greatest challenges of synthetic biology lie in the complex structures and difficult predictability of living organisms. Compared to for instance engineering chemistry or physics, biology is challenging due to its capacity to replicate and evolve. (Heinemann & Panke 2005) This poses a problem when looking at the long-term stability of modified systems; the behaviour of bioengineered systems is unpredictable and “noisy”. Furthermore the genetic circuits tend to mutate rapidly and thus become non-functional. (Tucker & Zilinskas 2006) The interference of mutations may become an issue the more complex the synthetic structures are inside living hosts. However this is not a new challenge for biotechnology but rather something that has been faced in several new developments concerning biotechnological processes. The ability to engineer biology in a structured and directed manner is challenging thus the complexity of successful applications is still limited. (Heinemann & Panke 2006) While previously gene modifications have been made only through discovery-based, trial and error design, synthetic biology strives to offer foundational principles and technologies to enable systematic forward-engineering of biological systems and thus a more directed prospective design process (Clay & Fong 2013, 47). Nevertheless although major breakthroughs have been made, this is still costly and relatively inefficient (Heinemann & Panke 2006).

Bio products are currently made mostly from lignocellulose, which is separated from biomass. Although the products possess several exceeding qualities, the use of biomass for these purposes has its debates. At this point, biofuels and bioplastics compared to oil-based products are significantly more expensive, which lessens their competitiveness. One solution is to place a carbon tax for oil, gas and coal to reflect the external costs. Furthermore the crop production for biomass is not without challenges: it accelerates deforestation, runoff, water contamination and increases atmospheric pollution. (Mayes 2014) The challenges of utilizing biomass are further scrutinized in the upcoming “LiF – Living Factories” –chapter of the Thesis.

4.5. The risks and ethical perspective of synthetic biology

Rapid advancements in biotechnology in the past have led to certain concerns over potential risks by different aspects of the field. The same applies for synthetic biology. (Bhutkar 2005; Tucker & Zilinskas 2006) It should be acknowledged that since engineered micro-organisms are self-replicating and capable of evolution, they should not be categorized into the same risk category as toxic chemicals and radioactive material. Furthermore it is good to note that the field is still in such an early phase that some risks may arise only later on in the utilization. (Tucker & Zilinskas 2006) Naturally, as may be predicted when talking about modifying something “living and natural”, also synthetic biology possesses its risks which may be categorized into three groups. One is associated with modified organisms escaping to the nature, proliferating on their own and causing environmental damage or threatening public health. The second threat involves harmful side effects synthetic micro-organisms may cause in the environment while the third is the threat of bio-terrorism or exploiting synthetic biology for hostile or malicious purposes. (Keisling 2013; Bhutkar 2005; Tucker & Zilinskas 2006)

A bioethicist Laurie Zoloth once stated: “Synthetic biology is like iron: you can make sewing needles and you can make spears. Of course, there is going to be dual use.” (Elias 2005) Dual use refers to the manner in which knowledge gained from beneficial research, scientific materials and procedures may be used for unintended, harmful purposes. Of this an example is nuclear material, which may be used for producing energy but also for instance weapons of mass destruction. In the case of synthetic biology, it is feared the technology could be misused to modify existing diseases or even create a highly pathogenic biological agent. Furthermore there is an approaching “do-it-yourself biology”, or DIYbio, “open science” movement, which aims on having more of the scientific research, technology and innovation available for anyone willing to absorb it. Although the ground cause of the idea is earnest, it possesses the threat of potentially dual-usable biotechnologies being more easily accessible for the wrong people. (Noble 2013)

The rapidly developing field of synthetic biology has also triggered an ethical debate of which one main subject is where to draw a line between an engineered machine and a living organism – while the main goal in the field is to develop from scratch synthetic biological systems that function as the organic ones, the distinction between biological and synthetic begins to blur. If the synthetic entities are given only instrumental value thus as “non-life” commodities of mankind and not considered as intrinsic or valuable as an individual entity regardless their utilization potential, what happens when potentially more complex lifeforms are synthetically created in the future? Does the ethical side limit the development of the field? Furthermore there is the question of whether “life” can be restricted to the definition of a living organism which is formed from genes. If defined in this way, also synthetically generated organisms are living but nevertheless this fights against the ethical view that life is much more than genetics. The problems arise when thinking about progress in the field and potentially moving to mammalian cells; is it ethical to develop synthetic organisms into mammalian species such as mice? Furthermore, is it ethical to expand the applications to human life? (Bhutkar 2005; Yearley 2009)

It is believed the risks associated with synthetic biology are best managed when the related parties such as academia, health professionals and governments work together and acknowledge and understand the threats and how to prevent them. (Noble 2013)

4.6. LiF – Living Factories

The Living Factories –programme (here on referred to as LiF) is a Tekes-funded project conducted by VTT Technical Research Centre of Finland together with the partners Aalto University and University of Turku. The main goal of the programme is to bring synthetic biology to its full potential in Finland. The name of the programme comes from its main focus of building superior Living Factories for the sustainable production of chemicals, which includes fuels and materials. The aim is to prove the significance, strength and potential of synthetic biology and get the industry to co-operate within the upcoming two and a half years. The programme focuses on developing a new, internationally competitive environment which combines research, education and industrial activities and which furthermore utilizes unique biological functions combined with engineering sciences. (Hyytiäinen 2014)

Reducing oil dependency and developing more sustainable and environmentally friendly yet efficient production processes from renewable materials are the key drivers of the LiF-programme. The LiF programme strives to develop energy and carbon efficient microbes for sustainable bioprocesses for industrial production. Traditionally plant biomass has been the main raw material for biorefinery developments; microbes use lignocellulose derived from organic sources as their primary source of energy in the fermentation processes. Compared to traditional chemical processes for breaking down biomass from crops, bioengineered micro-organisms are faster and more cost-efficient (Mayes 2014). Nevertheless utilizing biomass possesses some challenges, for there are conflicts of interest on whether this raw material should be used on energy, fibres, bulk chemicals, fuel or perhaps considered for extraction of high value compounds. Furthermore it may be seen that the growing of this non-food biomass reserves land from agriculture. The vision is for bio-production to rely on primary energy and carbon sources. These are for instance wind, water and sun energy and furthermore one carbon (C1) compounds such as CO2 and methanol, which are unlimitedly available in nature.

One main bottleneck in microbial cell factory establishment has been the long production times associated with the trial and error methods. Long production times are inefficient and expensive hence a more efficient solution for microbial factories is truly needed. (VTT 2015; Mayes 2014) In addition to the environmental aspects the LiF-project has major goals regarding process efficiency and cost savings: it is estimated that the platform of chassis organisms and biological parts together with the developed modelling and automation will enable products to be generated up to 10 times faster and cheaper than what they currently are.

VTT, together with IBC Finland conducted a web survey for 20 Finnish technology companies in the end of December 2013 in order to discover the preliminary market potential of synthetic biology. The response was mainly very positive and most of the companies found synthetic biology to have true potential for the future. Nevertheless only 15% of the companies that answered had mentioned synthetic biology in their strategic planning or documents even though most of the answering companies found synthetic biology to most likely be an important part of their field in the future. The companies felt they needed more information about the technology and how it could be used in their specific field.

The programme has specific milestones for one, two and five years of execution concerning its outcome and impact. The milestones focus on both improving the technology and diffusing it to the industry efficiently. It is seen that within years the synthetic biology activities in Finnish technology companies should have significantly increased and furthermore new business ideas for Finnish SME's would have stemmed.

5. RESEARCH METHODOLOGY

The empirical part of this study was conducted by interviewing representatives from twelve bio-economy companies. The following chapter characterizes the form of research and interviewees and moreover justifies and discusses the made decisions. Finally the questions of reliability and validity in the context of this study are scrutinized.

5.1. Qualitative research

The forms of conducting empirical research are commonly divided into quantitative and qualitative methods. Quantitative analysis aims more on finding causalities and correlations from numerical data while qualitative analysis strives to describe, understand and interpret different phenomena in our reality. Eskola & Suoranta (2003) define basic characteristics for qualitative analysis to be the positioning of the researcher, the using of the perspective of the researched and theoretical or discretionary sampling. The aim of qualitative research is not to test theory and hypothesis but rather to thoroughly and in detail observe the given occurrence (Hirsjärvi et al. 2009). Interviews, observation, text analysis and transcribing are the most common forms of qualitative research (Metsämuuronen, 2003, 161-162).

This research strives to understand, explain, determine and interpret certain phenomena and processes taking place inside organizations thus the choice of qualitative methods was natural. Furthermore the emphasis of the research is on determining how and why something is done inside organizations rather than to what extent. More accurately, the research aims to map the certain characteristics of the innovation process inside the companies rather than simply charting how many of the companies have an innovation process. Qualitative analysis aims on describing real life and therefore approaches the researched matters and phenomena in a comprehensive manner (Alasuutari 1999). The research method is at times criticized for its small sample groups which lead to the information being highly subjective and also to a great extent left to the interpretation of the researcher. Nevertheless this research method offers the possibility of in-depth motivations and feelings of the interviewees and thus serves a very different purpose compared to quantitative research. (McDaniel & Gates, 2013, 80-82)

Interviews are the most commonly used tool for gathering information in qualitative research. Research interviews aim on systematic gathering of information and are most often divided into four categories: structured, half-structured, theme and open interviews. A structured interview leaves as such no space for free discussion, because the order and format of the questions and answer choices are given to the interviewee. A half-structured interview follows the same lines with the distinction of open answers. In theme interviews only areas of discussion (theme areas) are prepared, which leaves room for open discussion and different paths in the conversation resulting in versatility in the answers amongst the interviewed. The interviewer does not have fully structured questions, but merely a support list of the areas wanted to be covered. An open interview is the closest to a normal discussion; all of the theme areas are not covered with all the interviewed and the discussion is rather free. (Eskola & Suoranta, 2003, 85-86)

This research could be characterized as a half-structured theme interview. When the purpose of the gathered data is to reveal the ‘what’ and ‘how’ and furthermore find explanations to ‘why’, non-structured, such as half-structured or in-depth interviews are often used (Saunders et al. 2007, 313). The interview had four themes which formed the structure for the interview. The themes were reinforced with a set of supporting questions. As Hirsjärvi & Hurme (2009) discuss, typical for theme interviews is the open structure of the questions. In the course of the interviews the questionnaire was not strictly followed, for some questions were modified or left out and the order could be changed according to each situation. The decision to let the interview flow more towards a conversation was consciously made and furthermore it became clear that not all of the interviewees should be asked precisely the same questions; the companies varied in nature and by phrasing the questions in a different manner more coherent results could be accomplished. Thus the characteristics of a half-structured theme interview were actualized.

According to Hirsjärvi and Hurme (2009) the literature does not determine any absolute measure for the amount of interviews for a qualitative study. The amount of interviewees may be considered sufficient when the final interview does not bring critically new information to the material. Hence own consideration was used to determine the optimal number of interviewees based on the assumption of how many perspectives would formulate a thorough picture of the subject.

5.2. Gathering the data

The empirical part of this study consists of twelve half-structured theme interviews. Nine of the interviews were conducted face-to-face and three through Skype due to geographical distances. There were one to three interviewees from each interviewed company and the interviews were reserved an hour each, which most often also actualized. The interviewed facets were chosen with consideration towards the subject and in order to represent a variety of companies operating in the field of bio-economy (See Table 1). The interviewees were chosen with the help of VTT in the hope of getting a largely diverse view of bio-economy companies. Thus the industries vary widely covering biotechnology, energy, paper and forest products, food production and chemicals. Biotechnology is a broad concept which holds within areas such as enzyme production and pharmaceuticals. The common factor between the companies and their choosing criteria is that they can potentially adopt synthetic biology into their processes in the future. Some of the companies wished to stay anonymous for the study therefore no company names or further identification details in addition to industry and size group are provided in this work.

Size	Company	Industry	Position of Interviewee/s
Small	Company 1	Biotechnology	Upper Management
	Company 2	Biotechnology	Business Development
	Company 3	Biotechnology	R&D Management
	Company 4	Biotechnology	R&D Management
	Company 5	Biotechnology	Innovation & Technology Management
	Company 6	Biotechnology	Upper Management
Large	Company 7	Energy	R&D and Innovation Management
	Company 8	Biotechnology	R&D Management
	Company 9	Chemicals	Innovation & Technology Management
	Company 10	Energy	R&D and Innovation Management
	Company 11	Agriculture	R&D Management
	Company 12	Paper & Forest	R&D and Innovation Management

Table 1. The interviewed companies.

One of the key aims of this study was to find distinctions and compare the way the innovation process and technology adoption is managed in small and large enterprises. Hence for the analysis of the interviews the companies have been divided into small and large enterprises based on the generally accepted definitions in Finland. A company is considered small when it has less than 50 employees and its gross revenue does not exceed 10 million euros. Controversially, a large enterprise employs over 250 individuals and has gross revenue of over 50 million euros. (työ- ja elinkeinoministeriö, 2015) Representatives from six small companies and six large multinational enterprises were interviewed. The interviewees were mainly managers working closely with either innovation management or research and development, as may be seen from the presented chart.

5.3. Data analysis

The main sources of data for the empirical part of this study are the interviews, which add up to approximately 132 pages of transcribed speech when written in Arial font size 12 and spacing 1,5. The interviews were conducted during spring 2015 and the interviews were transcribed by using discretion – since the research at hand studies and emphasises context rather than characteristics of the interviewee and their speech, meaningless “filling words” were left out of the transcribed text. The interviews were completed in Finnish and later only the straight quotes were translated into English.

The data analysis followed to some extent the framework given by Tuomi and Sarajärvi (2009):

1. Deciding, what is important in the data

2a. Going through the data and marking the factors which are important based on the previous decision

2b. All else is left out

2c. The marked factors are separated from the other data

3. Categorizing, theming or otherwise handling the data

4. Writing a summary.

The interviews were already under the certain themes which made the process of theming simpler. Important points were highlighted from the interviews and they were moved to a separate document. The straight quotes were also selected from these emphasized parts. The researcher found the integration of the interviewees' answers into one document an efficient way to recognize and evaluate similarities and differences. The theming of the transcribed speech helped to identify the main findings and thus find the core for the empirical part.

5.4. Reliability and validity

Although researches commonly strive to produce accurate work and thus avoid mistakes, reliability and validity vary according to the empirical study. Reliability refers to the extent to which the study has produced objective results – are the results independent of the researcher? Validity on the other hand refers to the ability of the research method to measure the wanted factors. Nevertheless these terms are more accurate in quantitative research for it can be argued that qualitative research can, if ever, only partly fulfil these demands. Since qualitative research is based on individuals' subjective views the results cannot be taken out of the context and thus if the interviews were repeated, the answers could easily vary. Furthermore in qualitative research reliability may suffer from for instance the interviewee not being honest or not understanding the question. The researcher could also modify the answers towards a certain trend and leave out outliers. Misunderstandings are possible for both parties. (Hirsjärvi, Remes & Sajavaara, 1997, 213; Tuomi & Sarajärvi 2009)

In order to enhance the reliability of this research, the process has been attempted to mould into a clear and transparent form. Nevertheless the generalization of the study's results outside of researched field should be proceeded with cautiously, for that is not the aim of this study. The aim is on producing accurate and thorough knowledge and conclusions based on the small sample group concerning the given phenomena. Therefore the extent to which the results may be generalized is left for the reader to decide.

6. EMPIRICAL RESULTS AND FINDINGS: INNOVATION AND TECHNOLOGY ADOPTION IN FINNISH BIO-ECONOMY COMPANIES

This part of the study introduces the results of the empirical part of the research and ties it together with the existing literature. The subjects are discussed in the same order as in the literature part to create a coherent view and clarify the structure to the reader. Finally a theoretical model based on the previous literature and results of this study is introduced.

6.1. Innovation and organizational innovativeness

The interviewees had a relatively unified view of how the term innovation is defined. Innovation was generally viewed as an element of novelty which brings significant added value to the company. This novelty could be anything from slight changes in processes, products or services to whole new products, processes, services or other technologies. Coherent to the theory of Abernathy and Clark (1984), the importance of successful commercialization was emphasized as the key factor separating innovation from an idea or invention.

"The definition of innovation in this house is that an innovation or idea becomes an innovation only at the point when someone buys it. Only a commercialized product can be an innovation."
Company 5 (small)

There was no diversification to be made between large and small companies in the definition, but rather the slight nuance differences were due to individuals' different perspectives. While all identified the element of novelty in the definition and most companies emphasized the importance of commercialization, one interviewee viewed innovation through bringing added value to customers and for another it was mostly about finding faster and more efficient ways to manage in-house processes. Company 10 on the other hand took the definition to a broader level, emphasizing utility in general:

"Utility is important; an idea doesn't turn into an innovation before it brings some kind of benefit, smaller or larger. The idea needs to be implemented and it has to be useful."

It could be said that the interviewees' conceptualizations of the term were very close to the literature (i.e. Kline & Roseberg 1986; Rogers 1962; Garcia & Calantone 2002), which could to some extent be linked with the hype and emphasis innovation has had in the modern world. One interviewee stated that the term innovation is even starting to be a bit worn out due to the way it has been continuously emphasized through the past years. Nevertheless innovating was seen as a prerequisite for surviving in the fast-paced competitive markets, as also for instance Porter (1990) and Assink (2006) emphasized. All in all innovation was seen as a broad concept which can be divided into different categories:

"Our innovation activities consist of three different areas: our own inner innovation activities, what we develop with others and how we adopt and utilize new technology that has been developed by for instance our suppliers."
Company 12 (large)

The interviewees were generally familiar with the distinction between radical and incremental innovations. Thomond and Lettice's (2002) innovation continuum (see Figure 2) describes well the interviewees' perception of radical and incremental innovation; radical innovation was viewed to possess great market uncertainty and create new markets at best while incremental innovation was viewed as more frequent, smaller enhancements. Interestingly, although there are several other innovation categorizations also (i.e. Abernathy & Clark 1984; Garcia & Calantone 2001), they seemed to not have established a place in the industry; in the discussion the division was only made between incremental and radical innovations. However, similarly as in the literature (i.e. Garcia & Calantone 2002), also the interviewees identified the difficulty in determining a radical innovation. One interviewee pointed out how one of their major innovations which had also established new markets was viewed by one of their old research leaders as in no ways a radical innovation but rather utilizing and broadening existing expertise to a new material. All of the companies found their innovations to be mainly incremental by nature. Nevertheless almost all of the interviewees were able to name at least one disruptive innovation in their organization. For smaller companies the disruptive innovation was mainly the technology platform or other core technology the whole business operates around, while for large companies it could be expanding to whole new markets with a new-to-the-world product.

”I could say that (our innovations are) mainly product enhancements, but currently we have one very large innovation that we are commercializing and internationalizing. It differs (from the others); it is not a product variation or enhancement but a product built on innovation. We’ve put a lot of resources on it.”
Company 11 (large)

To some extent innovativeness and risk-taking seemed to be dependent on the available resources, mainly financial. Hence although a small company may possess significantly innovative individuals, the large companies could generally be seen to be able to bare more risk. Thus the results support Mueller and Tilton’s (1969) claim of large companies introducing a larger relative percentage of innovations than small companies.

”The new product is a big risk and we think it will fly far. We took large investment risks and went straight away to the large scale, now that you think of it, wow! Our company is a clear pioneer and risk taker. The risk wasn’t taken without consideration but nevertheless it was big. There was courage and the attitude hasn’t changed; at least how I see it.”
Company 7 (large)

According to the literature (i.e. Mueller & Tilton 1969; Christensen & Overdorf 2000), small companies are more likely to produce radical innovations while large companies focus more on sustaining or incremental innovations. The results of this research however somewhat differ from the literature, for there was no direct correlation between company size and the amount of radical innovations; all the interviewees found radical innovations to be rare. The literature expresses how in many cases small and new companies need to innovate radically in order to establish a market space (Danneels 2004). Yet according to the interviews it seems that also large companies felt the pressure of being constantly innovative in order to maintain their position on the markets. Furthermore, although innovations were mostly incremental in the organizations, both large and small companies also underlined the importance of radical innovations. Both company sizes seem to have their pros and challenges in developing radical innovations; small companies may suffer from the lack of resources and thus the ability to take risks while large companies may find bureaucracy and strategic issues in their way.

Especially in the large companies innovation development was seen as a very long-term process. Reasons for this could be capacity, resources and risk taking ability; large companies can focus on several different projects while small companies may often have to focus on one core competence.

"Here's the problem that a small company can't just start going to every direction really broadly. On the other hand, if the selection of products consists of only a few products that enhances the risk concerning commercial success. The balance needs to be found."
Company 3 (small)

The nature of the industry may also explain the long-term focus on innovating because a typical time-to-market for companies in the field of bio-economy is around ten years. Even longer development times are not unheard of. Several of the companies expressed certain challenges tied to the industry which were mostly focusing on how slow bringing new products to the market in the industry is. The length of the process is not always even in the hands of the company, for IPR-issues, prototyping and testing take a lot of time in the industry. One interviewee brought up the difference to IT-companies, where products do not necessarily have to be as thoroughly tested as when mirroring to for instance pharmaceuticals, energy or enzymes.

"If we compare to the IT-industry or other, this is slow and the scale is large. It requires big investments that are considered very thoroughly. The processes have to be tested very thoroughly and they have to look really good in order for the company to invest large amounts of money on it."
Company 7 (large)

Naturally the time span for small enhancements is shorter and most interviewees emphasized how it is important to balance between incremental and radical innovations. The interviewees found both innovation types crucial for successful business, as also Abernathy and Clark (1984) emphasized. Several of the companies explained that they have some kind of ‘innovation case’, which has a mixture of a variety of ideas and innovations with different levels of radicalness. This was also seen as a way to minimize and decentralize risk.

“We’re trying to maintain a combination (of technologies/innovations) where we have certain cases in which someone is already using the technology in perhaps a different context, then we have those very uncertain ones in which no one has succeeded and success is around ten years from here. There needs to be a balance and both must be done.”
Company 10 (large)

The concept of organizational innovativeness is very interesting, for when mirroring the adopter categories of Rogers (1983), it is clear that no company would identify themselves as laggards. On the contrary, as could be expected, all the interviewees found their companies to be very innovative and ahead of their time. Yet, when talking about bringing new technologies or products to the markets it was clear some interviewees had an even firmer focus on producing elements of novelty.

“Our personality is that we want to create new, something that doesn’t exist yet. I remember when the company was founded and at first we were running after money. We expressed our ideas to different facets such as venture capitals, and the answer was word to word “this is star wars” – referring to them seeing the ideas as very good but a bit too futuristic. Often innovations have the challenge that the idea is good but the timing is too early. The idea can be as good as ever but still people aren’t ready to accept it. That’s the situation we like. It tells us there is something no one else has yet come up with. That is innovation; it is ahead of its time.”
Company 1 (small)

Furthermore, when reflecting Rogers’s (1983) technology adoption timing innovativeness model (see Figure 9) to the results gathered through this research, the critique the model has received seems valid (see Wright & Charlett 1995). As mentioned previously, the interviewed companies decentralize risk by managing projects with different levels of uncertainty. This in fact seems like a rational way of acting; the basic income must be secured before it is possible to manage the major uncertainty tied with disruptive innovations. Therefore it seems inaccurate to group companies according to their innovativeness level, for the measures are not absolute. No company is an absolute innovator or risk taker, for the risk must be balanced with the expected and realized income. Controversially based on the interviews it seems that all of the companies are constantly innovating and developing new approaches within their resources. This would imply that depending on the given variables, all companies are at times innovators and vice versa in some cases laggards. Rogers's (1989) theory states that innovators must possess the financial resources to manage also unsuccessful innovations. This, mirrored through the results of the study, would imply one of the greatest limitations for innovators to be the lack of financial resources. This leads to the question of since companies innovate within their resources, should innovativeness be measured through inputs and realizations or through the individuals inside the company? Or in other words, if given the resources, would smaller companies be even more innovative? There seemed to be variety in the answers, for some interviewees seemed to find funding as a large restrictor, while others were more optimistic:

"Innovation is of no use if you do 100 different things simultaneously and none of them go forward. There are two restrictions: money and personal restrictions. Both of them are important; it is always said that there's no money, but we believe that if the idea is good, money will be found. Where it usually collapses is what goes on in your head, the attitude. What are you ready to risk etc. That's the biggest bottleneck and restrictive factor. You create your own prison."

Company 1(small)

Often, when discussing the concept of innovativeness, the interviewees started telling about the company's yearly amount of patent applications. This could naturally be one concrete yet in no means absolute way of measuring innovativeness; once again, a patented invention is not an innovation before it has been successfully commercialized to add value to the company. This, therefore is more an indicator of effort and inventiveness than actual innovativeness. Another way of measuring innovativeness for the companies seemed to be the size of the R&D budget.

6.2. Idea generation and evaluation

Although interviewees identified a lot of their ideas and innovations to be need-based, ideas seemed to stem from an infinite amount of sources. As Chesbrough and Crowther (2006) also acknowledged, it was well understood that not all potential and ideas lie within one given organization. The following picture demonstrates how the gathering of ideas may be seen as an open process in which ideas are generated and approach the organization from a major amount of internal and external sources (See Figure 13). The ideas are only later evaluated at the first gate. Naturally some of the sources are ambiguous in classification and overlap each other yet they all seemed acknowledgeable due to nuance differences.

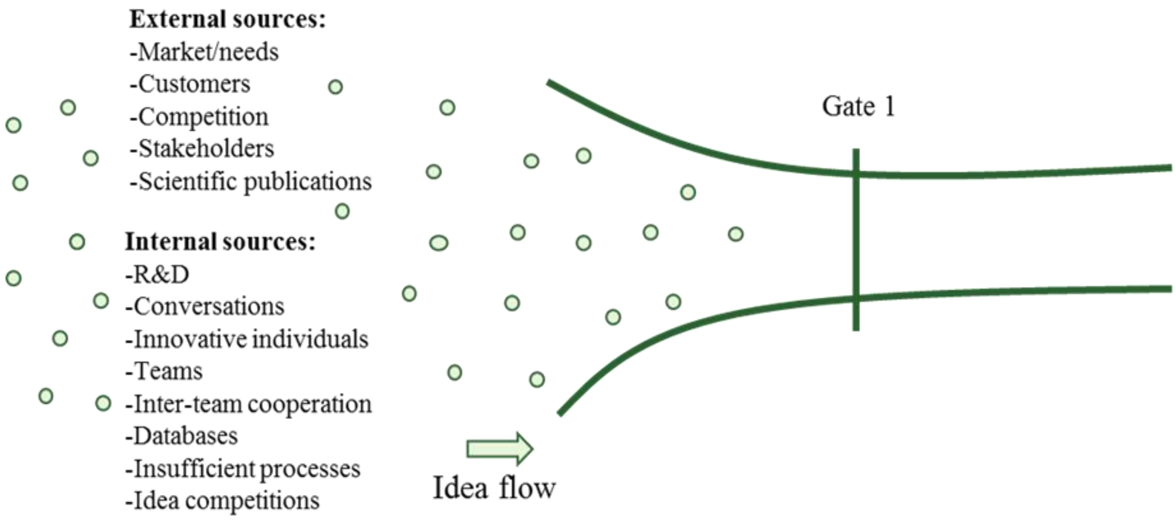

Figure 13. The Idea Generation Process.

The easiest approaches to new innovations were either market needs or the realization that some process or product could function better with enhancements. Both Assink's (2006) and Rogers's (1983) models (see Figures 5 & 6) start from the recognition of a need, whereas Cooper's (1990) model (see Figure 7) is based on an occurred idea. To the researcher the latter seems like a more open approach, for as the interviewees also identified, not all ideas are need-based. Furthermore it could be argued that the most radical of innovations seldom occur to fill a certain identified need, but rather develop new markets thus fulfilling unidentified needs. Therefore research-based innovation should not be undervalued, for as the literature also identifies (i.e. Kline & Rosenberg 1986), it develops a strong core for the business. Innovations of this nature are nevertheless most often incremental; bringing added value but not disrupting. One interviewee mentioned their company aims on the researchers having up to ten percent "Gyro Gearloose" –time to innovate freely. This could lead to more potentially radical ideas or innovations, for as another interviewee phrased, the best ideas do not come under pressure but rather:

"… When the mind rests. Then also exciting ideas may arise. Of course another source is conversations. You have to realize you can have an idea but it doesn't make it viable; that it could live in reality. That is why it's good to have a team with different insights so different aspects can be discussed and acknowledged. In the end we all have our own thing or place when the mind is the most innovative. Usually it's not at the workplace."
Company 1 (small)

The value of a good team and bright employees was emphasized in many interviews when discussing idea generation. It was commonly seen that ideas generate through discussions and controversially that the worst way to try to innovate would be to isolate from others. This also supports the observation that a large part of today's researcher's job is to follow developing trends, technologies and competitors in the field. All in all employees were seen as a crucial source for ideas hence one raised issue was how to realize their potential to the maximum. Several of the interviewees explained they have some kind of idea bank or platform, where all employees may leave ideas regardless their position. This is a way to lower boarders for expressing ideas and moreover encourage employees to innovate. Furthermore employees were encouraged to innovative thinking through versatile award-systems, such as "invention/idea of the year".

"In advance the best way to get good ideas is to communicate the strategy and goals to the employees so they know what is expected. If people don't know what is being done then the ideas are usually outside the frame. When communication of the goals and wished accomplishments is done well, then the ideas are good

per se."

Company 5 (small)

Coherently to the literature (i.e. Schön 1963; Rothwell et al. 1974; Burgelman 1983; Ettlie et al. 1984; Howell & Higgins 1990) the role of champions in the idea generation and innovation process was emphasized in the interviews. While the role of the individual could be expected to be more significant the smaller the company, the extent to which large companies found an individual's input on innovation important was surprising. The interviewees from large companies expressed how although they have the versatile structured idea generation processes, if the individual with the idea does not 'take care of the idea', the idea may get lost in the enormous information flow.

"Inner entrepreneurs who go a little bit against the rules and develop a bit secretly are needed. In the cases that come to mind certain burning-souled individuals can be identified who have taken the cases forward. This isn't a cemented road in the way 'there's an idea let's go with that' but rather it requires a lot of stretching. Support from the upper management and also peace to function."

Company 12 (large)

While the importance of talented, innovative and motivated employees was emphasized, also the importance of the company culture arose in the conversations. The organization was said to have a major role in bringing out the innovativeness in the employees. Hence it could be speculated whether an individual's innovativeness is an absolute quality or derivative from the environment. Perhaps the characteristic is the same but only some environments allow the utilization of the feature to its full potential – perhaps most individuals are capable of innovative ideas when given the right support?

"We strive to maintain the organization in a form in which everyone knows the significance of their input and are excited and motivated about it. This develops a collective alacrity through which good ideas stem from. Of course they come from the individual level; the individual is the key. Nevertheless individuals cannot be innovative in an organization that doesn't support them."

Company 5 (small)

A very interesting subject for the researcher of this study was the process of how good ideas are identified through the enormous information and idea flow the companies face. The answer to this matter was not straightforward and some companies also said they recognized the fact that also good ideas may be left without further processing due to different reasons, which are scrutinized in the next part of the study. Especially in the large companies the idea evaluation seemed to be rather objective; the idea must fulfil certain criteria in each gateway of the innovation process in order to receive further inputs.

”The key to gathering the best ideas is to acknowledge all the important aspects: technological, economical, safety and environmental. If we only had i.e. decisions from sales personnel, only one aspect would be recognized. In the management team we can take to account all the aspects, consider what is important to us and mirror it to our strategy very actively. This is the way to choose the best ideas. Bad ideas don’t exist as such but in this context prioritising is important.”
Company 5 (small)

“It’s a continuous process. Just like in the literature and theories, there are usually more ideas and then some are dropped out all the time while some develop forward. The criteria have to do with the business potential and how the technology functions. The good ideas are recognized only with hard work! Commonly ideas require some testing, either technological or market potential. In the latter case we need a team or resources which gather feedback from the customer or application side.”
Company 12 (large)

6.3. Innovation process

All of the large companies and most of the small ones described they have a structured innovation process. The most common innovation process structure was some kind of application of the stage-gate model (See Figure 7). Commonly the models had a certain amount of stages and gates, where the progress to the next stage was controlled by mostly objective measures at each gate. These measures were for instance IPR issues, critical financial evaluations or other cost-effectiveness factors. Depending on the company and its core business, the importance of safety factors was emphasized in the gateways. The clear trend was that absolutely no risks are taken with safety issues; the innovation can be otherwise very promising but if the research cannot reach one hundred percent certainty concerning the safety of the technology, the development is ended.

The innovation process was even surprisingly similar in the companies which identified they have a structured innovation process. The companies explained how the process had developed through the years so that it was a more company specific version of a regular model.

”If we’re talking about the development of the process, then the concept is basic engineering after which an investment decision is done. There are very many gates to go through and they each have certain criteria that must be fulfilled. Each research project has their own management team and a project owner from the business or corporation, depending on the length of the project. The owner and management team make the decisions. Research projects have their own team which monitors the project portfolio and makes decisions on what project, how it is continued and started. They also monitor the resources, both financial and human. There’s constant competition on what project precedes and what doesn’t.”
Company 7 (large)

Many of the companies were open about their innovation process and willing to describe it in detail. As could be expected, especially the large companies were very happy to open up and praise their innovation processes, for without a doubt the development has required large inputs and the matters have been thought of to a significant extent. Yet, for the researcher it was somewhat surprising how uneasy and silent some companies were about the subject; perhaps either they feared saying something that could be useful to the competitors or then they did not want to admit the innovation process was not as good as they wished it to be?

”We have a very developed and very structured innovation process; it has probably all the phases anyone could have ever come up with. It works excellently and is well built. It’s a model where ideas are pushed into a funnel, idea generation, and then they start to refine. There are different phases where the idea is refined and they each have their own name. There are committees accepting or

declining the next phases. I'd say it's a very managed process."
Company 9 (large)

In the smallest companies, where the innovation process was not as structured, the decisions to take certain ideas forward and begin to put further financial inputs on them was mainly done through conversation. These companies employed approximately ten individuals and the CEO was close, so naturally also the final decision maker was closer to the core business than in companies with thousands of employees. The innovation process in this type of a company generally began from an individual coming up with an idea and expressing it to the team. According to an interviewee the atmosphere towards new ideas is very accepting and ideas generally are not neglected. The whole innovation process was based on a significant amount of communication as could be expected in companies of this size. Another acknowledgeable factor was the speed in which ideas crossed the first phases when the company size was so small.

When reflecting the interviews to the two other innovation process models introduced in this study (see Figures 5 & 6), they both seem to have their strengths and limitations. Rogers's (2003) model (Figure 5) is as such a good basis for the process for it characterizes the basic phases. Yet it seems like a relatively closed linear model building on the principle that all innovation would be need or problem –based. Thus based on the interviews and the researchers own interpretations it could be argued that the model represents the development of a very routine incremental innovation. Nevertheless even for that characterization it seems too simplified and closed. The same critique cannot be given about the disruptive innovation model by Assink (2006) (see Figure 6); the model characterizes the innovation process as a non-linear, multiphase, complex and transactional set of actions, which on the other hand goes in line with the research of many others (i.e. Kline and Rosenberg 1986). The disruptive innovation model emphasises the transaction within the process which was also stressed in the interviews and moreover arguably is a shortage in Rogers's model. Perhaps the fault in Assink's (2006) model is that it does not acknowledge the possibility of ideas being eliminated from the process at some point of the development which according to the interviewees was a very critical factor. As one interviewee explained, the most expensive is an innovation that is not realized to quit at the right phase. The model rather views the process as continuous in-house development in which the idea circles around until it is processed enough to become a radical innovation.

The interesting part is that although there are countless innovation process models, all of the interviewees who were willing to open up their process described something very similar to the stage-gate model. On the other hand, the stage-gate model is the least academic of the models, which could imply a more practical approach; perhaps the other models mainly aim to describe the phenomena while the latter mentioned model is also meant to be a tool for the companies?

6.4. Competition, co-operation and funding

The interviewees were unanimous about the importance of following the acts of competitors and technologies developing outside the company. Regardless the size of the company, the interviewees described that competitor and industry research and monitoring happens at least on a weekly and for many even on a daily basis. In the larger companies the competitor analysis was often seen to belong to the R&D department, where a large part of the job is about following new publications, patents and other science related to the industry. Thus competitor and market research and analysis were viewed as a routine task in all of the interviewed companies.

”We have to follow. One job of the scientists is to continuously follow patents, look at journals and articles also on the academic side, watch out for things that could become big also in our field. Part of the job for today’s scientist. On the developing side there’s IPR, we have these different patent groups that are followed; that is technology which is already coming. Another route is our sales and marketing, technical service people who are on the field and keep their eyes open and hear news. In this industry, if the competition isn’t fierce at least it is very tough.”
Company 9 (large)

Size was an irrelevant aspect for the interviewees when considering who the competitors are; the determining factors were mostly technology and price. Naturally the small companies at times faced economies of scale and resource limits when competing against large companies, for price is commonly a determining factor in the markets. Nevertheless one aspect to viewing competition is to see it as the current dominant technology, which is deeply adopted by the industry. One company emphasized how their largest competition was this kind of technology due to the challenges of persuading the potential customers to switch. Although switching could be well justified, customers were thought to be rather inclined on sticking to old technologies and habits.

Most of the companies regardless of size found that they constantly have versatile research, development or other projects going on with facets outside the organization. For larger companies the co-operation was often versatile R&D projects with universities or research laboratories such as VTT, while smaller companies often outsourced some part of their development or research process due to lack of specific resources. Based on the interviews it seems the smaller the company is, the more it needs to focus on its core competence thus outsource phases of processes, which can be done more cost efficiently or faster elsewhere. For instance the small biotech companies often do not have own laboratories or piloting and large-scale production possibilities to the needed extent. This is due to strategic reasons of keeping the organization light structured. One interviewee explained how at times customers demand short timespans for research projects. If it is out of the core competence of the company, it may be smarter to outsource the research to the local university and pay them; often the customer is also willing to pay more for fast results. Small companies especially are forced to optimize between their own competencies, buying from the outside, co-operating and outsourcing.

” (We outsource) when needed. It’s part of managing the process; when we run out of hands we need to prioritize, which is necessarily not the only good reason for prioritizing. If the task is valuable enough it is beneficial to find someone to do it from the outside. Or acquire additional resources. This is a choice the management team goes through.”

Company 5 (small)

Several of the small companies based their business on public and/or private funding. Common public sources were EU and Tekes and private sources were venture capitalists and equity investors from Finland and abroad. Some were moving towards customer based income but clearly funding was still an enabler for these companies. Interestingly, Tekes was seen as a major influencer and enabler by almost all of the companies, regardless of size. The most important factors the companies needed from Tekes were funding and support. Tekes offers both risk money for new innovation projects and low-margin loans if the company fulfils certain conditions concerning i.e. self-sufficiency.

Tekes's support and know-how through certain research projects was widely acknowledged. Explaining factors for the importance of Tekes's support for companies regardless of size are most likely the industry and moreover the fact that Tekes is the only organization of this nature in Finland. What is more, one explanation could be that creating new always holds within the aspect of uncertainty and companies generally want to minimize risk. Thus it could be that although large companies could in many cases theoretically bare the risk of innovating new, they do not have the will or perhaps courage to. In these circumstances the financial support of Tekes may be very valued, for it decreases the company's risk and furthermore enables the development of new technology. Therefore through enabling companies to take larger risks, Tekes could be seen also an influencer on the national level. One of the small companies explained how the first funding they got as a start-up from Tekes enabled the possibility of gaining the attention of private funders. The larger companies almost unanimously told that they take part in different Tekes research environments and projects.

”Tekes, as mentioned already. Almost only joint research projects. And if it can be called a joint research project, Tekes can give the funding or it may be so that us and Tekes so that Tekes gives us a low-margin loan for investment and funds our research, but we do the work and report to them.”

Company 9 (large)

Participating in Tekes projects as an observer was also seen as a good way to stay up to date and follow technology developing on the outside of the company. The silent participation in Tekes-projects requires small financial inputs yet gives the option of buying the new technology before the competitors, which may provide competitive advantage.

”We also participate in public projects but their role for us is more about developing the company’s know-how and following the industry. We don’t get so many innovations out of those. Still they have their own meaning from the company self-development perspective. Therefore they may support other earmarked projects.”

Company 11 (large)

The difficulty of finding public and private funding sources aroused mixed feelings amongst the small companies; others found it easy while some said it turned out to be rather complex at times to find investors or justify public funding. According to one of the interviewees, the public sector is now really hyping and investing the bio industry, which is a very good thing for companies in the sector. On the other hand, private equity investors often require the company has also public funding and Finland has only few private investors. Several of the companies had done funding rounds also abroad where private funding is more common and were faced with the issue that Finland is not necessarily the most desirable location for investors. The competition is tough and investors generally want some kind of proof of return-to-investment.

“Long times-to-market are problematic; you have to find patient funders. Good risk investors for us count with a 10 year margin whether they are getting their money back. It feels like these are quite rare and rather the investor’s risk and profit expectations are often focused on a lot shorter time span. Moreover keeping them hopeful requires constantly growing revenue that could quite fast reach the level in which the company could be self-sufficient. This is difficult when balancing with investors.”

Company 3 (small)

”There’s the harsh fact that Finland isn’t a very interesting place geographically. Venture capitalists like to invest close. (This reflects) the attitude that we have to do twice the work in order to persuade people to invest here and also have a very innovative product. Finland is a remote area; we can imagine we are as big as ever, but it is irrelevant if some venture capitalist doesn’t think so. If we were in somewhere like Silicon Valley things would be a lot easier.”

Company 1 (small)

Naturally, also large companies face issues concerning funding, although the nature is different to some extent. While small companies seek public and private funding, large companies compete over money inside the house. Nevertheless also the large companies sought for and received public funding as either risk-money for new innovations or indirectly, when the money is directed straight to for instance partnering facets.

”When you compare developing new technology in a large company to a start-up seeking for funding, we are in fact pretty much in the same position with the difference that we seek the funding from inside the company. There must be a team and a strong business perspective to show it fits us. The strategic management must be committed and make the decision that now we will invest on a new long-term thing.”

Company 12 (large)

6.5. Technology adoption

When discussing the subject of buying new technology from the outside the clear trend was that the interviewed companies seldom buy ready technologies. Nevertheless the companies mostly saw this as an option if the purchase were profitable and well justified. As the model of Frambach and Schillewärt (2002) also shows (see Figure 10), the companies seemed to consider a great deal of internal, external and innovation characteristics prior to adoption. The main issue seemed to be compatibility; technologies are rarely possible to integrate to the company as such, as the literature also emphasises (i.e. Rogers 2003). Moreover, IPR issues were mentioned: the bought technology must be well protected through patents, for otherwise it is of little value to the company. Generally the feeling amongst the interviewees towards buying new technology seemed to be that to this day there had been no need for ready new technologies. It could be argued the companies ponder on the characteristics introduced in Figure 10 regardless if the innovation is from an internal or external source. These are qualities linked to the organizational environment, innovation and organizational qualities. The companies preferred in-house development but nevertheless found it very important to keep their eyes open towards technology developing on the outside.

”We can buy research from the areas in which we have made the choice of not bringing the technology inside the company. Another option is that we take more risk and perhaps get support from some investor and go towards new uncertain developing technology. Either we can decide later to make it part of our company’s inner competences or keep it as outer subcontracted research.”
Company 8 (large)

Currently the companies were mainly buying consultation, research and licensing. As mentioned previously, smaller companies often outsource part of their development process such as market research, piloting and testing or bulk production. Often the concept of buying technology from the outside is also a question of interpretation; the projects could be joint projects, where know-how is bought from the outside and the technology is developed together. However one interviewee explained that if this development was to do with their core competence, then the co-operation was often preferred not to be a consortium but rather a subcontract deal.

”Since we don’t have our own laboratory or testing facilities we mostly co-operate with universities in research and projects. We may order research from them or do joint research depending on the case. But still I feel the ideas and stimulants are from us, which is why I feel the technology is self-produced even though it would stem from joint research with a partner.”
Company 11 (large)

”If the subject is common or recombining we can get Tekes funding and buy ordered research. Also we can take part with “peeking money” in a big public project. Then we follow the technology and see if it could be of utility for us; we keep our eyes open. As you asked previously this is one way to follow (the market), taking part in public projects through steering groups.”
Company 8 (large)

The literature mostly agrees on large companies being more likely to adopt new innovations (i.e. Dewar & Dutton 1986; Damanpour 1987) whereas based on the interviews for this study the matter was not as clear. As mentioned previously, depending on interpretation small companies could in fact be seen to adopt more technology than large companies, who seemed to be more likely to carry the whole innovation process themselves. Moreover one of the smaller companies' interviewees explained how they purchase only ready, piloted technology because it reduces risk and moreover gives more freedom when not having to focus on strictly one technology:

"Our (innovation) process has little phases because the technology is usually already piloted and tested in some academic project. You can just take the publication and observe, because they are usually published; someone has done the work for us. This decreases our risk significantly."
Company 2 (small)

When comparing the technology adoption model conducted by Rogers (2003) (see Figure 11) to the open innovation stage-gate model by Cooper (2008), certain similarities may be identified. Rogers's (2003) adoption model also focuses on searching for new ideas from outside of the organization, although the process is not classified as open. In fact the two models have rather similar phases with the distinction of Cooper's (2008) model including the gate-system. Thus both of the models have characteristics which correlate with the results of the study. Furthermore the similarity of these two models combined with the results of this study could work as a justification for the argument that the innovation process and innovation adoption process are in fact two very similar processes with the distinction of the origin of the idea.

6.6. Risk management

The companies generally accepted the risk combined with the uncertainty of new technology, which is also emphasized to a great extent in the literature (i.e. Harper & Becker 2004; Kline & Rosenberg 1986; Rogers 1983) and recognized the fact that risk and profit walk hand in hand. Nevertheless when asked how large risks are taken concerning new technology, the reactions were mostly amused; there was no straightforward answer and furthermore the subject seemed sensitive for the interviewees. Commonly the subject was addressed in a diplomatic manner, explaining how large risks should be viewed and calculated through the overall project case and based on the company's self-sufficiency and other expected revenues.

In a way this was also an expected answer because from the business perspective the risk concerning new technology must be managed in order for the company to continue profitable functions. Nevertheless this, in the author’s opinion, is one distinction between the literature and the interviews. While the literature (i.e. Rogers 1983) to some extent gives the image of major differences in innovativeness and risk management, in practice it seems that the companies are relatively similar and they all take risks within their resources.

“We don’t usually waste resources to things outside the given frames. Really good ideas can be surveyed to some extent. We look at the strategy which includes a large risk, but the innovation process obeys a certain plan and we don’t just fool around outside of that.”
Company 5 (small)

”We also participate in projects of which little is known about. But then we usually proceed step by step. We take little steps until we see the project works, then we take larger steps. This is in a way a step-by-step thinking model. First we input what needed to get the project running. Then when we see its working we add rounds and go for bigger volume. And quit the project if it doesn’t work.”
Company 10 (large)

According to the interviews a crucial factor to managing risk in innovation development is the objective scrutinizing and evaluation of the processes and furthermore the courage and understanding to terminate projects if they seem too risky. There is the risk of getting too attached to a project and thus not seeing the objective facts clearly which is why it is good these decisions are often made by teams.

“When you put a lot of money on some product at some point evolves the ‘point of no return’. That refers to the situation that we cannot push the innovation through with any price to get our own money back. We have to be sure this doesn’t happen to us. We are even over realistic; if some results don’t seem good enough we have to be able to kill projects at any point. That is unconditional for us.”
Company 1 (small)

6.7. Bottlenecks and challenges in innovation and adoption

The potential bottlenecks and challenges which arose through the interviews for this study are presented in the following Figure (see Figure 14). It should be acknowledged however that most of the factors affect each other and thus cannot in reality be so strictly grouped under certain themes.

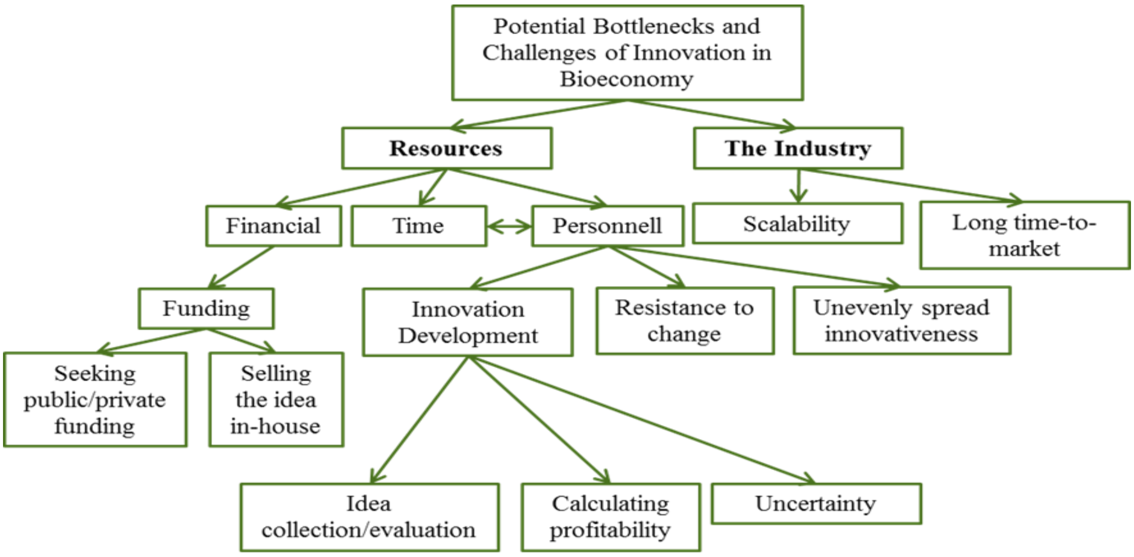

Figure 14. The Potential Bottlenecks and Challenges of Innovation in Bio-economy.

A common bottleneck for companies with bulk production was the uncertainty concerning scalability. As Abernathy and Utterback (1978) also identified, high-volume companies seemed to be slower in adopting new complex technology due to the occurring issues in concerning price and productivity when the masses grow. Newly developed products could function well in the laboratory facilities but when transferred into large-scale production it was found that the qualities may alter. The challenge in this is the predictability; the innovation could have functioned flawlessly on smaller scale and thus eaten a lot of resources and nevertheless not function in its true scale.

Another issue was to do with new ideas; some interviewees expressed they had difficulty with being able to grasp the best ideas while some mentioned they feel that good ideas simply do not arise often enough. In the latter case the interviewees felt they would have the eagerness, resources and other qualities to take the ideas forward if they simply matched the qualifications.

”The balance of terror; the amount of information coming in is massive and the more people are channelled to handle it, the more information stems (out of the process). The dough spreads and somehow we need to stay in the boundaries of what is smart and try to find the best we have. The shots don’t always hit the goal. Failure. Maybe if you have ten shots one goes in the goal, which is a good thing. And as I said about benefit and implementation, nothing is of utility to the company before it has been implemented and put into use which is why this must be an aim and resources should be allocated for it.”

Company 10 (large)

The most common bottlenecks for innovation activities seemed to be resources; financial, personnel and time. Finding the time to concentrate on other than the key tasks seemed to be one bottleneck for innovativeness – when all time is used on routine tasks, how can new technology be developed? While small companies experienced resources and the seeking of funding as challenges for innovating, this was even seen as a bottleneck for innovativeness by one of the interviewees:

“Currently one of the largest (bottlenecks for innovation) is selling the new projects in-house. There is really tough competition over the investment money. We have to maintain the current facilities which bring the money and income flow. In addition to that we have several different businesses which all compete against each other for investment and research money.”

Company 12 (large)

Some companies expressed the difficulty of managing the uncertainty of both innovations and the industry; the long time-to-market/use typical for the industry also acknowledged in the literature (i.e. Kline & Rosenberg 1986) combined with the uncertainty of innovation resulted in issues with predicting and calculating the profitability of innovations. Simula et al.’s (2009) research supports the results of this study which indicate the calculation of profitability in innovation activities being relatively complex. This is due to the lack of a direct view or regulation of what batches should be allocated to the innovation. The general feeling seemed to be that R&D costs are considered as “drowned costs” without payback expectations.

”We don’t have measures or goals for innovations in particular, but we have an extremely good and efficient process with clear payback-time goals for investments. Similarly as we talked about 10-year projects which proceed to the investment phase, then we don’t calculate the research money’s return. We follow it but there aren’t such goals. In research and innovation activities it should be accepted that you need several projects and just hope there is that one golden egg.”

Company 12 (large)

One of the interviewees from a larger company expressed the difficulty of the innovativeness not being spread evenly in the organization; some units were very innovative and constantly thinking ahead of time while others had no interest in this kind of activity. Breaking these boundaries and co-operating more between units on a day-to-day basis was something with room for improvement, as could be expected in large multinational companies. Also an interviewee from a smaller company told that the distinction regarding innovativeness between individual employees should be made in order to reach full potential.

Repenning (2002) discussed the subject of organizational resistance to change, which was an aspect which also arose from several interviews; whether talking about technology adoption or implementing own new technology to the company, individuals are often reluctant to changing learned habits. One of the interviewees from a smaller company discussed how they were actively implementing a structured innovation process and the project had turned out to be more complicated than expected. Through the process the interviewee had noticed that unlike they had predicted, the new process cannot just be dropped into the company. It requires careful long-term commitment in implementation. This in fact is an example of a certain kind of technology adoption and the bigger the change is, the longer the process concerning change could also be expected to be.

What is more, as the literature explains (i.e. Christensen & Overdorf 2000; Mueller & Tilton 1969), large companies may face problems with slowness in processes due to complex organization structures, long decision-making chains and bureaucracy. Nevertheless the largest issues based on the interviews concerning process times and slowness in innovation development were not size but industry related. The innovation process requires several facets from outside the company to accept the different phases. These processes are commonly slow; for instance the handling and processing of a patent application can take up to years. Furthermore beginning from invention notifications to piloting, testing and safety regulation processes, the innovation process's time span is often out of the company's hands. As mentioned previously, financial issues are always a bottleneck for innovating at least to some extent regardless of company size; generally, large companies' projects compete for in-house money while small companies seek funding from the outside. The unifying factor for both small and large companies nevertheless is the need for risk money in new innovation development – thus one bottleneck is the lack of resources for uncertain projects. This is where Tekes has an important role as an enabler for companies to take larger risks in developing new technology.

6.8. Synthetic biology

When discussing synthetic biology with the interviewees it became clear rather fast that the term lacks an accurate definition and thus leaves room for interpretation. Moreover these interviews supported the presumption that synthetic biology has no to this point entered the industry in Finland, while in for instance the US it is already applied in the industry. On the other hand, this also depends on the used definition, because according to the interviews bio-pharmaceutical companies already use technologies that may through some definitions be classified as synthetic biology.

"What is SynBio, where is the line drawn? What's SynBio and what's regular gene modification. The line isn't clear. For some SynBio is building cells and thus creating new systems while currently it is mainly about doing pathways or small metabolic modifications. I believe that when we get to the point that organisms are actually created from scratch then acceptability may become an issue. But now that we are talking about these small modifications I think they are a standard currently in biotechnology."

Company 7 (large)

The interviewees could in fact be divided into two groups concerning synthetic biology: those who had closely followed the science developing around the technology and those who had a hunch of the term but no closer insight to the details. The general atmosphere concerning the new technology was interested and positive. The interviewees who had followed the technology and were familiar with VTT's research on the matter found synthetic biology to possess great potential and saw it as the technology of the future. Also the interviewees who did not have too much previous experience concerning the subject were interested to hear more. The natural reaction to the subject was that of course the companies are interested in new technology if there is identifiable utility that exceeds costs.

For the interviewees who were familiar with the technology, the potential was clear. Nonetheless the interviewees were still missing proof of the technology and moreover clear cases concerning how they could utilize it in their business.

"I think it's the logical way to proceed. Proof is needed, even in the smallest scale. Proof that it is possible. Then there is always the point of business potential; what would our role be and what could we achieve from co-operating (with VTT)." Company 12 (large)

The companies operated in different fields thus a unified view concerning the subject is difficult to be drawn. As the literature recognizes (i.e. Moore & Benbasat 1991; Tornatzky & Klein 1982; Agarwal & Prasad 1997), the perceived characteristics of an innovation are subjective thus the radicalness and newness of synthetic biology for each organization should be viewed case-by-case. The literature emphasizes the concept of re-inventing, which to a great extent means that the technology cannot be expected to behave similarly in all companies, but rather that it would mould through time in organizations to different forms that serve each company's needs best. Coherently to the theory by Govindarajan and Kopalle (2006), one interviewee identified how synthetic biology will probably begin its diffusion from the smaller niche pharma markets and continue towards larger markets finally ending up also in high-volume production.

Generally, little concern arose regarding the acceptability or ethical issues of synthetic biology. A reason for this could be the industry; gene modifications were already a part of operations for many of the companies. Furthermore none of the interviewed companies were operating in the food industry, in which the acceptability of gene modifications has been on the table recently. Nevertheless interviewees from both small and large companies expressed their concern towards image and found it very important to do comprehensive market research before adopting any new technology. The risk of ethical issues and other bad publicity must be minimized; with today's technology information travels fast which is a crucial factor especially for the companies operating close to the consumer interface.

"Image is also one thing. The image is hard to build but fast to destroy. That we cannot afford." Company 1 (small)

6.9. The theoretical model for the innovation process in bio-economy companies

This thesis brings forward a new theoretical model for the innovation process based on the previous literature and findings of this study (See Figure 15). The model is an extended version of the theoretical framework (See Figure 1) opening the innovation process and furthermore putting side by side the internal and external sources of ideas and technology. Moreover the model differs from the framework in what stages belong to the initiation and implementation stages; the results implied that wherever the idea or technology stems from, it is handled in a similar manner from the early stages. The model is a hybrid of the previous models focusing on the observations of organizational openness in the modern world and similarity in the previous technology adoption and innovation processes. The author of this study would find it to some extent incorrect to talk about innovation rather than idea or technology at the screening stage, for as the literature and this study points out, an innovation is merely an invention without the element of utility, which cannot be verified at the very earliest stages.

Since in the bio-economy companies external technology seems to often be adopted at an early, incomplete phase, also the external technology has to go through the similar process the internal ideas follow. The idea gathering phase indicates the way organizations gather ideas from an infinite amount of internal and external sources. The sources of the ideas are defined more accurately in Figure 13. Innovation may often be research- or need-based, yet it could be argued the most disruptive of innovations seldom stem from the basic R&D

process. The innovation process is a set of stages and gates, where the gates are monitored by certain management teams with objective qualifications the idea/innovation must fulfil at each stage. At each gate the decision of continuing, terminating or revising the idea or technology is done, which is resembled in the model by the arrows. The duration of each stage is unique for innovation seldom behaves in a unified manner. Especially in the case of technology adoption, the duration of each phase depends on the readiness of the technology. The dashed outline of the model indicates the openness of the phases throughout the process: there are external influencers and the process must be possible to terminate at any phase, if proven unprofitable. The balls floating in the model resemble the ideas that come into the organization in large quantities, are dropped out in the duration of the process and finally a very small percentage makes it through the process.

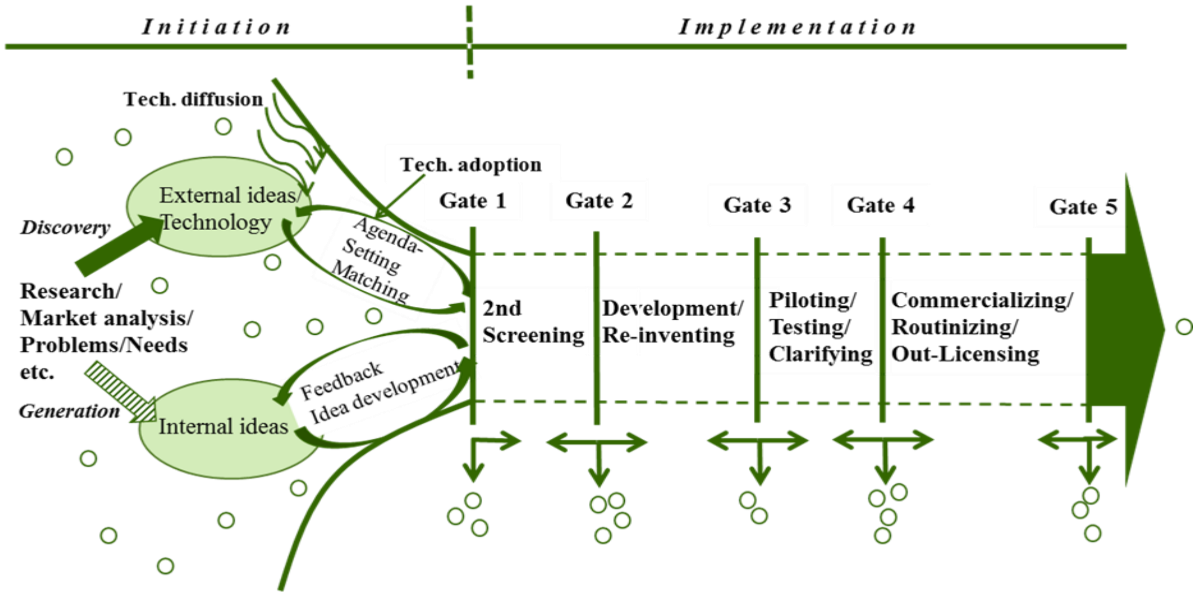

Figure 15. The theoretical model of the innovation process in bio-economy companies.

The introduced model is a simplified and generalized description of how bio-economy companies process innovations from the idea generation to a ready product or process. Disruptive innovations are managed more case-by-case thus this model cannot in all cases be extended to them. The more radical the innovation the more it possesses uncertainty which makes it difficult to be framed into any given model. Nevertheless it could be argued the disruptive innovations also begin from an internal or external idea or technology and must to some extent go through the phases of development, testing and launching. It seems the greatest difference is in the controllability and thus fulfilling the objective measures at the gates; disruptive innovation often requires certain risk-taking that is not justified by the objective measures that incremental and routine innovations which are put through the process fulfil.

7. DISCUSSION AND CONCLUSIONS

In this chapter the findings discussed in the previous part of the study are summarized after which the conclusions based on the previous literature and results of this study are introduced. The chapter finishes with determining the possible limitations and by discussing the potential future research directions concerning the subject.

7.1. Summary of the Findings

The main interest of this study was to scrutinize the organizational innovation and technology adoption processes and to understand how organizations generate innovations. When mirroring the results of this study to the innovation and innovation process theories it becomes clear that theories are productions of their time, which supports the acknowledgements of Elite (2006). As has the innovation process theory moulded from linear to non-linear and complex, also the technology adoption process has changed and new theories have emerged. The concept of open innovation in the modern world has to some extent faded the line between technology adoption and organizational in-house development; depending on interpretation could it not be argued that if ideas are classified under the term technology, most companies in fact absorb new technology constantly? Furthermore it could be reasoned that most ideas, whether from outside the company or not, go through the similar technology adoption phases. The coherence of Rogers’s (2003) technology adoption model and Cooper’s (2008) open innovation stage-gate model combined with the results of this study support this claim. These factors lead to the attempt of a new theoretical model for the innovation process (see Figure 15), which combines the previous models with the key findings and observations of this study. As the model shows, when discussing the theory of organizational technology adoption the author of this study claims that the ideas basically go through the similar process regardless where they stem from.

Today, methods and technology are more easily accessible than ever. Organizations see it as a necessity to follow developing technology and competitors, which leads to companies being open to an ever growing extent. Many of the interviewees described their companies to have characteristics of open innovation without necessarily using the term. Most of the companies were involved in joint research and development projects and licensing technology or in out-licensing developed technology not matching their core competence. When the concept of idea generation was discussed, an infinite amount of possible internal and external sources for ideas and innovations arose. The amount of external sources reflects the openness of organizations in the common world, for it seems to be commonly acknowledged that not all wisdom stems from inside the company, which is also one principle of open innovation (Chesbrough & Crowther 2006). Perhaps the trend of the modern world is that companies seldom are closed to the extent they could have been in the past. Furthermore joint ventures and other forms of joint R&D projects were common for all of the companies.

Organization size affects the way companies manage, process and adopt ideas and innovations. Differing from the literature (i.e. Mueller & Tilton 1969; Christensen & Overdorf 2000) it was found that small companies were not more prone to develop radical innovations, for all of the interviewed companies found developing new technologies and other innovations a core competency in the competitive markets. Furthermore radical innovations were very rare for all companies and resources seemed to be the main restrictor for innovation. Interestingly, both large and small companies identified scarce resources; small companies sought public and private funding while large companies expressed tough competition in justifying in-house funding. Tekes was seen as a major enabler for innovation due to the support and risk-money for new innovations it offers when companies regardless of size fulfil certain criteria.

The most important enablers for innovative activity were viewed to be sharp individuals inside the organization, effective and cooperative teams and furthermore, an innovation-supportive and enabling organization. Interestingly, while the literature (i.e. Ettlie et al. 1984; Howell & Higgins 1990) emphasises the role of champions, they are generally viewed to be important especially in small companies and start-ups. However the interviewees explained that also large companies need these entrepreneur-minded strong and brave individuals to stand behind and carry through the ideas. Nevertheless, it was emphasized in several conversations that without a well-functioning team and good management, no individual could stand out. The organization was in fact viewed as the most important factor when it comes to innovation, for even the most innovative ideas cannot be put through without the organization's support.

All of the interviewed large companies had a structured innovation process, which was commonly some company-specific application or otherwise similar to the stage-gate model introduced by Cooper (1990). Based on the interviews it could be generalized the smaller the company is, the more unlikely the innovation process is to follow some very structured process model. A large influencer for this is necessity; if the company has approximately ten employees, the innovation can more easily proceed in the organization without tough structures while if this were applied in large organizations, the ideas would probably be left to their starting point. The evaluation of ideas seemed to be a very objective and rational process monitored by management teams. If the company had an innovation process, the invention would need to fulfil certain criteria in and after each phase of testing. Controversially also without the structured process the invention would go through a certain set of actions which determine whether it is good enough to be continued and invested on further. From the business perspective the importance of understanding to terminate an innovation process at the right time if necessary was emphasized; the most destructive innovation is one that was not understood to quit early enough.

Another interesting and perhaps to some extent self-evident finding of the study is that theories and practice seldom go hand in hand; the interviewees were without exception aware of the innovation process theories yet most admitted that commonly the process happens case-by-case. Nevertheless the interviewees explained that the companies try to stick to the processes and especially incremental innovation often goes through the certain chain of actions. Yet it became evident that the theories are, to an arguable extent, mostly moulded to describe the actions of large enterprises; in small companies the procedures often seemed to be less structured. The development of disruptive innovations was seen to differ from the process in many ways; coherent to the research of McDermott and O'Connor (2002) the uncertainty, risk and both financial and human resource inputs all added a twist to the management of the innovation process. Perhaps, as many interviewees explained, disruptive innovations are so rare their development process cannot be put into a certain frame but must rather be considered as unique and individual cases.

It could be argued that all of the companies innovate within their resources, thus large companies' projects are often in a much larger volume. Small companies explained how they need to focus on their core competencies and technology even though at times other interesting ideas outside this area could also come across. Both of the company types had their limitations and enablers for innovation; in small companies ideas move and evolve fast while large companies may suffer from bureaucracy and strategic issues. Nevertheless the industry was seen as a large influencer in the time span of the innovation process, for several of the phases were monitored by a third party. Moreover the innovations must be thoroughly tested and piloted, which combined with the patent application and other third party issues often lengthened the time-to-market or time-to-use.

The question of technology adoption depends on where the line is drawn; while ideas are constantly adopted from the outside both consciously and unconsciously, the forms of technology adoption for the interviewed companies were licensing, joint ventures and research projects, consultation and ordered research. Small companies often purchase to a greater extent from the outside due to centralized functions – if an action such as an area of research or piloting is not a core competence, outsourcing is often more cost efficient. Generally it was found that purchasing ready technology is often unjustified; the companies preferred to develop in-house due to the technology seldom fitting to the organization as such anyhow. Nevertheless the common opinion was that if the technology could as such be justified in the way that it brings some added value to the company and would be more cost efficient than developing in-house, purchasing ready technologies would also be possible. One matter of acknowledgement and discussion is whether an idea or innovation may be called disruptive at the point of organizational adoption, for as the definitions show, a technology may be considered an innovation only at the point of commercial value or other significant utility. Thus it could be argued that whether the technology is adopted as an idea or a ready technology, the radicalness is determined only after integration to the company's processes and commercialization, depending on the innovation's nature.

The interviewees expressed many challenges and bottlenecks concerning the innovation process and technology adoption. The industry-related challenges were mostly tied to scalability and the long development times. Nevertheless most of the challenges were internal and tied with resources; financial, time and personnel related. Arguably the largest restrictors for developing innovations are the scarce resources companies have, especially for uncertain projects. Innovation possesses always a great deal of uncertainty – the common rule could be stated 'the more radical the innovation, the more risk and uncertainty'. Furthermore the larger the element of newness, the more testing and piloting the invention requires, which increases the costs. Thus radical innovations have a long time-to-market or time-to-use, are very uncertain and possess a large risk, yet the possible profit is also greater than with incremental innovations. Nonetheless at times the risk may be difficult to justify, which increases the importance of Tekes as a source for risk-money for new innovation development. Finland was seen as geographically challenging for finding foreign investors and the domestic investor markets are relatively small. Several of the interviewees emphasized that they would in fact be more willing to grasp new opportunities if they could get more financing from outer sources. This arouses the question of whether in fact all companies would be more dynamic and innovative if given the resources; is innovativeness less tied to the individuals and more to the scarce resources? Naturally the subject is not this straightforward, for especially very small companies seem to be built around very innovative individuals who find solutions to overcome financial issues.

The case of adopting synthetic biology was approached in the same manner as the question of adopting any technology; evidence and justified purpose are needed. The potential of synthetic biology was recognized by the interviewees who were familiar with the subject and the general feeling about the technology was positive curiosity. Naturally the thought of being part of developing and adopting new-to-the-industry disruptive technology was tempting, yet as has been pointed out in this study, companies balance risk with reward – without evidence the risk is too large. The technology does not have to be ready in order to be appealing for the companies, for many of the interviewed companies regularly participated in joint research and development projects. Controversially, the approach of joint development and partnering could be a better approach in integrating synthetic biology to the Finnish bio-economy. This is due to the manner in which companies seemed to be reserved over buying ready technology, active in partnerships and interested in generating new technology. The ethics or other issues concerning synthetic biology as a technology did not raise major concerns, although some of the interviewees pointed out that customer and market research should be carefully done prior adoption to avoid any risk with company image.

7.2. Conclusions

Innovation is a much discussed subject in the modern world; even to the extent that the term may at times be considered worn out. New technology and innovations are seen as the key to staying ahead of competitors thus innovation is truly emphasized in companies as a part of actions from idea gathering to implementation and commercialization. There are versatile tools for gathering ideas from employees and moreover reward systems for innovativeness are commonly used. These are only few examples of supporting employee ideation activities. Most likely due to the past years' hype around innovation, the distinction between radical and incremental innovations seems to be common knowledge although in several occasions there may be difficulty in determining a radical innovation due to the lack of strict and clear criteria. Nevertheless the research indicated that companies often have at least one radical innovation which in small companies is often the core competence or platform technology.

The aim of this thesis was to understand how companies generate ideas and technology from both internal and external sources into ready technology and innovations. Although the results indicated to some extent similar factors as previous innovation research, also differences and new findings were identified. Innovativeness as a subject is very interesting, for naturally no company would identify themselves as laggards or in fact anything but pioneers or at least early majority. However the research indicated that no company is an innovator in all situations or controversially, that all companies are at times laggards if they do not view the emerging technology profitable. The more radical the idea or innovation is, the more uncertainty and risk it possesses hence it is evaluated even more thoroughly before further inputs. The question of innovation adoption timing is dependent on so many organizational factors it would be inaccurate to group companies in an absolute manner through their level of innovativeness.

Companies innovate and bare risk in the boundaries of their resources. Innovating seems to be a rational process monitored by objective measures and strict control from management teams. This to some extent shatters the image of fearless pioneers who manage great risk and push radical innovations to markets. Nonetheless perhaps the image may be compared to the difference between theories and practice; generalizations and exaggerations are made in order to generate clear distinctions and models. In real life risk is strictly monitored which can be indicated through how innovations are developed step-by-step by increasing inputs when the technology fulfils certain criteria. If a leap to a very radical and uncertain area is made, the risk is calculated and balanced through other, more certain functions. Perhaps innovativeness is a company characteristic measured not only by realized innovations but also by an organizational culture, which enables individuals to bring forward, generate and process new ideas both from internal and external sources. In both small and large companies champions are needed, yet without an innovation-supportive organizational culture the ideas can seldom be pushed through. The question remains whether organizational innovativeness in fact correlates most with the organizational, financial or individual employee aspect; if given unlimited resources, would all organizations be innovators? Most probably the combination of these three aspects is needed in order to develop an ‘innovator organization’: a supporting organization, sufficient financial resources (innovation or risk money) and innovative individuals.

Technology adoption is similar to in-house development in the way that the technology must nonetheless be re-invented to fit the organization. Based on the research, purchasing and adopting ready technology is very rare in bio-economy companies whereas other forms of technology adoption and open innovation are practiced to a great extent. It could be argued that the level of disruptiveness of the technology is difficult to predict before it has been implemented, for the concept is relatively subjective and dependent on the company's former procedures and technologies. Thus the innovation and innovation adoption processes are relatively similar regardless whether the idea or technology is absorbed from the outside or developed in-house. Furthermore through developing technology, companies are ever more aware of the competitors' and markets' actions, which also enable a growing amount of external sources for ideas.

Although companies preferred to develop technologies in-house or in joint ventures, the possibility of purchasing ready technology was seen as an option if it could be very well justified through for instance savings or process enhancements. Nonetheless the trend seemed to be that especially if the technology matches the core competence or it can be justified through efficient use of resources, companies are more willing to develop the technology themselves or with partners from an early phase. The interviews give a positive outlook for the future of synthetic biology in Finland, for the general atmosphere on the market regarding the technology was curious and optimistic.

7.3. Limitations of the study, recommendations and future directions

This study possesses several limitations which limit generalization of the results. The largest potential limitation is the subject of the thesis; the innovation process, risk management and idea generation all seem to be delicate subjects for companies most probably due to fear of accidentally telling matters that could be beneficial for competitors. Since the empirical part was gathered by interviewing company representatives and the interviews were conducted only for the purpose of this thesis, naturally there could be distortion in the results. The interviewees would most likely want to give a highly positive picture of their innovation process and other in-house actions and controversially, the researcher can think of few rational reason an interviewee would describe negative issues or shortages in detail in the given situation. Thus there is the possibility the results are overly optimistic and give an excessively positive view of the organizational situations. Furthermore although the amount of interviews was carefully considered and the final interviews rather supported the findings than brought new results, the sampling is relatively small and there is always the possibility that other bio-economy companies would act very differently. This is a common limitation for qualitative research implying the results should be thought of as individuals' opinions rather than absolute facts. Therefore certain discretion should be used when generalizing the results.

The research leaves room for a lot of further research; especially the concept of diffusing synthetic biology to the Finnish market is a new subject for research. It would be very interesting to get even deeper into companies' innovation processes and understand on a deeper level how the processes work, how ideas are generated and how radical innovations are born. This however would be a difficult subject for further research due to the limitations mentioned in the previous paragraph. Another interesting subject for future research is to what extent innovativeness is tied to resources; could there be also other measures to innovativeness than the amount of new inventions on markets? It would be interesting to research to a greater extent the subject of whether companies would develop more disruptive innovations if given the financial resources, or are the actual bottlenecks in fact something other than financial. One of the main findings of this study – the similarity of the innovation and technology adoption processes is also in need for further research. Perhaps the subject could be scrutinized with a larger sampling and also in other industries.

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APPENDICES

Appendix 1. The theme interview

Theme 1. Innovation background

- What does innovation mean in your company?

-How is innovation linked to your business?

- Is innovation and innovativeness emphasized? How does it show?
- Is it a central goal for the R&D department?
- Is innovation considered important?

-How broadly are competitors and technology developing on the outside followed in the company?

-Of what nature are innovations typically in your business? E.g. new technologies, products, processes…

- Incremental or also disruptive?

-Do all the innovations come from inside the company or do you buy e.g. research, technology, consultation, other services or ready products from the outside?

- Is buying technology from the outside seen possible in the future?

Theme 2. Innovation process

-What kind of phases are there in an inventions path from an idea to a product, service or process?

- What facets take part in the process (internal or external)?
- How long would you describe the technology's path from an idea to a product/process/service or to a part of the company's functions?

-Does the company have a structured innovation process?

- "What happens, when an interesting idea is identified?"
- Any structured model or established ways of functioning with ideas/innovations?

-How does absorbing bought technology differ from that from inside the organization?

-How does the nature of the innovation affect its adoption?

-What is the time frame like in innovation development?

- Time to market → is long time potential thought about a lot?
- What is a long/short development time?

-How is it decided what ideas are emphasized and invested in; how are good ideas identified from the bad ones?

- What departments/facets make the decisions in the end?

-Is the role of Champions emphasized in innovation adoption/development?

-How ready should the purchased technology be?

- Is the company willing to invest in product development or do you want to purchase ready technology?

-How much is new technology/innovations invested in financially (some percentage etc.)?

- Does the input come internally or also from external sources?
- How difficult is it found to seek funding?

-When is an innovation successfully part of a company's processes?

- How do you monitor profitability?
- How long can the payback time be?
- Are there other measurements apart from financial?

Theme 3. Challenges

-What kind of challenges have there been in adopting/absorbing/developing new technology?

-What are the largest obstacles inside the company in receiving new technology?

-How large risks do you take concerning innovation?

- How certain should success/profit be in order to be ready to take the risk?

-Does the technology's potential need to already be proven by the markets?

- Does the company grasp uncertain ideas (to what extent)?

-What factors could help to absorb new technology?

-Any other subjects you would like to bring up?

<u>Theme 4. Synthetic biology</u>

A brief opening on LiF and synthetic biology

-How familiar are you with synthetic biology?

- *Examples of how synthetic biology could be utilized in the company..*

-“What should happen in order for you to be ready to adopt synthetic biology into the company’s processes?”

-How ready does the technology need to be?