Lappeenranta University of Technology
Faculty of Technology Management. Department of Industrial Management
Kouvola Research Unit
Research Report 242

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Innovation Management of Biorefineries in Finnish Forest Sector

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ISBN 978-952-265-271-3
ISBN 978-952-265-272-0 (PDF)
ISSN 1799-3563

Kouvola 2012

FOREWORD AND ACKNOWLEDGEMENTS

This report is an outcome of a European Regional Development Fund (EAKR) project called BIOTULI (New products and business models for the biorefinery industry). The project examines new antibacterial products and the opportunities they offer for small and medium scale companies. Also new business models are being created and innovation processes are identified for the future growth sector of biorefining. In addition, processes for using the by-products for energy production are examined. The project has four work packages and this report is part of the Innovation work package which aims at determining the current state of innovation activities in Finnish forest industry and the challenges faced when getting into biorefining as well as analysing the innovation management practices suited for forest biorefineries. The work has been carried out in the Department of Industrial Management at the Kouvola Research Unit of Lappeenranta University of Technology during 2011-2012.

It has been great to have been able to work in this interdisciplinary and unique project. I would like to thank Vesa Karvonen, the Director of the Centre for Separation Technology at LUT, for initiating this project as well as enabling and supporting it. I would also like to convey my appreciation to the Regional Council of South Karelia for financing this topical project. The expertise and insight of company representatives from Andritz, Stora Enso, and UPM is gratefully acknowledged. I would also like to express my special thanks to Prof. Marko Torkkeli and M.Sc. Pekka Salmi from LUT Kouvola for their valuable comments and advice.

Kouvola, 22th August, 2012

Melina Maunula

ABSTRACT

BIOTULI report, WP 5 Innovations

Innovation Management of Biorefineries in Finnish Forest Sector

This report is part of the BIOTULI (New products and business models for the biorefinery industry) project and it aims to give a comprehensive overview of the opportunities integrated biorefining can offer to Finnish forest industry companies and to assess what changes it would require from these companies to implement biorefining into their business. Also the strengths and weaknesses of the Finnish forest industry companies connected to biorefining are examined through innovation management theory frames, industry comparisons, company examples and couple of case-examples.

The biorefinery concept allows companies to renew their business strategy and to maximise their value creation from the resources brought to the mill and to produce multiple bioproducts in an efficient manner. At their best forest biorefineries can be environmentally friendly alternatives for traditional production methods, simultaneously creating new innovative products and processes. They can help to maintain the profitability of old business functions whilst gradually pushing the company into a new, more efficient, and environmentally friendly way of doing business.

The conclusion of the report include the statement that the Finnish forest industry has a good starting point for biorefining and many advantages compared to other countries and industries. Innovation management tools and methods can be used to ease the transition and to enhance the innovation process of the company but in order to succeed also the principles of open innovation must be embraced.

Keywords: biorefining, integrated biorefinery, innovation management, cross-industry innovation search, strategic foresight, project portfolio management, forest biorefinery, Finnish forest sector, pulp and paper industry

TIIVISTELMÄ

BIOTULI-raportti, WP 5 Innovaatiot
suom. **Biojalostamon innovaatiojohtaminen Suomen metsäteollisuudessa**

Tämä raportti on kirjoitettu osana BIOTULI (Biojalostamon uudet tuotteet ja liiketoimintamallit) -projektia ja sen tavoitteena on antaa kattava yleiskuva mahdollisuuksista, joita integroitu biojalostus voi tarjota Suomen metsäteollisuuden yrityksille. Yritysten vahvuuksia ja heikkouksia biojalostukseen liittyen tarkastellaan innovaatiojohtamisen teorioiden kautta, toimialavertailuin, yritysesimerkein ja muutaman case-esimerkin kautta.

Biojalostamo-konsepti tarjoaa yrityksille mahdollisuuden uudistaa liiketoimintastrategiaansa ja maksimoida arvonmuodostus raaka-aineista, jotka tuodaan tehtaalle. Parhaimmillaan metsäbiojalostamot voivat olla ympäristöystävällinen vaihtoehto perinteisille valmistusmenetelmille, edistäen samalla myös yrityksen innovatiivisuutta. Ne auttavat säilyttämään nykyiset toiminnot ja tuotantolaitokset kannattavina, siirtäen yritystä vähitellen kohti uutta, tehokkaampaa ja ympäristöystävällisempää toimintatapaa.

Johtopäätöksenä voidaan todeta, että suomalaisella metsäteollisuudella on erityisen hyvät lähtökohdat biojalostukseen ryhtymiseen. Innovaatiojohtamisen menetelmiä voidaan hyödyntää tarvittavan muutoksen aikaansaamiseksi, mutta ennen kaikkea biojalostustoiminta edellyttää uuden innovatiivisemman ja yhteistyöalttiimman ajattelutavan omaksumista.

Hakusanat: biojalostus, integroitu biojalostamo, innovaatio johtaminen, innovaatioiden etsiminen toimialojen rajapinnoista, strateginen ennakointi, projektiportfolion hallinta, metsäbiojalostamo, Suomen metsäsektori, sellu- ja paperiteollisuus

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The forest industry has historically been very important to Finland and its role in the economy has been substantial (Oksanen, J. et al. 2010. pp. 10-11). It still is among the industries with the biggest imports with a share of about twenty per cent of the total imports of Finnish industry products (National Board of Customs. 2012. p. 11). Finland has one of the strongest forest clusters in the world and many of the technologies currently used in the industry have been developed by Finnish companies (Oksanen, J. et al. 2010. pp. 10-11).

However, the traditional forest industry is facing challenges and the industry is in transition. Overcapacity, mature market conditions in main markets and low-cost production in South-America and Asia are lowering the prices of traditional paper products. Pulp and paper companies in Finland have responded to the structural change by adjusting capacity and enhancing efficiency (Hetemäki, L. 2006. p. 36) but the costs cannot be reduced much further and the competition is increasing (Thorp, B. 2005. p. 35). Also the overall economic situation has been difficult during the last years. The amount of employees in the biggest forest industry firms in Finland, M-real, UPM and Stora Enso, has already decreased by 37,000 between 2005 and 2011 (Heikkilä, M. 2012a. p. 22). There have been cutbacks in production and factories have been closed. At the same time there have been very few new companies starting in the forest sector, which is worrying. (Oksanen, J. et al. 2010).

The current kraft mills were designed to capture the economy of scale and to produce huge amounts of uniform products and modest amounts of energy. Now the industry is in desperate need of new innovations and products with more added value. Companies with innovative and customer-focused strategies seem to have a lot brighter future than the companies relying on old business models and trying to save themselves through mergers and acquisitions. The biorefinery concept offers the opportunity to maximise the value creation from the resources brought to the mill and to produce multiple products like biochemicals, biomaterials and bioenergy in an efficient manner. (Thorp B. 2005. pp. 35-36)

Although there are many other potential products and product categories worth developing, like for example nanotechnologies, intelligent paper and packaging products and building materials, biorefining might well be the opportunity with the most extensive growth potential in Finnish conditions (Hetemäki, L. 2006. p. 37).

1.1 BIOTULI

BIOTULI is a project, coordinated by the Lappeenranta University of Technology. It is carried out in 2010-2013 and has four work packages: Separation techniques, Business models, Energy, and Innovations. The project focuses on the area of South-East Finland and more specifically the region of Kymenlaakso. In addition to the Lappeenranta University of Technology, local universities, Finnish innovation and development organisations of the area, as well as companies operating in the forest sector are participating in the project.

The project aims to find new or known industrially exploitable antibacterial compounds that could be used for example in medical products. Compounds with antimicrobial characteristics are being found and isolated from the wood material using several chemical and enzymatic degradation methods. Inter alia lignanans, flavonoids, stilbenes, aldehydes, ketones and tannins are examples of biologically active phenolic compounds.

The compounds are researched and developed in order to determine their usability in healthcare products and services. Also the food processing industry is looked into. New product markets and business models are particularly examined from the SMEs' (small and medium sized companies) point of view. In addition the use of by-products as a source of energy is examined, concentrating mostly on the production biocoal.

This report is part of the Innovations work package. The main objectives of this work package are to

1. determine the current state of the innovation activities in Finnish forest industry companies and to review what kind of changes the implementation of a biorefinery would require from those companies.
2. analyze and compare examples of similar innovations in other sectors, and on these basis assess how different methods and best practices of innovation management could be applied to biorefining in Finnish forest industry.

1.2 Objectives and motivation of the report

The aim of this report is to give a comprehensive overview of the opportunities integrated biorefining can offer to Finnish forest industry companies and to assess what changes it would require from these companies to implement biorefining into their business. This is a qualitative study based on literature and numerous web-searches. Also some company representatives from the industry were informally interviewed to get a more profound view of the subject.

The report focuses on biorefineries, especially integrated ones (instead of stand-alone facilities), as biorefineries can be especially profitable when combined with the existing resources and capabilities of the forest industry (Hetemäki, L. 2006. p. 37). This is why the report also focuses on the use of wood and woody residues as raw material. However, most technologies that can be used for wood can also be modified to suit other biomass feedstocks (Alén, R. 2011. p. 58). Even though the primary driver of development in green chemistry seems to be the production of transport fuels (Alén, R. 2011. p. 56), this report does not address the subject of liquid biofuels. The bioenergy part of the report concentrates mostly on biochar, and the biorefinery part on co-production of different bioproducts and biomaterials with the highest possible added value.

The need for new products and service innovations can be addressed through many innovation theories. In this report the project portfolio management is used to showcase how a structured innovation process should be implemented and used to profit the innovation activities of the company. Also the viewpoints of open innovation have been used to demonstrate a new way of developing and managing a company in a networking manner. When considering biorefining it is clear that it requires co-operation and acquiring knowledge from other industries. New revenue models must be adopted as well as knowledge about the new markets and technologies. The ability to change and adapt to new circumstances is of great value. Also promoting an innovative atmosphere and networking is important.

New ideas often spark from the interface of different industries. An example of such innovation process is presented in the Benecol case, in chapter 10. The cross-industry innovation search theory provides theoretical background and points out things that need to be noticed in this kind of innovation process. The report also contains few company examples to demonstrate things like how current state-of-the-art biorefineries operate and innovate, in which markets they concentrate, what kind of products they produce, and how they differ from each other.

Also the current state of the Finnish forest industry and the future prospects of the industry are examined. The forest industry is also compared to the Finnish metal industry in order to compare the innovativeness and innovation processes of the two industries. The other industry comparison in this report concentrates on how the Finnish forest industry and the Finnish chemical industry have reacted to the changes in the business environment and how this is effecting their future prospects. As an example of an industry struggling with structural change the Detroit Three -case about the automobile industry in US is presented. It showcases the dangers of counting on former leading position and not following the changes in the business environment.

All parts of the report are constructed to give a comprehensive view of biorefining as a business opportunity for Finnish forest industry firms. The products of biorefineries can be multiple and very different from each other, requiring also different revenue models. Biorefineries can have different business models as well but these things have not been concentrated on in this report. However, the environmental and socio-economic impacts of biorefining are looked into and a broad view of the benefits and disadvantages of biorefining are explained. The company level focus is on innovation activities and provides tools to understand how companies must alter their operations and thinking patterns in order to be able to capture the opportunities biorefining has to offer.

2 INNOVATION THEORIES

The innovation management theories that are later used to demonstrate the innovation environment and situation in the Finnish forest industry are generally outlined here. These theories are connected to the industry in chapter 8, where they are combined with information about the industry. The innovation management tools, like the Stage-Gate-model, are also shortly explained in this chapter. Their applications to the forestry sector are discussed later.

2.1 The basic model of innovation

The basic model of innovation states that innovation begins with a need and a technology to address that need and that is how an idea is formed. The idea-stage is followed by stages of selection, concept testing, development, use and diffuse. (Paap, J. & Katz, R. 2004, p. 16)

Theoretically innovations occur through technology push or market pull. This means that ideas spring up from either original internal forces of technology or a market need. In practice usually both of these forces have their impact on the process. However, one of the two has often a stronger influence than the other and thus the source of the innovation can be described as technology push or market pull. (Chidamber, S. R. & Kon, H. B. 1993. p. 11)

Innovations can be categorised in many ways and it depends on the subject which is the most beneficial way. As this study doesn't focus on some specific innovation or even on certain type of innovation, it's best to use a simple categorisation that can be applied to all situations. A quite simple categorisation of the innovation types is represented in figure 1.

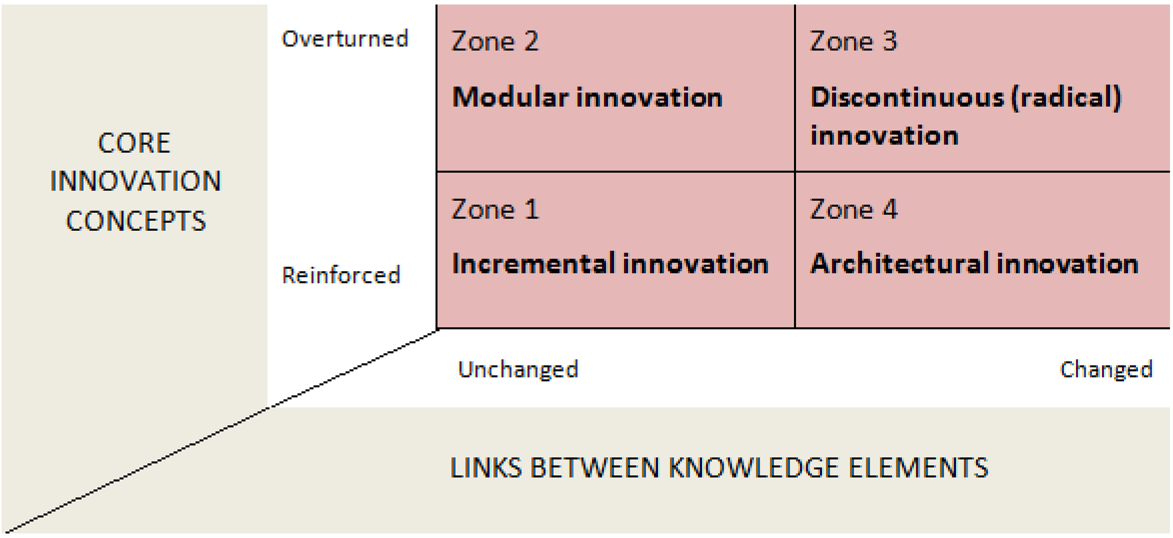

Figure 1. Innovation zones (Tidd, J. & Bessant, J. 2009. p. 39)

Zone 1 in figure 1. represents incremental innovation in which steady-state improvements are made to the existing products and processes. Zone 2 has overturned core innovation concepts but unchanged links between knowledge elements, which means that some significant changes are made in one element of the business but the overall architecture, remains unaltered. Zone 3 represents the most radical change where the rules of the whole industry might amend. In Zone 4, the Architectural innovation, only the links between knowledge elements are changed and new combinations of the elements emerge. (Tidd, J. & Bessant, J. 2009, pp. 38-39)

Innovation can also be described as breakthrough inventions and fusion innovations. Breakthrough inventions are based on fundamental scientific research that leads to new markets. This type of innovation is unpredictable, rare and hard to manage. Fusion innovations come to exist trough intentional combination of separate disciplines of knowledge. They don't necessarily require new fundamental knowledge but instead they require the identification of separate but complementary disciplines. (Miller, W. L. & Morris, L. 1999. pp. 18 and 21)

Dominant design is the standard architecture which typically is the solution preferred by the market but that isn't the only thing effecting the standardization. For example political measures or laws can make huge difference. Emerging dominant designs have the capability to restructure business models and even the whole industry. (Murmann, J. P. & Tushman, M. L. 1997. pp. 1-4 and 12)

2.2 Project portfolio management

"Project portfolio management is a set of business practices that brings the world of projects into tight integration with other business operations. It brings projects into harmony with the strategies, resources, and executive oversight of the enterprise and provides the structure and processes for project portfolio governance." (Levine, H. A. 2005, p. 1)

"Defined, a portfolio is a collection of projects (temporary endeavors undertaken to create a unique product, service, or result) and/or programs (a group of related projects managed in a coordinated way to obtain benefits and control not available from managing them individually) and other work that are grouped together to facilitate the effective management of that work to meet strategic business objectives. The components of a portfolio are quantifiable; that is, they can be measured, ranked, and prioritized." (PMI, 2006. p. 4)

Project portfolio management brings together traditional operations management and project management as well as combines traditionally separate functions of portfolio planning and portfolio management (Levine, H. A. 2005, p. 19). If an organisation doesn't have an effective project portfolio management its projects may easily be disconnected from the rest of its operations. This means that even though the projects are managed right they might not be the right projects for the organisation. So, the efforts made in and for those projects are irrelevant and unnecessary for the company but the project management just doesn’t see that.

Simplistically it is so that there are two major problems that can be addressed through efficient project portfolio management: The situation where there are such projects in the pipeline that should not have been selected in the first place and the situation where projects stay in the pipeline even when they no longer serve the best interest of the company. (Levine, H. A. 2005, p. 3) And through this, resources are released for purposes that really do support the goals of the organization. Project portfolio management offers information about how well the company is doing and data for deciding what to do in the future (Pennypacker, J. & Retna, S. 2009. p. 11).

Adopting a project portfolio management culture requires very little acquisitions or additions to the workforce. What it does require are some new skills and additions to management software and most importantly top-level commitment and a co-operative environment. (Levine, H. A. 2005, p. 3) Project portfolio management can exist on an organisational, business unit, or enterprise level. It works best when implemented enterprise wide, but in fact this is rarely seen in real-life companies. (Pennypacker, J. & Retna, S. 2009. p. 17)

The implementation of a project portfolio management process can be started by reviewing the existing portfolio or by improving the project selection process. In fact the whole implementation process (build the project portfolio, manage the project portfolio, adjust the project pipeline if necessary, consider proposed projects to fill availabilities due to completed, delayed, or terminated projects, and update the project portfolio) forms a loop anyway, so the starting point is not that significant. Usually firms start with reviewing their portfolio and making room for new projects better suited for the organisation. (Levine, H. A. 2005, p. 31)

Project portfolio management can be used to answer questions that executives ponder like for example the following questions phrased by Harvey A. Levine:

“What mix of potential projects will provide the best utilization of human and cash resources to maximize long-range growth and return on investment for the firm?”, “How do the projects support strategic initiatives?” and “How will the projects affect the value of corporate shares (stock)?” (Levine, H. A. 2005, p. 16)

One risk in project portfolio management is that the techniques used might focus too much on the details and the big picture might be missed. Another problem can be that the graphics that are used are not founded on solid data and lead in fact to the wrong conclusions. So it is very important that the people in charge really understand the subjects and don’t let the charts and graphics made to sell the project fool them. Project portfolio management deals with multiple business plans and opportunities, where as traditional business plans and analyses are needed in addition. (Levine, H. A. 2005, pp. 6-7)

A research made by the Industrial Research Institute states that the main problems of project portfolio management are that there are excessive amounts of projects in the portfolios and that the ratio between different project types is not optimal. It is also usual that the projects are not finished by the time originally planned. The link between business strategy and the project portfolio is generally moderate and resources are mostly shared according the strategy. (Cooper, R. G. et al. 1998, p. 21-22)

2.2.1 Portfolio management techniques

Portfolio management techniques can be divided to four groups: (1) economic indicators, (2) business strategies, (3) portfolio maps or bubble diagrams, and (4) scorecards and checklist. (Cooper, R. G. et al. 1998, p. 27) There are many variations of the methods and they can be combined or used simultaneously. Different methods reveal different problems and prospects so it is wise to use diverse techniques to get a broader view. (Cooper, R. G. et al. 1998, p. 29)

Economic indicators like RONA, ROI and NVP are used to prioritize projects and to make decisions about the continuation of the project. Economic indicators are the most commonly used portfolio management technique in companies, but not the one with the best results. Business strategies are used in portfolio management, for example by sharing projects into project portfolios that are used inter alia to allocate resources. This is common and gives good results, but is rarely the most important portfolio management technique in the company. (Cooper, R. G. et al. 1998. pp. 27, 29) Portfolio maps and bubble diagrams are graphic and combine different perspectives but they are considered to be time-consuming and usually don't take to account the limitedness of resources. Thus they are not as commonly used as the other techniques. (Cooper, R. G. et al. 1998. p. 31) Scorecards are used mostly when comparing projects with each other and when assessing their potential of success. Scorecards are not very commonly used and checklists are used even less than scorecards. (Cooper, R. G. et al. 1998. p. 27) Checklists fit well to the Stage-gate process where they are used to decide whether or not the project will get the resources to continue. (Cooper, R. G. 2009. p. 51)

2.2.2 The project portfolio management process

The project portfolio management process itself starts with a prioritisation and selection phase where proposed projects are evaluated using a set of pre-defined selection criteria. This phase eliminates the projects that don't pass the minimal criteria from the selection phase. The candidate projects are then prioritised by evaluating benefits, risks, alignment, and other business and project factors. The projects that are in the top-end of this ranking get the resources. The performance of the active projects is monitored against the project goals and the selection criteria. The portfolio can be adjusted to get the maximal return which means that projects are restructured, delayed or even terminated. (Levine, H. A. 2005. p. 4)

The business case is a tool used to provide data about each decision criterion to enable comparison between proposed projects and to determine which one best suits the portfolio. It helps to understand the value, cost, and benefit of implementing a project and lists the assumptions used to reach the conclusions. Combined with project plans the business case enables scenario and option analysis and ideally as a result there is more than one option to choose from. The business case tool requires understanding of the criteria used to judge the projects and like all decisions of this magnitude it requires that the decision about the project is made by the people that have the responsibility, accountability, and authority for the needed resources. (Pennypacker, J. & Retna, S. 2009. pp. 6-8) Even though individual project business cases can seem compelling, it is important not to forget the bigger picture and look at the whole portfolio pipeline to determine the suitability of the project (Pennypacker, J. & Retna, S. 2009. pp. 6-8).

Figure 2 shows cross-company product portfolio management process relationships within and between different parts of the organisation (PMI, 2006. p. 9). Mostly the information flows logically (as it should in a company as well) step by step with only few feedbacks. Of course the picture is simplified and does not show all the functions or feedbacks as it only concentrates on the relationships between different organizational activities (PMI, 2006. p. 9).

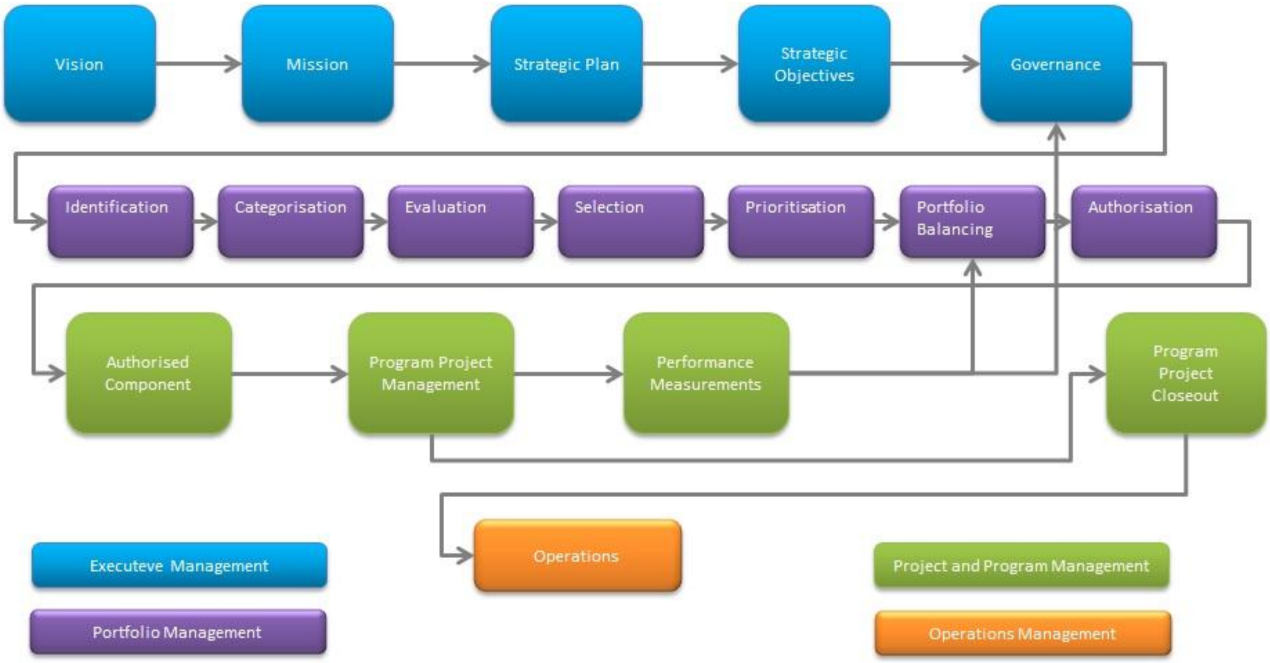

Figure 2. Cross-Company Portfolio Management Process Relationships. (PMI. 2006. p. 9)

The implementation of a project portfolio management system is usually gradual and even when implemented it has to be reshaped and moulded as the company and its environment changes. A Project Governance Process Map is a diagram that shows all the funding and governance steps and checkpoints that the organisation has for its project funding lifecycle and helps to understand where the process can be improved (Pennypacker, J. & Retna, S. 2009. p. 11). Technology road-map is a clear and visual strategic tool for planning and coordination. It links markets, products, technologies and projects on a timeline and shows their interdependencies, taking to account the changing market requirements and opportunities of developing technologies.

2.2.3 The structure of the portfolio

The amount of projects in the portfolio depends on the size and length of the projects. If the portfolio contains only couple of big projects there is a high risk that none of them will succeed. The achievements of small projects are usually small, but they are more likely to be completed. On the other hand it's usually easier to manage fewer projects. (Twiss, B. 1982. p. 154) The projects can be executed in series or in parallel, or some combination of the two.

When projects are executed in series the management is usually easier as there are fewer projects to manage and the best project leaders can be used on every project. The projects are also completed faster and the company can respond to change much more quickly. When the projects are executed in series, the problems that prolong the project affect the company more than if the projects are executed in parallel. A parallel execution can also improve the efficiency of resource utilisation. (Maunula, M. & Raiko, A. 2010. pp. 14-15)

Usually a product portfolio contains projects with different size and resource needs. They might be in different stages of their development process and the portfolio is constantly changing as some projects are deleted because they are not performing as hoped and others are completed. (Twiss, B. 1982. p. 153)

2.2.4 Stakeholder roles and responsibilities

"Portfolio stakeholders are individuals and organizations that are actively involved with the portfolio, or those whose interests may be positively or negatively affected because of portfolio management. They may also exert influence over the portfolio, its components, processes, and decisions. The levels of involvement by stakeholders may vary from organization to organization or from portfolio to portfolio within an organization." (PMI, 2006. p. 16)

Executive managers indicate the strategic goals and receive the knowledge of the performance of the portfolio. In smaller companies executive management also assumes some portfolio management responsibilities. *Portfolio review board* defines the framework, rules, and procedures for making portfolio decisions and monitors their alignment with the overall strategy. *Portfolio managers* or portfolio management teams are responsible for the portfolio management process itself. (PMI, 2006. pp. 16-17)

Sponsors give their support to some work (project, program, portfolio etc.) and promote it to the portfolio review board. If the work is approved the sponsors interest is to help the work to proceed as planned and achieve its goals. *Program managers* work with the sponsors to get funding approval for their programs. The program manger aids in supplying a good business case to the project portfolio management process and helps to ensure that the program performs according to plan and achieves its goals. (PMI, 2006. p. 17)

Project managers are responsible for the planning, execution, tracking, and delivery of projects on budget and in schedule. Project managers provide project performance indicators to the portfolio review board. Also other project managers (not the ones assigned to the particular project) are stakeholders in the sense that the project manager and portfolio management benefit from networks of project managers, as they help to maintain balanced distribution of recourses through improved communication and sharing of best practices. (PMI, 2006. p. 17)

Program or project management office can be part of day-to-day operation, help with strategic direction, provide project management support functions, or be responsible for resourcing or managing portfolio components. *Project teams* focus on a particular project and are responsible for carrying out component deliverables. The responsibilities of *operations management* are the on-going business operations. (PMI, 2006. pp. 17-18)

Functional managers assure that the proper resources are allocated to the portfolio components and that they are performing well. They also make sure that the skills and capabilities of their staff are current and in line with the needs of the organisation. *Finance managers* perform financial analysis and review portfolio budget performances. They also provide management information needed in decision making. (PMI, 2006. p. 18)

Customers benefit from new and improved products and services. The needs of the customers are important in defining the content of the portfolios. *Vendors and business partners* are often involved in executing programs and projects and are thus very important for the product portfolio management process. (PMI, 2006. p. 18)

2.2.5 Organisational impacts

The organisation culture has a major effect on the innovativeness and renewal capacity of an organisation. It is good for a company to harness the skills of its personnel for idea development throughout its operations and even outside of the company. Customers, suppliers, partners and even competitors can be of great inspiration. Careful selection of partners and building trust over long periods of time facilitates open co-operation. Successful co-operation requires projects, and methods used to describe and control them, to be compatible between the organisations. Usually successful co-operating requires also that both parties involved benefit from it, and it tends to be so that the best results come from co-operation with equal participation from both parties. Large companies often build their relationships so that it is vital to the partner. However, in these kinds of relationships the one-sidedness tends to undermine innovation. (TEKES. 2008. p. 4)

The theory of open innovation is based on the idea that a company cannot perform alone in the modern business circumstances. To generate new ideas, more efficient innovation processes and new business opportunities companies should use external sources of knowledge. This can be done through cooperation with other organisations or through licensing or purchasing products, processes and concepts. (Chesbrough, H. 2003. p. 43) The idea of open innovation can be utilised in any part of the innovation process and it is more of a state of mind than an implementable process. The benefits of open innovation can be achieved in many ways but the atmosphere of the company needs to support it.

It is important that the people, processes and tools to enable successful portfolio management are committed for the purpose. The lack of organisational support will impair the success of portfolio management significantly. The organisation must be able to accept and implement the changes implied by the portfolio and handle the change. Portfolio management should in fact facilitate change but this requires the commitment to portfolio management from the whole organisation. (PMI, 2006. p. 19) Project portfolio management should change the culture of the business as it demands the hard questions to be are asked (Pennypacker, J. & Retna, S. 2009. p. 4).

Lack of efficient and effective processes and procedures in other functional areas of the organisation can considerably hinder the results of product portfolio management as well as the implementation of those results. (PMI, 2006. p. 19) This means that profound implementation of project portfolio management often requires organisational changes across the company (Pennypacker, J. & Retna, S. 2009. p. 4). Innovating should involve the entire organisation and extend to suppliers, customers, and other external partners. It should not be tied to organisational structures within an organisation. Instead there should be cross-functional organisational processes to support it. (Miller, W. L. & Morris, L. 1999. p. 22)

Also the economic situations have their effect on portfolio management. The financial conditions of the organization, project or program can either offer or eliminate possibilities. (PMI, 2006. p. 19)

There are different types of change that need to be considered when looking at a portfolio or an individual project. Change can impact technology, physical assets and/or people. But only people get unsettled by change, so that is ultimately what must be concentrated on. The timeframe of the change and changes is important, as people deal much better with a graduate change and don't usually like to be in an environment that often changes. A company should do change analysis that help decision making and take to account the degree of disruption, the timing of the change and the individuals and groups the change is effecting. (Pennypacker, J. & Retna, S. 2009. p. 13)

Most of studies made about the effects of risk taking, innovativeness and competitive rivalry towards firm performance suggest that risk taking and innovativeness influence positively firm performance and the influence of competitive rivalry is negative. A study by Jenny Gibb and Jarrod M. Haar, using the three-way interaction model, states that when firms are confronted with high competition, it is important for them to engage simultaneously in high risk taking and innovative activities. This is the only way for them to secure both high competitiveness and development. (Gibb, J. & Haar, J. M. 2010, pp. 884-885)

2.2.6 Stage-gate approach

The original Stage-gate -model has been presented by Robert G. Cooper in the middle of the 1980's. In North America, the approach is very popular: about 70 per cent of companies use the Stage-gate -model, or some similar approach to new product development (Cooper, R. G. 2009. p. 47).

As can be seen from the figure 3 the Stage-gate -model divides the new product development process into stages that are separated by gates. Usually there are from four to six stages. For the project to pass the gates it has to meet certain criteria of success. The gates are in fact checkpoints where the future of the project (Go, No-Go, Wait) is determined and the needed resources are allocated to the project if it is allowed to continue. (Haverila et al. 2005, p. 272)

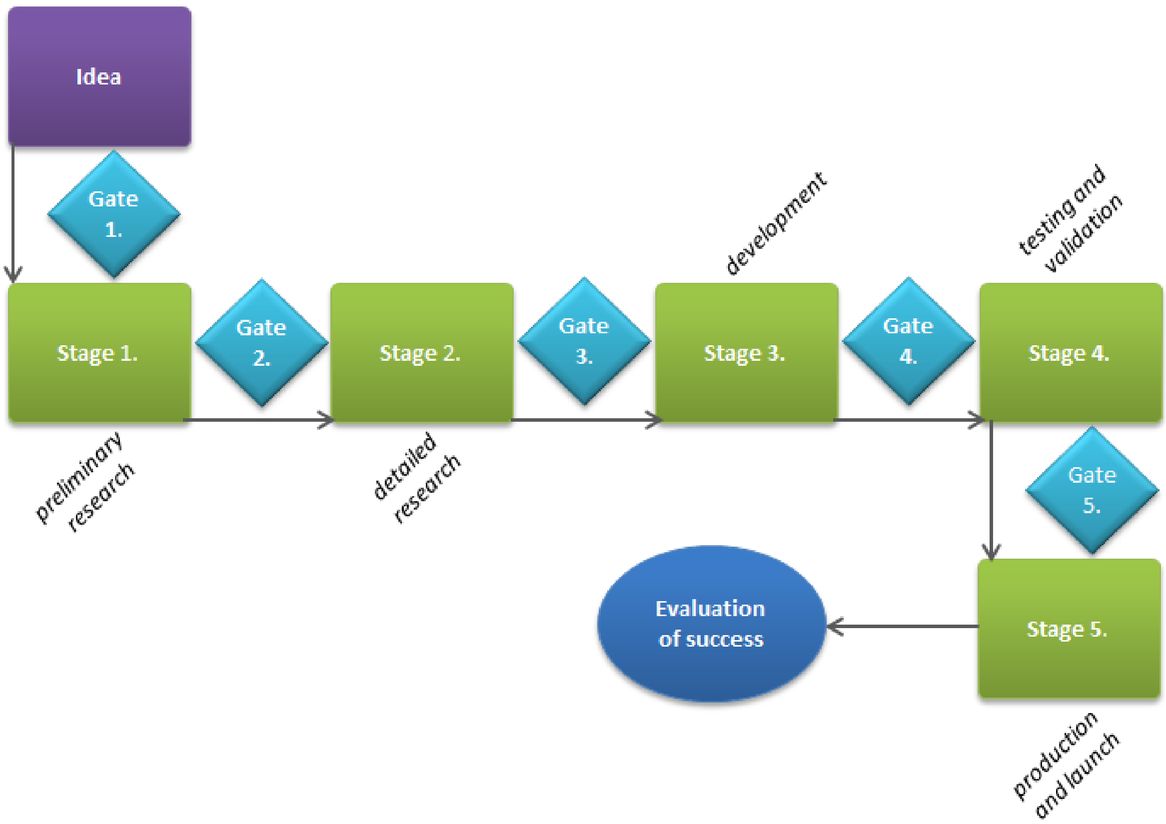

Figure 3. Stage-gate -process in new product development. (Cooper, R. G. 1990. p. 46)

Most of the problems of the stage-gate -model are ones that cause the gates not to work properly. Big problems are situations where all projects pass all of the gates, which pretty much makes the whole system useless, and situations where the needed resources are not allocated to the projects at the gates. The large amounts of information can make the decision-making hard, and it should be specified what information is demonstrated at gate meetings and it should be presented in a compact manner. (Cooper, R. G. 2009. pp. 48-49) And, of course the gate-keepers should be competent and chosen appropriately according to the size and importance of the project. Also other difficulties and problems that are mentioned when talking about product portfolio management are relevant in the Stage-gate process as well.

The portfolio management techniques, presented earlier, agree with the stage-gate, but Robert G. Cooper presents the following ones as methods to increase the effect of project portfolio management in Stage-gate. Strategic buckets is a graphic method in which the projects are divided to groups and then the resources are divided to those projects according to what the projects have received and how the resources should be divided according to the strategy. Then these are compared for example by drawing a pie chart. Also scorecards and checklists are suitable for combining Stage-gate and portfolio management. (Cooper, R. G. 2009. p. 51)

The Stage-gate -model has been altered in companies to suit their needs. Companies have tried to make it more efficient, adaptable and scalable. Also the time after launch, innovation during the process, and the adoption of a more open system have been under thought. (Cooper, R. G. 2009. p. 51) Many new Stage-gate -models have been designed for different purposes and it is not used in only new product development anymore (Cooper, R. G. 2009. p. 53). With Value-chain -analysis the effectiveness of gates in the Stage-gate process and the process in its entirety can be enhanced (Cooper, R. G. 2009. p. 52). Flexibility can be added by giving the project team more power, or by allowing the stages of the Stage-gate to overlap (Cooper, R. G. 2009. p. 53). Post-launch evaluation extends the project team's responsibility of the project beyond the actual Stage-gate (Cooper, R. G. 2009. p. 54). There are also Stage-gate –models that enhance the innovativeness of the process by changes in the beginning of the model or by incorporating strategic elements, contact with the clientele or by using open innovation (Cooper, R. G. 2009. p. 9). Many computer programs have also been made to help with the Stage-gate –process (Cooper, R. G. 2009. p. 55).

Miller, W. and Morris, L. state in their book Fourth Generation R&D - Managing Knowledge, Technology, and Innovation, that often the management of R&D and innovation focuses on incremental development of technology portfolios and products for existing markets, using stage-gate methods. As a result of that the broader needs and opportunities are not being understood properly and remain unaddressed. As the clarity of a situation increases exponentially the opportunities decrease and therefore complex decision making and timing trade-offs are inherent to innovation. The point of action can be achieved earlier if the needed level of clarity can be achieved faster. (Miller, W. L. & Morris, L. 1999. pp. xii and xv)

Many of the organisational decision-making methods in use, described previously in this report, foster the use of explicit knowledge. Because innovation is based on learning it should be open-ended but on the contrary bounded rationale is by nature limited and limiting. (Miller, W. L. & Morris, L. 1999. p. 17)

2.3 Life cycle management

Life cycle management is a business management approach used to ensure a more sustainable value chain management in an organisation. It aims at long-term value creation and continuous improvement. It can be used to target, organise, analyse, and manage product-related information and activities. (UNEP / SETAC. 2009. p. vii)

Life cycle management requires organizations to look at the whole value chain, not just their own operations as value is added to the product at all life cycle stages. Life cycle management can be used for product development and to increase efficiency. It can also help to support key choices in technology or in investing. When the organisation is cooperating with customers and suppliers the effects can be expanded to the whole value chain. Life cycle management helps to provide overall benefits and positive consequences for all organisations involved. (UNEP / SETAC. 2009. p. viii)

Life cycle assessment is collection and evaluation of the inputs, outputs and current or potential impacts throughout a product life cycle. A social life cycle assessment assesses the social aspects of products and their potential positive or negative impacts during the life cycle. Life cycle costing is a method for calculating the total cost of a product or a service throughout its life cycle. (UNEP / SETAC. 2009. p. 5-6) A product value chain deals with one particular product as a corporate value chain covers the product portfolio of the organisation (UNEP / SETAC. 2009. p. 4).

2.4 Cross-industry innovation search in the front end of the innovation process

External search for innovations helps to identify new opportunities and lessens the risks of local search. New ideas often emerge from the combination of distant pieces of knowledge. Sabine Brunswicker and Ulrich Hutschek have linked concepts of cognitive psychology and management theory with theories of open innovation in their article Crossing Horizons: Leveraging Cross-Industry Innovation Search in the Front-End of the Innovation Process. In this article they also introduce a framework designed to assist firms in external innovation search in distant industries for fuzzy search fields. (Brunswicker, S. & Hutschek, U. 2010. p. 683)

Analogical problem solving and search for technological solutions in distant industries can improve product development. The search for solutions from distant industries also challenges the current thinking patterns. The technologies that are found are usually already been tested in the other industry and can have a significant and relatively fast impact when adopted to the firm’s context. This will increase the efficiency and lower the risk of the innovation activities in the firm. (Brunswicker, S. & Hutschek, U. 2010. pp. 686-687)

2.4.1 Cross-industry innovation process

Many traditional industry boundaries have blurred and new product markets emerged in the recent decades due to rapid scientific and technological progress. Often it has been a cross-industry innovation or a prospect of such that has broadened organisational fields and created new clusters in the intersection of established industries. (Ritvala, T. 2007. p. 1)

The cross-industry innovation (CII) process of Oliver Gassmann and Marco Zeschky is shown in the following figure. It suggests that firms can identify the analogy between the problem element and the solution only by first analysing the problem in detail (Step 1) and then deliberately searching for analogous solutions. This is especially important when searching for solution sources with structural similarities with the problem. However, also more obvious surface similarities can lead to novel innovations. (Gassmann, O. & Zeschky, M. 2008. p. 103)

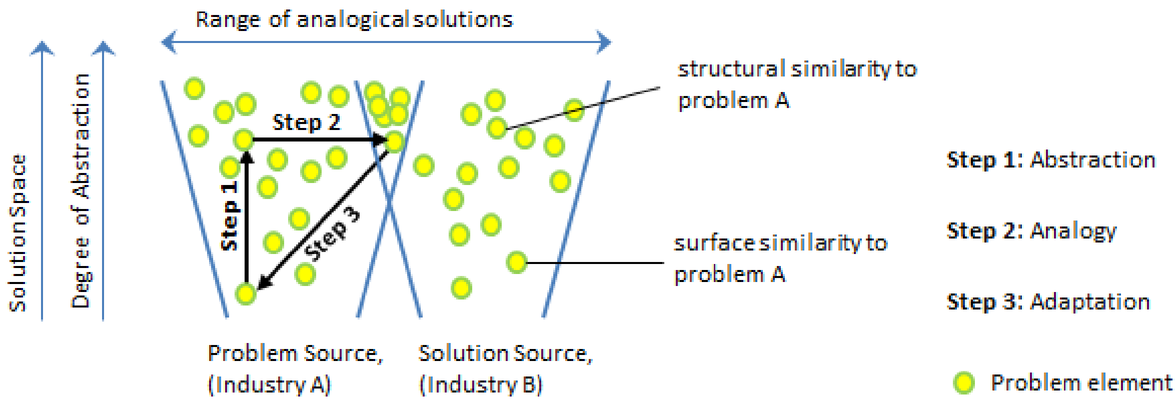

Figure 4. Opening up the Solution Space by Abstraction from the Underlying Problem (Grassmann, O. & Sezchky, M. 2008. p. 103)

To abstract the original problem a joint analysis of technical and contextual functions needs to be made. As a result the firm will be able to identify the structure and the structural relationships of the problem which allows them to look beyond the solutions elements with superficial similarities. (Gassmann, O. & Zeschky, M. 2008. p. 103)

A^4-Innovation Process for New Product Innovation by Analogical Thinking shows the process from the Strategic Intent to Adaptation. The model is quite simple in theory, although in practise it might not be so easy. It starts with ensuring an open mind set and allowing people to search ideas outside the core business (phase 0). (Gassmann, O. & Zeschky, M. 2008. p. 104) To be able to achieve successful radical innovations it is vital to be able to question own products and technologies. (Herrmann, A. et al. 2007. p. 100)

The Strategic Intent is followed by two phases that require creativity and divergence: Abstraction (phase 1) and Analogy (phase 2). In the abstraction phase the technical functions, problem context and customer benefits are analysed and key terms defined. After that, in the Analogy stage, the surface and structural similarities are searched. This is followed by Assessment and Adaptation phases in which rigidity and convergence are needed. In the Assessment phase (phase 3) the target source is analysed and knowledge is acquired and then evaluated and filtered. In the last phase, Adaptation (phase 4), the relevant knowledge is transferred and adapted to the company. (Gassmann, O. & Zeschky, M. 2008. p. 104)

2.4.2 A management framework for cross-industry innovation search

Because in the front-end of the innovation value chain the problems are still fuzzy the external innovation search is more difficult than in the later stages of the innovation process. This is why this chapter concentrates on cross-industry innovation search in the fuzzy front-end of the innovation process. (Brunswicker, S. & Hutschek, U. 2010. p. 683) Brunswicker, S. and Hutschek, U. (2010. p. 691) have outlined a systematic process to help in the search of novel solution principles and application ideas in the fuzzy search field in the front end of the innovation process.

Before the search can begin there needs to be a clear search strategy. First must be decided where to start looking i.e. what is the search field. After that a search domain is selected by identifying abstract functional relationships between market-functions and knowledge domains. Then the search objectives are determined. Here things like the expected risk, costs, duration and the amount of ideas need to be considered. Next the search method is chosen. The search can be either a broadcast search or an expert search. (Brunswicker, S. & Hutschek, U. 2010. pp. 691-692)

When the search strategy is complete the implementation of the cross-industry innovation search project can be started. Brunswicker and Hutschek suggest a two-staged process that begins with source selection which is followed by an ideation stage. The focus in these both stages changes from wide to concrete and back to wide and back to concrete. Both stages are also divided to five parts. The source selection stage is divided to market trend analysis, competency analysis, abstraction, domain selection and source selection. In the abstraction phase the market need is separated from the industry and market context to help the domain selection. In the source selection phase the potential candidates for the interactive ideation phase are selected. (Brunswicker, S. & Hutschek, U. 2010. pp. 694-695)

In the ideation phase it is important to remember that a good briefing is crucial as everyone involved should understand the objective and the scope of the project. Also the legal aspects like usage rights should not be forgotten. The ideation phase starts with system analysis that investigates relationships between customer needs, market functions, products and solution principles. This is followed by a functional analysis that concentrates on the relationship between the solution principles and technological functions. Next step is the idea generation and after that assessment. The final stage is the exploitation preparation in which ideas are selected, discarded or put on hold. (Brunswicker, S. & Hutschek, U. 2010. pp. 695-696)

When managing cross-industry innovation search it is important to take to account the cognitive distance and the technological distance of the solution source, as if the cognitive distance is too big the communication between the two parties might be very difficult and the technological distance influences the ability to absorb the information (Brunswicker, S. & Hutschek, U. 2010. p. 690). The project must benefit both parties to work as hoped. It is beneficial if the companies involved have similar innovation processes and their business cultures match and support the innovation atmosphere. There needs to be enough freedom to allow creativity but also structure to get the wanted results. (Brunswicker, S. & Hutschek, U. 2010. pp. 697-698)

2.5 Practices of strategic foresight

Dana Mietzner and Guido Reger have identified six different approaches of strategic foresight in their case study of 30 small- and medium sized biotechnology companies in Germany. They have also characterized the strengths and weaknesses of these strategic foresight practices. (Mietzner, D. & Reger, G. 2009. p. 273) The approaches and methods identified by Mietzner and Reger might be useful in strategic foresight of the biorefinery business in particular and are therefore chosen to be explained here. These approaches of strategic foresight are: science-driven approach, network-oriented approach, market-driven approach, gatekeeper approach, financial controlling-based approach and no strategic foresight (Mietzner, D. & Reger, G. 2009. p. 280). The methods applied in strategic foresight include heuristic methods, questioning, interactive methods and quantitative methods. The methods are usually quite simple and don't require a deep understanding of the methodology. (Mietzner, D. & Reger, G. 2009. p. 283)

2.5.1 Approaches of strategic foresight

The founders of biotechnology companies are usually professors or researchers and thus the linkages with universities are quite obvious. Alliances with universities might offer the firm access to emerging technologies and give opportunities for knowledge creation and learning. *Science-driven approach* of strategic foresight helps to determine new technological trends and weak signals as they are perceived early in the scientific environment where they are part of the daily work. Often the customers of these firms are scientists or scientific institutions. Companies that have this approach of strategic foresight are commonly involved in publicly financed research projects and their linkages to universities can have positive effects like enhanced product development outputs. Firms with this approach must be careful not to miss the systematic linkage to strategic planning. (Mietzner, D. & Reger, G. 2009. pp. 280-281) Science-driven companies don’t usually use interacting foresight methods but instead methods like bibliometric analysis (Mietzner, D. & Reger, G. 2009. p. 283).

In firms with *network-oriented approach* to strategic foresight the information procurement occurs through informal and formal networks of the employees. The information exchange is mostly informal. The tasks of strategic foresight are experimentally driven and the head of the company is responsible for strategic foresight. This approach combines the information accumulated on networks with strategic planning. Companies with internal capabilities can take advantage of opportunities and information of venture networks. (Mietzner, D. & Reger, G. 2009. p. 281) In network-driven foresight mostly heuristic methods like inquiries, internet research and publication analysis are used to collect information (Mietzner, D. & Reger, G. 2009. p. 283).

The *market driven approach* can be characterised by a strong focus on the collection and systemisation of customer and competitor data. The data is collected by sales employees and through regular customer inquiries and by screening selected customer websites. Often databases like customer relationship management (CRM) systems are used. The management board is responsible for the strategic foresight. The marketing or business development unit makes the early diagnoses which it reposts to the board. The downside of this approach is that it concentrates so much on the customer data and thus the technological changes can easily be missed. (Mietzner, D. & Reger, G. 2009. pp. 281-282)

The *gatekeeper approach* has a strong focus on observation of both present and new technologies and markets. It also has a relatively high future orientation of strategic planning and is considered to be the most sophisticated way of handling strategic foresight. Firms using the gatekeeper approach use key persons in the company to supply information for the management. This might be a risk if the gatekeepers are the only ones in the company doing foresight activities. In this approach the activities of strategic foresight are strongly experience driven. The gatekeepers collect the information form outside of the company through formal and informal networks and that information is processed using scenario analysis combined with SWOT analysis and portfolio management. The information processing is much more sophisticated in this approach than in the network-based approach. The systematic information collection is supported by knowledge management systems. (Mietzner, D. & Reger, G. 2009. p. 282)

The *financial controlling-based approach* of strategic foresight uses tools from financial accounting for early diagnosis and technical literature for source of information. This approach is entirely decision-oriented and it needs hard facts to work, rather than weak information. (Mietzner, D. & Reger, G. 2009. p. 282)

Companies with *no strategic foresight* only react to market developments, but don't regularly use market analysis and they only make short term plans. They focus on the current satisfaction of the customers' needs and on maintaining their competitive position. (Mietzner, D. & Reger, G. 2009. p. 283)

2.5.2 Reasons for low degree of implementation of strategic foresight

Dana Mietzner and Guido Reger have identified four reasons for the low degree of implementation of strategic foresight in biotechnology companies. One reason can be a defensive management which can affect the quality of the strategic planning process or hinder the strategic conversation. Another reason can be the time line of the planning. The focus is on the day-to-day business and short-term thinking and small and medium size companies often think that they don't need long-term planning as they can react to changes much faster that big companies. (Mietzner, D. & Reger, G. 2009. p. 286)

The two other reasons for low degree of implementation of strategic foresight are limited resources and little focus on the contextual environment. There isn't enough time for strategic foresight and there are limited resources to engage consultants or to make market analysis. Firms often concentrate in their early diagnosis and strategic planning on new technologies, customers, competition and other aspect of selected fields. Often the broader context, the global trends, other markets and so on, is not considered. (Mietzner, D. & Reger, G. 2009. p. 286)

2.5.3 Requirements for strategic foresight methods in biotechnology firms

According to Dana Mietzner and Guido Reger the main requirements for strategic foresight methods are

- specification and customisation of information,
- integration of customised information and typical strategic planning methods,
- integration of strategic foresight and operative business activities, and
- simple and efficient implementation of strategic foresight (Mietzner, D. & Reger, G. 2009. pp. 288-289).

Firms in the biotechnology field are not all similar and can have very different needs for information. This is why the knowledge management system needs customising. Because the industry is global the knowledge management system needs to gather information about foreign markets, current and emerging technologies, current and potential customers, competitors, suppliers, and partners. It's also important that informal information can be implemented to the foresight process and this information should be systematically collected from the gatekeepers and other people. A good knowledge management system makes it a lot easier to implement different foresight methods. (Mietzner, D. & Reger, G. 2009. p. 290)

Implementation of so called "open foresight" activities helps to share resources for the generation of future knowledge. It also supports the establishment of networks. In practice "open foresight" activities are common foresight projects together with a number of other firms from the same industry, research institutes, suppliers, policy, networks and customers. Of course, the experiences and future knowledge from the "open foresight" project need to be interlinked with the closed foresight and decision making process in the company. (Mietzner, D. & Reger, G. 2009. pp. 290-291)

3 FOREST INDUSTRY IN THE BEGINNING OF THE 2010S AND ONWARDS

In 2011 the prospects of the world pulp and paper industry are brighter than in the previous years. The slowdown in the pace of demand growth is still continuing, but not as rapidly as in 2010. There is an upturn in softwood prices, particularly in Chinese market, where the fiber demand is expanding. Also the overall outlook for the world economy is better and this has a positive effect on all industries including the pulp and paper industry. Containerboard producers are getting higher prices for their products in Europe. However, recovered paper prices are rising. The pulp demand is expected to remain for now solid. The growth in industrial production benefits the sales of packaging grades. (Young, R. 2011. p. 2)

The current situation is of course very important for the on-going operations as well as future investment decisions. Still, if only the short time changes are investigated the big picture and the changing environment will stay unnoticed. One of the most important trends of the last years has been the decline in consumption of paper and paperboard in the two traditionally biggest market areas as simultaneously the consumption has boomed in China. The consumption has been declining in North America since 2004 and in Western Europe since 2007. The newsprint consumption in US and Canada has declined to approximately half of what it was in 2004. In Japan and Latin America the consumption has been quite stable in the last decade. (Environmental Paper Network. 2011. p. 10)

It is important to notice that the consumption of paper differs very much in different parts of the world. For example in Western Europe a person consumes annually nearly 180 kg of paper and in North America the amount is even more: 229 kg per year. But the world average is less than 60 kg, with Asia reaching an average consumption of more that forty kilograms and Latin America slightly more than that. In Africa the consumption is annually less than ten kilograms per person. The differences are truly staggering. (Environmental Paper Network. 2011. p. 11)

Paper products are a part of everyday life for most people in the world. The manufacturing of paper is going to remain a major industry for the foreseeable future despite the decline in the consumption of certain products. The industry is most definitely going through a transformation which will have a major impact on all forest industry companies. (Environmental Paper Network. 2011. p. 3)

3.1 Development in the Finnish forest industry

In the 1990s the Finnish forest industry's growth was strong and many new firms were started in the first half of the decade. Also many mergers were made during the 1990s. In the 2000s the growth in demand slowed down, the value of dollar decreased and the production in developing countries increased. There have been very few companies starting in recent years, which is worrying because precisely new companies are usually regarded as most innovative. (Oksanen, J. et al. 2010. p. 11)

The development of the Finnish forest industry can be seen to have been effected by the following things: (1) technology, (2) environment, raw-materials and energy, (3) growing and declining markets as well as competition abroad, (4) customers and demand, (5) economy and market structure, as well as (6) knowledge and know-how.

3.1.1 Technology

Technological improvements have made the factories more efficient and automated. The same can be said about harvesting. The technological improvements and innovations have been very essential in the development of the industry but some technological solutions like for example electronic media are also replacing paper products. (Vinaccia, D. 2005. p. 12-23)

In the last decades the key drivers of technological development in the Finnish forest industry have been the economy of scale and increasing the production capacity. The aim has been to improve the efficiency of the process and lower the unit costs of the production. This has led to large industrial forest integrates, which include pulp and paper industry and occasionally mechanical forest industry as well. (Oksanen, J. et al. 2010. p. 10)

Finland has been one of the most important countries in developing the currently used technologies of the forest industry. These technologies have been developed after the middle of 20th century and are the basis for the Finnish forest cluster. Since that the technologies have been perfected and made more efficient. However, significant innovations have been rare. Now that the whole industry is facing large changes the firms are forced to renew themselves to maintain their competitive positions. (Metsäteollisuus ry. 2009, p. 12)

3.1.2 Environment

The environmental issues have affected the forest cluster greatly but are going to have an even more substantial affect in the coming years (Vinaccia, D. 2005. p. 14). The environmental effects of biorefining are considered later in this report in chapter 9.1.

In Finland the availability of raw materials used in the forest industry is good (Vinaccia, D. 2005. p. 15). Still, there are some things to keep in mind. If large amounts of wood will in future go to energy use this could affect the availability and price of wood. The global warming might cause the tree species to change and/or some new deceases to spread to Finnish forests. Used paper can be recovered even more fully than currently and some new technologies for utilizing recovered paper could arise. Other raw materials than wood can be used to produce pulp and paper products and trees can be genetically designed to be better suited to certain products and processes (Environmental Paper Network. 2011. pp. 26 and 28).

Although there are sufficient amounts of wood material for the forest industry to use in Finland, the tropical plantation system represents a fret as it has superior economics and pulp uniformity. Also the labour costs in tropical countries like Brazil and Indonesia are a lot lower than in Finland and other Nordic countries or the US. (Thorp, B. 2005. p. 36)

For the Finnish forest industry the domestic forests are an important source of raw material, but also a foundation for the whole industry. Another substantial raw material is water, which amounts to 5% of the production costs in a paper mill. That is as big as the costs of chemicals or staff in such production unit. In many regions of the world fresh water is a luxury and a very valuable raw material. The price of water has been climbing up and water is becoming a strategic raw material. From the Finnish point of view this can be seen as an opportunity for multidisciplinary clusters that can invent solutions for water intensive industries. (Grön, J. 2010. pp. 3-21)

Energy is a very important aspect not only in traditional forest industry but also in biorefining. The energy price affects the production costs of pulp and paper as well as the profitability of selling energy or fuels. The forest industry in Finland produces almost half of the energy it uses (Metsäteollisuus ry. 2004. p. 43). In most production units the energy efficiency has been getting better although many environmentally friendly solutions that are currently required add to the energy consumption (Metsäteollisuus ry. 2004. p. 43).

3.1.3 Growing and declining markets and international influences

The growth in both consumption and production of traditional forest industry products has recently been in markets that are far from Finland. Finnish pulp and paper companies have made big investments abroad and turned into globally significant operators that make more than half of their profits in foreign markets (Lindström, M. et al. 2004. p. 6 and 26).

The Finnish forest industry has always been influenced from abroad and often similar technological improvements have been adopted at the same time by competitors around the world. Imported and imitated know-how has encouraged and enabled technological development. In current market conditions new production investments are made mostly near the growth markets: Asia and South America, where the availability of raw material is good and forests grow quickly. (Oksanen, J. et al. 2010. p. 11) Also the markets of traditional paper products are growing mostly outside of EU (Metsäteollisuus ry. 2009, p. 12).

3.1.4 Customers and demand

Forest industry products are mostly business-to-business -products. To meet the demands of their customers also forest industry companies are shifting towards providing comprehensive overall solutions. The changes in the needs of the end-customers affect also business-to-business -operations but traditionally the demand has been quite stable at least in the pulp and paper industry. Population demography, lifestyle changes, values and attitudes affect the consumption of different products but in the past the focus of the industry has been in technological development and efficiency, internationalisation, and ensuring access to raw materials and other key resources. (Vinaccia, D. 2005. p. 19-20) But now that the consumption in present main market areas is declining the ability to fulfil specific customer needs is going to get more important than it has previously been.

3.1.5 Economy and market structure

The current global economic situation of the forest industry has been previously explained and later in chapter 2.3 the situation of the Finnish forest industry is looked into more specifically. According to the Ministry of Finance the overall economic growth forecast for 2012 in Finland is 0.8% and largely dependent on private consumption. The economic growth of many of the major trading partners of Finland is anticipated to fade. Investments are forecasted to decline and the unemployment rate to rise to eight per cent. (Ministry of Finance. 2012)

In 2011 the world economic growth started to decline but in 2012 the situation has started to look a bit brighter. The recession in the euro area appears to be lower than initially feared. Economies outside the euro area have maintained healthy growth rates. Tax increases and spending cuts made in order to balance the economy of deficit EU countries is slowing down the economic growth in the whole EU. The risk of deep recession has however subsided and the conditions for economic recovery have strengthened. (Wessman, R. 2012. p. 4)

Fluctuations in export markets are affecting the Finnish economy and the exports have declined. Also the inflation risk has increased. Non euro-areas have better growth prospects and combined with declining interest rates in the euro area the currency might be getting weaker in the near future. A significant challenge for Finland’s economic growth prospects is the decrease in working age population and rise in the amount of retirees. Weakening of the euro may continue and further strengthen the inflationary pressures. (Wessman, R. 2012. p. 5)

The economic situation of the company as well as the surrounding society effect the project portfolio management of a company as the financial situations can either offer or eliminate possibilities (PMI, 2006. p. 19). The investments of the manufacturing industry in Finland were just over 2.9 billion euros in 2010. In the following years the investments are expected increase to about 3.6 billion euros. In 2011 the investment growth rate was high, but one must take into account that the previous year before that was very low. Despite the improvement the investments were still below the 2000s average. Research and development activity is also declining. In 2011 industrial companies spent on research and development about 3.9 billion euros in Finland. In 2012 R&D investments are expected to decrease by about five per cent. It is concerning that the investments that are made are not going to replace the outgoing capacity and simultaneously the companies are not investing in intellectual capital either. (Elinkeinoelämän keskusliitto. 2012)

The BIOTULI-project is concentrating on the Kymenlaakso region and South-East Finland. South-Eastern Finland's economic outlook is moderate. In the pulp and paper industry the restructuring continues, but there is a rise in trade and tourism. The situation has remained good in transportation and storage. Russia's influence is reflected positively in many sectors, for example. trade, tourism, border activities, and transportation. Unemployment is expected to decline further in Kymenlaakso because of the structural change of the forest industry. In South Karelia the development is expected to be more positive due to growth in service operations. (Nieminen, J. 2012. p. 12)

The global markets of the forest industry have been previously outlined and the changes in the market conditions are also discussed in this report. The changes in the market structures are one reason behind the structural change of the industry. In order to fully cover the market situation one should ponder on different products and product categories of the industry separately, as the market circumstances can be quite different depending on the product. As the focus of this report is not in the traditional forest industry products it is not relevant to evaluate their markets and future prospects more than what is relevant considering the major trends of the industry or biorefining. These things are discussed in other parts of the report. Here the important thing is to notice that market fluctuations affect the forest industry and can be seen as drivers for development.

3.1.6 Knowledge and know-how

Finland has one of the strongest forest clusters in the world and has been developing many of the technologies used in the industry. The forest industry has been historically important to Finland and its role in the economy has been substantial. Traditionally the R&D activities of the Finnish forest industry companies have been located mostly in Finland which has been great for the accumulation of information, knowledge and know-how. Also the relationships with other industries especially the metal industry have been an important source of innovation. (Oksanen, J. et al. 2010. pp. 10-11)

Unfortunately the research and development investments of the Finnish forest industry have been recently rather modest (Hetemäki, L. 2006. p. 38). If the companies are doing all their biggest investments outside Finland there is the danger of it negatively affecting the technological development of the country. New technologies require new skills and practices, which can both be acquired only through experience. If the newest technology is not in place the experience and know-how will not accumulate. Long-term investments and the vitality of the paper industry must be based on new products and business models. (Hetemäki, L. 2006. p. 36)

3.2 The situation of the Finnish forest industry

In 2009 10.6 million tons of paper and cardboard were produced in Finland. That is over 2.5 million tons less than in 2008 and over 3.7 million tons less than in 2007 when the production was at its highest. The last time production levels have been this low was in 1996. 2010 looks a bit brighter than 2009, as the production of the first three quarters has in 2010 been 8.8 tons as it was in 2009 less than 7.8 tons. (Ylitalo, E. 2010. p. 328)

Roughly 8.1 million tons of paper and 2.5 million tons of cardboard were produced in Finland in 2009. 4.2 million tons of the produced paper was magazine paper and newsprint, 2.6 million tons fine paper and 1.2 million tons other kinds of paper. The production levels have dropped in pretty much all paper kinds as well as paperboard but most dramatically in the magazine paper and newsprint category which production decreased by 28 per cent. (Ylitalo, E. 2010. p. 328)

The gross value of production of the forest industry was 15.7 billion euros, and the pulp and paper industry represents about 70 per cent of that. The added value of production was 2.9 billion euros. The domestic investments were 0.28 billion euros, which is almost 70 per cent less than in 2008. (Ylitalo, E. 2010. p. 313) The operating margin of the Finnish forest industry sank to an all-time low in 2008 at 5.4 % of turnover. And the figures of 2009 look even worse. The operating margin of all manufacturing, counting in all industries, was in 2008 8.6 % of turnover. (Ylitalo, E. 2010. p. 334)

The same trend can be seen also in the total profit: The average of the forest industry was in 2008 -11.8 % of turnover, as in the entire manufacturing of all industries the average was 3.3 %. The figures of 2009 are a bit better in the forest industry as the figure of all industries is around zero. Still, when comparing the total profits the forest industry is performing much worse than other industries in general. The total profit of wood product industry has been at its highest in 1994 when it was 5.0 % of turnover and the total profit of pulp and paper industry has been at its highest in 2001 when it was 28.2 % of turnover. (Ylitalo, E. 2010. p. 334)

Numbers presented above show that the forest industry and especially the pulp and paper industry is struggling in Finland. Most drastically this can be seen from the decrease in employees working in the biggest forest industry firms. In 2005 M-real, UPM and Stora Enso had altogether around 93 000 employees. In 2011 the amount of employees is significantly less, around 56 000. And not even close to half of them work in Finland. (Heikkilä, M. 2012a. p. 22)

Still, the paper industry is one of the best paid industries in Finland and the average basic earning of a paper industry worker is a lot higher than the average for Finnish industry worker (SAK, 2011, pp. 1-2). In Finland a very large portion of employees are members of trade unions, in the forest sector the Paperiliitto. This has previously resulted in a sort of union cartel. (Pentti, 2008, p. 19) The wages are the result of trade union negotiations and in the situation of a powerful trade union, not to mention an union cartel, the union has a lot of bargaining power and can fairly easily achieve the benefits it desires. To some extent also the Finnish collective bargaining system has supported the situation that has led in a decrease of competitiveness in Finnish forest industry companies (Pentti,V. 2008. pp. 21-22).

The factories in Finland are modern, the staff is knowledgeable and the supply of sustainably produced raw material is good. Anyhow, Finnish forest industry doesn’t perform well when measured with cost competitiveness. Partly this is the reason for the need to make products with more added value. (Metsäteollisuus ry. 2009, p. 9) For Finnish forest industry to be competitive in the future the mind-set around it is going to have to change and it has to have supportive surroundings. It needs financing and educated workforce and especially the small firms have to be encouraged to innovate and grow. Public administration has an important role in providing the needed resources and atmosphere. (Metsäteollisuus ry. 2009, p. 11)

Surely the change must also come from within the companies. Even though biorefining presents a great opportunity, it requires a new business model. Ben Thorp (2005. p. 35) has written about the American pulp and paper industry that “The major challenge will be ridding industry organizations of the commodity ways of doing business, which is essentially producing high volumes of undistinguished products with low margins.” and the same could be said about the Finnish pulp and paper industry as well.

For the Finnish forest industry to be successfully able to create and commercialize new products its current operations need to be profit-making. In Finland the costs of raw materials, energy and workforce have in the last decade increased more than in the countries it’s competing with. The operations and structures have been streamlined so that the cost competitiveness has maintained in a fairly good level. And some process innovations are made to lower the production costs and to add value to the products. (Metsäteollisuus ry. 2009, p. 8) Despite the mentioned efforts, the companies have been forced to make cutbacks in the resent years and jobs have been lost.

The forest cluster can expand in the directions of building, energy, ICT and chemistry. This would make the cluster bigger and less coherent than it is now. The importance of co-operation will increase significantly as the knowledge must be shared with other parties. (Metsäteollisuus ry. 2009, p. 12) From the innovation perspective the convergence of industries is a good thing as innovations tend to happen in environments where information from different outlooks is combined.

3.3 Future business areas and product opportunities

The Finnish forest industry is making ready for low-carbon bio economy in which materials and natural resources are used very carefully and the added value of the products is high. The plan is to invent new products for both existing and new markets. An important benefit for the industry is that most of the raw material it uses is renewable and even the products are mostly recyclable. (Metsäteollisuus ry. 2009, p. 6)

The growth areas in forest industry's bio economy are construction and decorating, packaging and tissue as well as bioenergy. Global warming can be slowed down by increasing sustainable wood consumption and by using more renewable materials. Carbon dioxide is restored in growing forests but also in wood and paper products. Paper products that come to the end of their lifecycle can be used as renewable energy with biomass unsuitable for refinement. (Metsäteollisuus ry. 2009, p. 6) Wood product industry's research strategy from 2008 states, that by 2020 twenty per cent of the industry's turnover should come from bioenergy (Metsäteollisuus ry. 2009, p. 16).

The largest environmental impacts in Europe are currently from living, building and demolishing buildings. Building and demolishing also cause over 40 per cent of all of the waste (Metsäteollisuus ry. 2009, p. 6). This report concentrates on the opportunities of biorefineries and bioenergy but it’s important to notice that construction has a very important role in the future of Finnish forest industry. There are new innovations made in this area and the legislations are changing to encourage wood construction. The research strategy of wood product industry states that the value of wood products and solutions used should double by 2030 (Metsäteollisuus ry. 2009, p. 17).

New products should come to exist in the field of bioenergy, biofuels and biochemicals. New products can also be invented by combining wood and fibre with other materials. Intelligent paper and packaging products and intelligent building materials can be produced by adding various information technologies to the product. Nanotechnologies will also provide new product opportunities and product attributes. In addition innovations in medical applications and green chemical products are expected to enable a variety of biorefinery products. (Metsäteollisuus ry. 2009, p. 6)

This is at least the opinion of the Metsäteollisuus ry. which is a Finnish wood-processing industry trade association, whose members are operating in Finnish forest industry: pulp, paper and board industry, sawn wood products and sheet metal industries as well as other wood and joinery manufacturers of industrial products. The homepages of Mesäteollisuus ry. state that their goal is to achieve a more competitive and innovative environment for the Finnish forest industry in terms of production, employment and investment. (Metsäteollisuus ry. 2012)

Besides the industry representatives also the media offers a similar picture of the future. In February 2012 a Finnish technology and economy magazine, Tekniikka&Talous, had an article where they listed some products of the future. The article mentions wood-based composites, biodiesel, cellulose fibril, wood construction, smart paper and smart packaging, textiles, and nutraceutical compounds and medicines. Juha Kilpeläinen, the head of research and development at Stora Enso, stresses in the article three trends: the growth of wood construction, wider biochemical utilization of wood, as well as smart packaging and printed electronics. (Heikkilä, M. 2012a. pp. 22-23)

Although there are many products and product categories worth developing and investing in, biorefining might well be the one with the most extensive growth possibilities in Finland (Hetemäki, L. 2006. p. 37). The possibilities are huge but Finland is not the only place where the pulp and paper industry is going through a structural change, neither the only place where biorefining is considered as one possible solutions. In 2005 Ben Thorp wrote about biorefinery business model opportunities for the American pulp and paper industry and many of the views he has presented can be applied to Scandinavian and Finnish pulp and paper industry. The fact in Finland, as in America, is that companies with innovative, unique and customer-focused business strategies appear to have a bright future, but the ones stuck in their old ways trying to save themselves by mergers and acquisitions are not doing that well no matter how big they are. The old business model of bringing logs to a mill and transforming them into cellulose-based commodity products is not profitable enough. In order to be successful companies need to provide specific products and solutions for their customers and have customer focuser and unique strategies that enable them to do so. (Thorp, B. 2005. p. 35)

The current kraft mills were made to capture the economy of scale and to produce modest amounts of energy. However, this currently used business model is not going to be very viable in the future as the competition is increasing and costs cannot be reduced much further. The tropical plantation system and low labour costs favour the tropical countries in producing simple high-volume products. For the Finnish forest industry it is going to be increasingly hard to compete with its current product pallet. However, the existing pulp mills can be developed into forest biorefineries where diverse products like chemicals and fuels are derived from the wood material. The biorefinery concept allows paper companies to maximise their value creation from the resources brought to the mills and to produce multiple products simultaneously in an efficient process with fewer inputs and multiple outputs. (Thorp, B. 2005. pp. 35-36)

4 BIOREFINING AS AN OPPORTUNITY

It is a well-known fact that fossil resources, used in energy production and in producing various chemicals, are limited. This causes a need to develop new ways of producing bioenergy and alternative methods of manufacturing important biochemicals. Because of inter alia environmental issues, industrial chemistry is changing its focus from the petrochemical industry to the different aspects of utilizing various renewable feedstock resources. (Alén, R. 2011. p. 56)

There are two types of biorefineries that are considered. In a stand-alone biorefinery concept heat and chemical processes are used to convert woody biomass into fuel-grade ethanol, syn-gas, commodity chemicals, plastics, pharmaceuticals and other high value chemicals. The other type is an integrated biorefinery which is installed as part of a pulp mill. An integrated biorefinery extracts and converts components prior to pulping and converts by-products and waste from the pulping process. Some of the fuels produced in the integrated biorefinery could be used in the pulping process itself. (Cuoch, G. 2006.)

The term biorefining is defined and explained in the following section. After that this chapter concentrates on integrated biorefineries and the opportunities they offer to forest industry companies. Biorefineries can be especially profitable when combined with the existing resources and capabilities of the forest industry (Hetemäki, L. 2006. p. 37) as the forest industry already controls much of the raw material logistics and necessary infrastructures which can be utilised (Couch, G. 2006).

4.1 Defining biorefining

The biorefinery concept is in brief a process for fractionating and/or converting biomass (CO_2-neutral feedstock) into energy, chemicals or other biomaterials in an ecosystem-friendly way. The aim is to maximize the value of biomass and to minimize the production of waste. (Alén, R. 2011. p. 56)

Wood and other cellulosic materials can be traditionally processed in different ways by using mechanical, chemical or thermal conversion methods (Alén, R. 2011. p. 57). Presently the kraft process starts with pulping the wood chips in severe chemical conditions to remove lignin but this destroys some cellulose and most of the hemicellulose (Thorp, B. 2005. pp. 36-37). The current fibre-related utilisation of wood is limited because 50-55% of wood is used for fuel, 25-30 for construction, 10-15% for fibre and 5% for other uses. If pulp and paper mills are regarded as biorefineries, they are the oldest industrial ones, operating first about 140 years ago. New types of biorefineries, the ones that the term usually refers to, are much more resent. (Alén, R. 2011. p. 57) In a forest biorefinery process a new phase is located between chipping the wood and pulping. In this phase acetic acid and some hemicellulose are extracted in mild conditions (Thorp, B. 2005. p.37).

The primary driver for development in green chemistry seems to be the production of liquid fuels. In addition to transport fuels, that are low-value/high-volume products like ethanol and biodiesel, the products include commodity chemicals, specialty chemicals with high-value/low-volume and other bioproducts and biomaterials. (Alén, R. 2011. p. 56) This report does not cover liquid fuels or biogas, but concentrates on biochar and co-production of different bioproducts, biomaterials and biochemicals. New biomaterials can be an important driver in a new business model as they enable the development and production of both new and improved products and can be used in material substitution (Thorp, B. 2005. p. 37).

4.1.1 Thermal conversion of cellulosic biomass

Thermal conversion of cellulosic materials results in gases, condensable liquids (distillates, tars) and solid char products. When using wood the solid char products of thermal conversion are charcoal. Thermal conversion methods of cellulosic biomass are *pyrolysis* used to make bio-oils and further liquid fuels, *gasification* used to make syngas which is a gas mixture containing mainly hydrogen and carbon monoxide. Syngas can be then processed in many ways:

Through *catalytic conversion* it can be made into hydrocarbons, methanol and hydrogen. *Combustion* can be used make heat and electricity or with *acid or enzymatic hydrolysis* it can be used to produce sugars. Through fermentation ethanol and butanol can be manufactured, and *chemical fractionation* can be used to make extractives for the production of biodiesel through trans-esterification. With *liquefaction* liquid fuels can be produced by direct biomass to liquid process, and *anaerobic digestion* can be used to produce biogas. (Alén, R. 2011. pp. 64-65)

The relative proportions of the products in thermal conversion depend on the chosen method and the reaction conditions. Thermal conversion methods are usually fairly rapid and don't need as much water or external chemicals as chemical conversion methods, but they are unselective reactions that produce a lot of different products with low individual yields. (Alén, R. 2011. p. 64) Torrefaction is a mild pyrolysis process that lasts several minutes in air free circumstances at 225-300˚C. Torrefaction process dries the woody biomass and partly decomposes its hemicelluloses and removes volatile compound. It increases the carbon content and net caloric value of the biomass and thus enhances its energy density. (Alén, R. 2011. p. 67) Torrefied wood can be milled and pelletized to get to suitable form for storing and transportations. These torrefied pellets (TOP pellets) are suitable for large volumes and long transportation distances. (Wilén, C. 2011. p. 41)

4.1.2 Chemical and biochemical conversion of cellulosic biomass

In chemical and biochemical conversion the cellulosic biomass is usually pre-treated before hydrolysis. The sugars that have been produced in the hydrolysis by using mineral acids or enzymes go then to the fermentation phase which is followed by the recovery of products and by-products. Many of these current technologies focus primarily on the utilization of the fraction of carbohydrates (cellulose and hemicelluloses). (Alén, R. 2011. p. 59)

4.2 Biorefineries in the forest industry

Overcapacity, mature market conditions and new low-cost production abroad are lowering the prices of traditional paper products. The capacity has been adjusted and the production efficiency and profitability has been enhanced to moderate this development but in the long run these measures are not going to be enough. Finland has entirely or partly lost many of its former competitive advantages. (Hetemäki, L. 2006. p. 35) Without large investments in new technologies and products the pulp and paper industry will not grow (Hetemäki, L. 2006. p. 36) or even be able to maintain its current size in Finland.

Biorefinery products can be produced alongside with the current pulp and paper industry products and thus also the profitability of paper products can be improved through biorefining (Hetemäki, L. 2006. p. 37). Integrated biorefineries are optimised around the margins of the new product streams (Thorp, B. 2005. p. 38) and the production amounts of different products can be adjusted to achieve the best profitability in changing business conditions (Hetemäki, L. 2006. p. 37).

The forest industry has the raw material logistics and operation mills at place. In addition they have thorough knowledge about the pulping process and the structure of wood and its attributes in the process. All these things are going to be incredibly helpful when entering the biorefining business. The pressure of the structural change of the industry is pushing the companies toward renewing their business and revenue models.

But the process of getting into biorefining is not going to be simple. First of all change is generally resisted and it is going to take time for everyone to understand that the industry needs to change in order to survive and prosper. New skills are needed as well as additional financing. For companies that have had for a very long time primarily commodity oriented strategies the new business models can be hard to embrace. Often the biggest impediment to change is the mind-set of existing industry leadership. (Thorp, B. 2005. p. 38)

In addition to thorough knowledge of the used feedstock' structure a good understanding of the chemical behaviour of the chemical constituents like cellulose, hemicelluloses, lignin and extractives is needed in biorefining (Alén, R. 2011. p. 58). The measures needed to change a pulp and paper mill into an integrated biorefinery can differ very much depending on the facilities of the original mill and the features of the planned biorefinery (Lohi, T. 2008. p. 11). Biorefineries can also be constructed in stages so that they evolve little by little (Thorp, B. 2005. p. 37). Production volumes, biorefinery products, end-product logistics and many other things affect the planning and construction of the new unit or units. This is why biorefineries must be nearly almost designed separately for each factory (Lohi, T. 2008. p. 11).

Adopting an innovative strategy, focused on customer needs, requires very different thinking than a commodity oriented strategy. Not only executives but also marketing, sales and manufacturing personnel are going to have to change their outlook. When getting into biorefining a company must first start doing something different with the wood material (or other biomass) it is purchasing and to start generating revenue streams. Value added products are developed through market driven innovation and the integration to markets must be started early. The markets often take time to develop especially if the product is something completely new. (Thorp, B. 2005. p. 38)

In order to achieve developments companies need to commit strategically and be prepared to direct resources to the cause, despite the limitedness of their resources. Also the energy and chemical industry companies could participate in the development of biorefineries in Finland. Precisely at the interface of different industries entirely new products, processes and solutions could be created. (Hetemäki, L. 2006. pp. 38-39) For this there are many different theory frameworks but already the networks and contacts to other industries spark new ideas and possibilities. Still, to get the best results it is good to have some guidelines and management frameworks.

The cross-industry innovation process for the fuzzy front end of the innovation process by Oliver Gassmann and Marco Zeschky has been explained in chapter 2.4 . It also offers a management framework for the process and helps to avoid the most common mistakes. The cross-industry innovation process can save time in the innovation process as it offers solutions that have already been tested in some other industry. Considering biorefining it might also be very beneficial to have partners that have knowledge about different aspects of the process and product. (Gassmann, O. & Zeschky, M. 2008. p. 103)

Biorefining offers also image benefits to the forest industry as the pulp and paper industry has not always appeared that environmentally friendly. Biorefineries could be a great way to make the image of the industry greener. Biorefineries would also highlight the industry's ability and willingness to renew itself. (Hetemäki, L. 2006. p. 38) Rising oil and gas prices, climate change mitigation, uncertainty of imported energy and the need for distributed power generation also increase the attractiveness of biorefining (Hetemäki, L. 2006. p. 37).

In a biorefinery different fractions of wood are separated and further processed to components and products in forest industry or other industries (Lohi, T. 2008. p. 10). It is clear that this at least requires close relationships with other industries and an understanding of their needs. The problem in developing biorefineries in Finland is not as much in technology development as it is in the ability of different thinking and adoption of new business models (Hetemäki, L. 2006. p. 39).

Ben Thorp (2005, p. 38-39) has written "The opportunity to grow a natural resource based economy is now greater than ever before." and "Experience shows that the industry can probably develop the appropriate technologies better that it can develop the appropriate business strategies. However, the economics are so compelling that the physical outcome is easier to predict than who will drive and own the activity."

5 BIOREFINERY EXAMPLES

There are several biorefineries established around the world. This report concentrated above all in biorefining in which the raw material is woody biomass. The focus is also in such biorefineries that can be integrated alongside a traditional pulp and paper mill. The companies presented in the following chapters provide good examples of this kind of business model. Also the ways in which the organisations and individual facilities operate and have organised their innovation processes are discussed.

5.1 Borregaard

Borregaard has one of the world's most cutting-edge, sustainable biorefineries which produces advanced and environmentally friendly biochemicals, biomaterials and bioethanol. Borregaard also produces additives and fine chemicals. All the products are manufactured from sustainable raw materials and they replace oil-based products. Borregaard has 1,200 employees, eight production sites and sales offices in 17 countries throughout Europe, the USA, Asia and Africa. (Borregaard. 2012)

The first industrial plants have started at the place where Borregaard is now already in the 1600s. Modern industrial activities begun in 1889 as an English company The Kellner Partington Paper Pulp Co. Ltd. became the owner of the country estate. The Brits had developed a method of producing finer sorts of paper based on cellulose and their plan was to build up cellulose factories in areas where the raw materials were near and then send the cellulose to England for processing into paper. The company built a cellulose factory in the area near Sarpsfossen waterfall. In 1895 Borregaard accounted for a third of Norway's total cellulose production and in 1909 Borregaard was the largest industrial workplace in Norway. In 1918 the factory was taken over by Norwegian owners and it took the name Borregaard after the historical place in Sarpsborg. Until the Second World War, Borregaard manufactured mainly cellulose and paper. Since then the company has increasingly focused on different chemical products. (Borregaard. 2012)

In 1986 Borregaard merged with Orkla Industries becoming Orkla Borregaard. In 1992 Orkla Borregaard merged with Nora Industries and the new company took the name Orkla. The chemicals business area kept the name Borregaard. (Borregaard. 2012) In 2011 Orkla has altered its strategic direction and is now focusing its operations on branded goods, which is considered to be the area in which the company has the strongest competencies and can create most value. Orkla intends to grow and make acquisitions in this sector and reduces businesses activities outside this scope. It is going to be a demanding transformation but the ability to restructure is an essential criterion for long-term profitability in demanding markets. (Wiggen, B. M. 2012)

Orkla has a decentralised organisational structure in which individual companies are responsible for strategy and value creation. The Group comprises of a total of around 100 companies operating in different product sectors. Each company is responsible for its own operations and has independent profit responsibility. This structure ensures that decisions are made by people that are familiar with the market and understand the specific circumstances and options in different situations. (Orkla. 2012b. p. 4)

The operations of Orkla have been divided to five groups: materials, aluminum extrusion, branded consumer goods, associated companies (REC and Jotun), and financial investments. Borregaard is in this grouping under materials as the main products of Borregaard are speciality materials, ingredients and pharmaceuticals. (Lersch, M. 2009) More recently Orkla has excluded materials and associated companies from its division grouping and includes Borregaard now in the group of "other businesses" which doesn't really describe to company in any way (Orkla. 2012b. p. 4). Borregaard itself has four different business areas which will be presented next.

5.1.1 Business areas

Borregaard is divided to four separate divisions according to market and product type. Borregaard ChemCell is responsible for specialty cellulose and bioethanol, Borregaard LignoTech for lignin-based products and trading activities, Borregaard Synthesis for fine chemicals and pharmaceuticals, and Borregaard Ingredients for vanillin products for food. (Borregaard. 2012)

All four business divisions of Borregaard are presented in this chapter to give a comprehensive view of all the operations in the company. It is important to also notice the structure of the company. Of course it’s not rare for a company to be divided to separate units when having different products or product categories and revenue models. But in addition to that it must be remembered that the Borregaard in its entirety is just one part of Orkla which operates in branded consumer goods, aluminium solutions, renewable energy, materials and financial investment sectors. Orkla has approximately 30,000 employees and it operates in circa forty countries. (Orkla. 2012a. p. 3) Here only the divisions of Borregaard are presented as those are the ones most relevant to the subject of this report.

5.1.1.1 ChemCell

Borregaard ChemCell has been established in 1889. Borregaard has produced pulp for more than 100 years and delivered specialty cellulose for chemical processing since 1921. Over the last decades Borregaard has worked actively to develop and advance their specialty cellulose products. Nowadays Borregaard ChemCell provides a broad range of high-quality, tailor-made specialty cellulose qualities where the focus is on parameters like viscosity, brightness, purity, density and reactivity. The products are manufactured in Sarpsborg, Norway in a modern, flexible manufacturing plant, which has lately been upgraded with Borregaard’s state of the art central control center. (Borregaard. 2012)

Borregaard is the global leader in biobased chemicals and has a unique concept for their production from sustainable non-GMO wood (spruce). Biochemicals are sustainable and environmentally friendly substitutes to petrochemicals. Borregaard ChemCell has a wide range of products and services including ethanol products and a board range of specialised cellulose products. The most important customer categories of the company are manufacturers of cellulose derivatives such as cellulose ethers, cellulose acetate, nitrocelluloseand micro-crystalline cellulose. Specialty cellulose and second generation bioethanol from Borregaard ChemCell can be added to a wide range of everyday products like tile adhesives, cement mortars, filters, paint and varnish, printing ink, car care and cleaning products, biofuels, foodstuff and pharmaceuticals. (Borregaard. 2012)

In Borregaard ChemCell's cellulose production sugar compounds are released from the wood. These sugar compounds are converted into ethanol through fermentation. Ethanol from Borregaard can be used in chemical-technical applications, such as car care products, household chemicals and solvents, as well as pharmaceuticals and biofuels. There are five cellulose application areas: (1) cellulose for esters with end-uses like food, pharmaceuticals, cosmetics and personal care applications, construction, coatings, oil drilling and paper coating, (2) cellulose for acetate with end-uses like filter tow, textiles, plastics and film, (3) nitro cellulose with end-uses like printing inks, lacquers, coatings, nail varnishes and energetic grades, (4) cellulose for microcrystalline cellulose (MCC) with end-uses in food and pharmaceutical applications, (5) cellulose for viscose which can be used in production of viscose filament and viscose staple fibre. (Borregaard. 2012)

Borregaard ChemCell has made long-term commitments and large investments to ensure the sustainability of their operations. The seek innovation and value added to serve their customers in the best possible way and are determined to generate continuous quality and productivity improvement. To keep in the right track ChemCell maintains close contact with its key customers. (Borregaard. 2012)

5.1.1.2 LignoTech

Borregaard LignoTech has started in 1967 and is now the leading supplier of products based on lignin. The products of the company are sold to circa 80 countries. Borregaard's lignin products have high performance and good environmental qualities. The products are thereby based on a natural raw material and provide good alternatives to oil-based products. (Borregaard. 2012)

Borregaard's lignin products are used as dispersing agents in concrete and in for example textile dyes, pesticides, batteries, ceramic products, animal feeds and briquettes. From the wide range of products, it can be seen that LignoTech provides solutions for many different industries, most importantly agriculture, construction and animal feed additives. (Borregaard. 2012)

5.1.1.3 Borregaard Synthesis

Borregaard Synthesis manufacturers fine chemicals for the global pharmaceutical and related markets. It serves targeted applications including advanced intermediates, x-ray contrast media intermediates, active pharmaceutical ingredients, and specialty excipients. Over the past decade Borregaard Synthesis has engaged in a continual process of restructuring and streamlining to meet market needs. The division is very much focused on its core capabilities and positioned to meet the demands of the modern pharmaceutical market. (Borregaard. 2012)

Due to its strong position in selected core technologies, Borregaard Synthesis has a leading position in the supply of fine chemicals for pharmaceuticals. The Synthesis division can offer its customers secure, consistent and economically competitive operations. It has seven independent production units, pilot plant, 500 m^3 reactor capacity and state-of-the-art facilities in Sarpsborg, Norway. Continuous improvement optimises the efficiency of the division. (Borregaard. 2012)

5.1.1.4 Borregaard Ingredients

Borregaard is one of the world's leading suppliers of vanillin and ethylvanillin and the only one producing them from wood. Borregaard has been producing vanillin from spruce for fifty years and for the last twenty years it has been the only company producing vanillin from wood. Fifty years of production means fifty years of experience and building-up the knowledge. As less than one per cent of the raw material goes to extracted vanillin, the remaining 99 per cent need to be utilised in other ways. Borregaard produces 1500 tons of vanillin per year, as the ranges and volumes of other bioproducts differ and some of the material goes to energy-use. (Borregaard. 2012)

Borregaard offers a wide range of specially adapted vanillin’s for different applications like chocolate, bakery, dairy and sweets. The products are mostly used in the food industry but there are also applications in perfumes and raw materials of the pharmaceutical industry. (Borregaard. 2012) Borregaard vanillin has the smallest CO^2-footprint from all vanillin products in the market (Borregaard. 2009. p. 7)

5.1.2 Production

Borregaard produces speciality cellulose, lignin vanillin and ethanol. The process constitutes from different parts. First the raw material goes into a wood yard and further to digester. Bark, side streams from the production, and biogas from the waste water treatment are used to generate energy. After the digester the process divides to two streams. In order to produce speciality cellulose a bleaching plant and a drying machine are needed. The other stream begins with an ethanol plant, followed by a vanillin-plant and ending with lignin plant. From 1000 kg of wood are produced 400 kg of speciality cellulose, 400 kg of lignin, 50 kg of ethanol and 3 kg of vanillin. (Rødsrud, G. 2011. p. 3)

It has been estimated that the turnover of the Borregaard biorefinery is almost twice as much as the turnover of a traditional cellulose pulp mill as it contains the same or even a bit bigger turnover from cellulose and in addition to that turnover from products like ethanol, lignin and vanillin. As the turnover of traditional cellulose pulp mill is in this estimation around 425 €/ton of feedstock the turnover of a biorefinery is almost 800 €/ton of feedstock. (Rødsrud, G. 2011. p. 6)

5.1.3 The innovation process of Borregaard

Borregaard invests considerable resources in research and development (R&D) concentrating on organic and wood chemistry (Borregaard. 2012). The company has also received research funding from the EU and the Norwegian authorities (Borregaard. 2010). Borregaard has a strategy for specialisation and increased value creation which is pursued through R&D actions. Borregaard has research centres in Norway, Spain, South Africa, and the USA. Its research centre in Sarpsborg employs 60 professionals working within the development of environmental technology and new products. Borregaard has extensive collaboration with customers, universities and research institutions in several countries and maintains close relationships with its customers to be able to provide innovative solutions for them. (Borregaard. 2012)

Innovation activities are seen to be important for the future of the company as currently a quarter of the sales of the company come from products that they did not have five years ago. The innovation success of Borregaard is a result of in-house R&D and co-operation between different units of the company as well as customers, external institutes and universities. Also new application areas for existing products have been invented. In 2011 Borregaard won an innovation prize for its efforts in developing processes for the production on second generation bioethanol. (Borregaard. 2012) Borregaard’s research and development efforts are further strengthened through the construction of two pilot plants for new processes and products (Orkla. 2012b. p. 42).

As it is supposed to, the innovation process of Borregaard produces both physical products and knowledge. The researchers use 2/3 of their time on the improvement of existing processes, products and applications and 1/3 of their time developing new ones. In Borregaard the strong innovation efforts are seen to increase the value added to their customers. Chemistry can help to solve many of the challenges the world faces today in resource consumption, health and environment. Long-term R&D at Borregaard has resulted in solutions that respond to large, long-term global challenges. By using natural, sustainable raw materials, Borregaard produces advanced and environmentally friendly biochemicals, biomaterials and bio-ethanol to replace petroleum-based alternatives. In this way the company contributes to reducing emissions of greenhouse gases while producing profitable products for growing markets. (Borregaard. 2012)

According to the annual report of Orkla, innovation is extensively incorporated into every stage of their value chain through systematic use of normative tools. Deep consumer and customer insight increases the quality of the innovation process in use. (Orkla. 2012a. p. 16) Value is created through the ability to develop human capital which is done in Orkla's training programs. The courses are important in spreading experience gathered during the years to all parts of the Orkla Group. (Wiggen, B. M. 2012)

5.1.4 Health, safety and environment

Orkla Groups operations are affected by global sustainability challenges and the Group strives to address sustainability-related risks and seize the opportunities (Wiggen, B. M. 2012). The ability to meet challenges in relations to environment, health and safety are in Borregaard perceived to be key factors for the company's future. Borregaard continuously measures multiple health, safety and environmental parameters to ensure continual improvement in these matters. (Borregaard. 2012) The company for example uses life-cycle analysis to confirm the sustainability of the products they manufacture (Bredal, T. H. 2010). The life-cycle analysis has been updated in 2011 (Orkla. 2012b. p. 45).

Borregaard has managed to reduce its emission to air significantly during the past years. More than 70 per cent of thermal energy supply is based on renewable sources and energy recovery from waste. Also the consumption of fossil fuels has been reduced. (Orkla. 2012b. p. 45) Borregaard's emissions of CO_2 are mostly generated from use of fossil fuel to produce heat but also the emissions of purchased energy are taken to account and cover about 35 per cent of the total CO_2 emissions. (Orkla. 2011. p. 36) Borregaard also monitors its emissions to water, its odour emissions, and waste management (Orkla. 2012b. p. 45).

Borregaard aims at creating long-term value for all of its stakeholders including shareholders, employees and customers. The company develops business opportunities while respecting the environment and human rights. In addition Borregaard invests in the local community by sponsoring and supporting events and activities. The company seeks to contribute to a good and attractive living environment by sponsoring sports, culture and learning. (Borregaard. 2012) Borregaard also seeks to positively affect the diversity of its workforce (Orkla. 2012b. p. 43).

5.2 Arizona Chemical

Arizona Chemical is the leading producer and refiner of pine chemicals. According to their web-pages their products are designed to help make the world healthier, cleaner, safer and more efficient. Their products are used in thousands of everyday products including fragrances, personal care items, plastics, household cleaners, inks, paints and rubber products. The company has the largest fractionation and upgrade capacity of pine chemicals worldwide. (Arizona Chemical. 2012)

Currently Arizona Chemical has ten manufacturing plants located in the US and Europe and their direct sales cover all regions of the world. Their research units are located in Almere, Netherlands and Savannah, Georgia and they have two principal executive offices, one in Florida and one in Netherlands. (Arizona Chemical. 2012)

5.2.1 The history of Arizona Chemical

The roots of Arizona Chemical are in salt mining as it started as a salt mine venture between International Paper and American Cyanamid in 1930. After the salt mine was closed the manufacturing plants located in Panama City, Florida and Springhill, Louisiana started to process tall oil and turpentine. By 1946 tall oil processing was the core business of Arizona Chemical. Pine oil was commercialised by the company in 1956. (Arizona Chemical. 2012)

By 1960 Arizona Chemical had become the most important raw material provider for the adhesive industry of North America and during the next decade the demand for environmentally friendly raw materials further increased. Arizona Chemical provided pine-based resins for adhesives and rubber industries and for production of tall oil fatty acids for the coating industry. In 1980 Arizona Chemical implemented an ambitious growth strategy and during the following decades the company made several strategic acquisitions in Northern Europe. The company acquired inter alia Finland's Forchem's tall oil and turpentine business in the early 90s. (Arizona Chemical. 2012)

In the 20th century Arizona Chemical went through consolidations as it sought to optimise its manufacturing facilities for streamlined production. In 2007, Arizona Chemical became a stand-alone company as it was sold by the International Paper to a private equity company Rhône Capital. In 2009, Arizona Chemical acquired Abieta Chemie in Germany to strengthen its position in the tires and rubber industry. Currently Arizona Chemical has more than 1100 employees and state-of-the-art refineries in five countries on both sides of the Atlantic. The company provides sustainable raw materials to hundreds of companies which in-turn serve millions of consumers worldwide. (Arizona Chemical. 2012)

5.2.2 Using by-products of kraft pulping process

Arizona Chemical refines and produces chemicals from the co-products of pulp production but does not interfere in the pulping process. It only uses its by-products to manufacture its own products that are mostly sold to the global chemical industry. The company is able to generate the highest value from crude tall oil while optimising the energy efficiency and minimising emissions and waste by using state-of-the-art manufacturing practices. Arizona Chemical refines and upgrades co-products of kraft pulping like crude tall oil (CTO) and crude sulphate turpentine (CTS). 91% of the primary raw materials of the company are CTO or black liquor solids (BLS) which are converted into CTO, 5% are limonene and 4% CST. (Arizona Chemical. 2012)

The raw material in manufacturing processes of Arizona Chemical is wood more specifically pine. The chipped wood enters a kraft pulping process from which the outputs are crude sulphate turpentine (CST), crude tall oil (CTO), pulp, and black liquor. (Arizona Chemical. 2012) CST can be used in manufacturing different aromas, fragrances and flavours as well as ink binders and adhesives (Arizona Chemical. 2010). CST constituents vary by source and are alpha-pinene, beta-pinene and delta-3-carene. CTO consists of 30-50% fatty acids, 15-35% rosin acids and 30-50% pitch. Pine chemicals distilled from CTO are the raw material for a variety of different plastic and oil products. Pitch is a bio-liquid that is used for energy generation. Pulp is of obviously used for paper manufacturing and black liquor for production of steam and electricity as well as chemicals for the kraft pulping process. (Arizona Chemical. 2012)

Crude tall oil can be distilled and refined into valuable raw materials like tall oil fatty acids, distilled tall oil, tall oil rosin and pitch. Fatty acids can be used to produce paints and coatings, biolubricants, fuel additives, and performance polymers. Rosins are a raw material used in inks, adhesives, paper making, road marking, and tires. Sterols are a fraction that is not always isolated at Arizona

Chemical but they can be used in health enhancing food additives and pharmaceuticals. (Arizona Chemical. 2012)

5.2.3 Markets and product categories

Arizona Chemical divides its markets to eight categories: (1) adhesives, (2) bio-energy, (3) chemical intermediates, (4) consumer products, (5) personal care, (6) printing inks, (7) roads and road marking, and (8) tires and rubber (Arizona Chemical. 2012). From those Arizona Chemical has identified four target markets: adhesives, tires and rubber, roads and construction and personal care (Arizona Chemical. 2011b). In this chapter all of these product categories are introduced separately to showcase exactly how diverse the options in biorefining are. The point being: All of these products can be manufactured from the by-products of a pulping process and this company is already doing so.

5.2.3.1 Adhesives

Arizona Chemical is the leading supplier of tackifying resins made from renewable resources in the global adhesive market. The broad product portfolio of Arizona Chemical provides raw materials for tapes and labels, packaging, nonwovens, bookbinding and flooring applications. Arizona Chemical operates in a way that enables their customers to formulate adhesives that meet their changing needs. (Arizona Chemical. 2012)

Arizona Chemical provides adhesive tackifiers which are used as primary resins as well as modifiers in hot melt PSA applications. The products offer increased peel and tack performance, improved adhesion to difficult-to-bond surfaces and enable environmental stability for high performance solution acrylics. Same products can also be used in packaging as do two additional product categories of Arizona Chemicals. The company also offers the latest technology for specialty water-based tape and label applications that can be used for example in medical tapes and wraps. (Arizona Chemical. 2012)

5.2.3.2 Bio-energy

When distilled, CTO yields 30–50% pitch fuel, a sustainable and renewable bioliquid that is used for industrial energy and heating applications. Arizona Chemical's pitch fuel enables their customers to decrease their greenhouse gas emissions. Compared to heavy fuel oil (HFO), pitch fuel generates 70% lower CO_2 emissions. (Arizona Chemical. 2012)

The maximum quantity of sulphur is regulated as the reduction of sulphur in diesel helps to mitigate acid rain. But the desulphurisation process also removes lubricating properties and thus low sulfur diesel causes wear in transport diesel engines. Arizona Chemical's tall oil fatty acid (TOFA) is used as a lubricity additive in low sulphur diesel. 200 million tons of environmentally friendly low sulphur diesel is produced yearly. (Arizona Chemical. 2012)

5.2.3.3 Chemical intermediates

Arizona Chemical produces raw materials to be used in coatings, lubricants, metal working fluids, fuel additives, mining and oil fields. The company has many high quality products for different coating formulations. They also offer fuel additives, raw materials for the lubricant industry, as well as tall oil fatty acids and dimer acids for drilling fluids and production chemicals segments of the oilfield industry. (Arizona Chemical. 2012)

5.2.3.4 Consumer products

Arizona Chemical supplies structurants and gelling agents to designers of products for the home care and consumer markets. The products are designed to be compatible with a wide range of active materials including fragrances, insecticides, biocides, pigments and dyes. The polymers are used in many different applications. (Arizona Chemical. 2012)

Arizona Chemical provides a technology for automotive air fresheners, home and industrial air fresheners, as well as insect repellent and pest control applications. The products used in these applications are called gellants. (Arizona Chemical. 2012)

5.2.3.5 Personal care

Arizona Chemical supplies a bio-renewable line of polymeric materials to the personal care industry. The products can be used in personal care formulations as film formers, water repellency agents, surfactant free emulsifiers, structuring agents, rheology modifiers, pigment stabilizers and actives delivery systems. (Arizona Chemical. 2012)

The personal care market is divided to three submarkets: make-up, skin care and sun care. The structuring polymers that Arizona Chemical provides can be used to produce hard gels from most cosmetic liquid ingredients and replace traditional waxes and oils. The bio-sustainable polyamide chemistry has direct applicability in the formulation of creams, lotions and sticks for skin care products as well as sun care products. The high percentage of pine tree derived carbon makes the products of Arizona Chemical ideal for development of aesthetically pleasing, sustainable personal care formulations. The products are supplied in either a solid or gel medium. (Arizona Chemical. 2012)

5.2.3.6 Printing inks

Arizona Chemical's products are a sustainable choice for printing ink as they have at least 70% higher bio-renewable content than their alternatives. The products are used in several major print processes, including lithography, flexography and publication gravure. Arizona Chemical for example enables printing on flexible films. (Arizona Chemical. 2012)

5.2.3.7 Roads and road marking

Arizona Chemical provides renewable rosin based binder chemistries that can be used in thermoplastic road markings. Thermoplastic road marking is the most widely used form of road marking and it is cost effective too. (Arizona Chemical. 2012)

5.2.3.8 Tires and rubber

Arizona Chemical is one of the leading suppliers of resins based on renewable resources for the tires and rubber industries. Their broad product portfolio provides sustainable raw materials to enhance tire performance and optimise rubber polymerisation. The company offers tread enhancement additives, synthetic rubber, and high performance tackifiers. (Arizona Chemical. 2012)

5.2.4 Innovation management

The organisational structure of Arizona Chemical is designed to support a culture of innovation. Identifying and fulfilling existing and emerging needs is critical for the strategy of the company. The approach to development and implementation of specialty solutions for their target markets has been globalised and modified to maximise innovation and achieve continuous improvement. The company is committed to double its investments in research and marketing by 2013 from the 2009 level. (Arizona Chemical. 2011b. pp. 6 and 8)

The employees of Arizona Chemical are accustomed to think and act globally. They work as a worldwide team, but value their differences and the power of cultural diversity. (Arizona Chemical. 2011a) People with different outlooks and knowledge bases create the most innovative teams (Alvarez, H. A. 2012. p. 2). Because differences spark creativity and innovation it is beneficial to employ people with stark differences in heritage and culture, as Arizona Chemical does.

The company is also committed to continuous improvement which as well promotes innovative atmosphere. (Arizona Chemical. 2011a)

In order to successfully create an innovative atmosphere a company needs a strong innovation processes that can be communicated in a graphical way. In Arizona Chemical a strong process has been implemented and clear mapping of the process helps to connect the marketing function, markets and the strategy of the company. (Oliva, R. 2012) Arizona Chemical strives to improve their business processes by using a new enterprise resource planning system and input from customers (Arizona Chemical. 2011b. p. 9).

Arizona Chemical Innovation Process (AZIP) relies on multifunctional capabilities. It provides cohesion and makes science and technology integral throughout the business cycle. With an integrated approach different teams in the company interact to facilitate the flow of activities from new idea to prospect to customer orders. (Arizona Chemical. 2011b. p. 8) Arizona Chemical uses the Stage-gate -model shown in chapter 2.2.6 in the theory part of this report. Stage-Gate International is a full-service provider of solutions enabling organisations to improve their product innovation and portfolio management capabilities and Arizona Chemical is one of its more than 5000 client organisations. (Stage-Gate International. 2008. p. 4)

5.2.5 Sustainability

All ten manufacturing locations of Arizona Chemical are accredited to high environmental standards. Many of the facilities have also received environmental certification. The raw materials they use, like CTO and CST, are sustainable and biodegradable originating from pine and do not deplete global food supplies. (Arizona Chemical. 2011a) The company uses an Aspects Analysis, an integrated method of determining the affects their activities have on the environment (Arizona Chemical. 2011b). The company has also made carbon footprint analysis of its operations and it shows that the emissions resulting from their products are less than half of the emissions caused by alternative products. (Arizona Chemical. 2011a)

Almost all of the products of Arizona Chemical have significantly higher bio-renewable content than the alternative products in the market. In the adhesives market Arizona Chemical helps their customers in maximising the renewable content in the products by including data with the percentage of renewable content in the resin in their product literature. Some of the resins have also been tested by a third-party laboratory. (Arizona Chemical. 2012)

Arizona Chemical is also committed in actively participating in communities in which it is present. Their employees participate in for example philanthropic events, mentoring programs and local educational institutions. The company systematically evaluates and improves its risk management, internal controls, business processes and corporate governance. (Arizona Chemical. 2011b. pp. 10-11)

6 ENERGY PRODUCTION IN BIOREFINERIES

In the forest industry energy has traditionally been a by-product of the pulping process and in pulp and paper integrates it has been used in the energy-intensive paper manufacturing process. However, pilot plants for heat and energy production are starting to be quite common also in the forest industry due to heavy taxation of fossil fuels, investment subsidies, emission trading, energy self-sufficiency objectives, decreasing production costs, regional policies, EU objectives, and environmental thinking. (Pätäri, S. et al. 2008. p. 164) A Chemrec representative Ingvar Landälv (2006. p. 40) has said that in Finland half of the consumption of automotive fuels could be produced through black liquor gasification. This estimation might be quite optimistic and has been made in 2006 so it must be remembered that the production capacity has changed since then. Nonetheless, the potential in Finland is huge. Landälv’s estimation for Sweden has been 30% and for Canada seven per cent. (Landälv, I. 2006. p. 40)

However, there are some problems with increasing the energy use of forest-based biomass: The added value is often considered to be larger when converting biomass into forestry products that to energy. Also the price-competitiveness doesn't seem as good as with other fuels. In addition the increased energy use would affect the supply and prices of raw wood material. (Pätäri, S. et al. 2008. pp. 164-165)

New policies will strongly effect the direction the biofuel industry will develop and what materials it will be using. Policy decisions affect the profitability of production of biofuel and determine which types of biofuels become most common. Current vague legislation doesn't necessarily support the environmentally friendliest alternatives, but rather sets all types of biomass and biofuels at the same starting point. This may lead to the worst options from the environmental point of view becoming the most common.

6.1 Problems and opportunities for biofuels

When any kind of biomass is burned inside the European Union to produce energy the generated biogenic emissions are entirely ignored. However, not all biomass is carbon neutral. The use of carbon positive biomass would increase the amount of atmospheric greenhouse gasses (GHG) and has equal effect to global warming as fossil carbon. An example of carbon neutral biomass is waste from which the carbon would in any case end up in the atmosphere and which has no economic or ecosystem service value. There are also carbon negative biomasses, for example biomass that restores soil carbon stocks of the degraded land where it's grown. The usage of carbon positive biomass is supported by policies that don't require that the biomass is regrown. For the biomass industry to be truly sustainable the biomass should always be regrown, preferably in the near future. (Greene N. 2011, p. 12)

There are two factors that determine the extent to which biofuels will be used in the future. The technical limitations define the quantity of biofuels possible to manufacture in a sustainable way. The economic policies determine the extent to which sustainable biofuels will be chosen over unsustainable biofuels. It’s not possible to turn unsustainable biomass into sustainable biofuel, no matter how efficient the biorefinery is. This means that despite the technical development the current policies need to be changed to achieve sustainable biofuel production. (Greene N. 2011, p. 11)

The impacts from producing and collecting biomass are hard to measure, price and regulate as they enter the environment over broad areas. Managing any one attribute, like fertilizers, soil carbon, water use or yield, can impact another one badly. Even if the biomass itself doesn’t directly increase emissions, it might indirectly do so. The environmental impacts of current agronomic systems can be fairly easily reduced. Unfortunately, it requires new performance-based policies to make the needed actions economically preferable. And the policies are not yet even efficiently debated, not to mention ready to be taken to use. (Greene N. 2011, pp. 11-12)

The biofuels policies should be improved to:

- overcome the challenges of cultivating and collecting biomass sustainably and converting it into clean burning biofuels.
- establish rules and regulatory oversight encouraging to use sustainable biomass in sustainable ways.
- help the advanced biofuels industry to get public support. (Greene N. 2011, p. 11)

In current biofuels policy the terrestrial carbon is entirely unregulated. This could be corrected by introducing an indirect land-use emissions accounting as a part of lifecycle GHG emission measuring. The accounting process is complex but it is the only way to ensure that the environmentally friendliest options are the ones that are encouraged the most. It’s alarming that GHG accounting as well as the minimal environmental safeguards are being protested against. Under current policies any significant increase in demand of biomass will be primarily met with unsustainable biomass. (Greene N. 2011, pp. 12, 16) This is something that needs to be realized when considering entering the business. If the legislations don't encourage the use of sustainable biomass it might not be profitable to do so. On the other hand the legislations might change as time passes and that might affect the availability and price of biomass as well as the profitability.

Nathanael Greene proposes that large government incentives should be channelled to initial commercialization of advanced biofuels. In particular he would grant government support for the manufacturing of the first billion gallons of biofuels when they meet the highest environmental standards. In addition he would bring into use voluntary sustainability certification standards. He would also implement severe environmental performance standards for all to follow. Mr Greene fears that if biofuels are commercialized without further safeguards and rules to guide the market the GHG emissions and other negative impacts of production will increase and in the long run have a negative rather than positive impact on the environment. (Greene N. 2011, p. 16)

6.2 Biocoal

Biocoal, often referred as biochar, is as the name refers a product that is made from bio based material and resembles very much char coal. As it has been previously explained biochar is produced by torrefaction of biomass in a temperature 225-300ºC (Alén, R. 2011. p. 67). The torrefaction process results in the biomass changing into a coal-like product and the best quality torrefied pellets (TOP-pellets) are produced when chips are torrefied at 240-250ºC. When it is milled and pelletized its energy density is higher that the energy density of traditional wood pellets. TOP-pellets are good energy carriers in large volumes and endure long transportation distances a lot better than other similar products. (Wilén, C. 2011. p. 41)

In large scale utility boilers TOP-pellets give high energy volumetric density and their properties are similar to char coal. The production units can operate in stand-alone mode, like the torrefaction unit constructed in the BIOTULI-project, or they can be integrated to industrial CHP or forest industry bed boilers. TOP-pellets offer a tempting business opportunity to companies with existing raw material and forest residue logistics. (Wilén, C. 2011. p. 41) That is why biocoal and TOP-pellets have been chosen to be concentrated on in this report as a part of the forest biorefinery concept.

Coal has been created from biomass for centuries but traditionally it has been used to improve soil, or in backyard grilling or small scale heat production (Mitchell, D. & Elder, T. 2010. p. 1 and 6). When used for soil improvement biocoal is also an effective carbon sink as it captivates carbon to the soil. The increased pressure to find alternative energy sources for fossil based fuels has made the bio char a currently interesting topic in energy use as well and it has been developed in order to replace fossil coal.

There are countless coal fired condensing power plants in the world that would be operational for decades to come but are threatened by coal prices getting more expensive and a strong political desire to reduce the use of fossil coal. On the other hand the political atmosphere favours bio based energy production. The properties of bio char are similar to fossil coal and therefore it could be possibly used in existing power plants with minimum modifications. (Hämäläinen, E. & Heinimö, J. 2006. p. 7)

The high temperature of torrefaction process decomposes the polymers of the bio mass giving it suitable characteristics for use in power plants (Bergman. P. C. A. et al. 2005. p. 14). Untreated biomass is difficult to use as its grindability is poor and requires a lot more energy (Abdullah, H. & Wu, H. 2009. pp. 4177 - 4179).

There are a number of different processes to produce biocoal. The bases for suitable torrefaction reactors come mainly from three fields: drying, pyrolysis (carbonation), and gasification. These technologies can be divided to two categories: indirectly heated and directly heated. (Bergman, P. C. A. et al. 2005. p.

27) In the BIOTULI-project biocoal is produced by a screw type reactor. Such demonstration plant was built already in the 1980s in France producing 12,000 ton/a biochar. The plant was shut down in the 1990s due to economic reasons. The screw reactor has low energy efficiency and its scalability is poor and therefore its production costs are not very competitive although the technology itself is feasible. The plant in France was shut down in 1990s. (Bergman, P. C. A. et al. 2005. p. 22) Also the dust formation in the torrefaction process is a common problem which can lead to dust explosions and spontaneous ignition (Wilén, C. 2011. p. 44).

There are commercialized TOP-pellets on the market and some power plants have used small amounts of TOP-pellets combined with fossil coal in order to test the suitability of the fuel. Probably also image purposes are behind these testings. The research of biocoal is widespread but the real breakthrough hasn’t happened yet and for now biocoal is just one option in a wide range of promising possible future biofuels.

For now the price of TOP-pellets is higher than the price of char coal. The total cost of torrefied pellets is somewhere around 6,5 € per GJ with a difference of one euro compared to coal. Almost half of the cost of TOP-pellets come from the cost of biomass. As the emission rights get more expensive the price of TOP-pellets becomes more competitive compared to coal. Already TOP-pellets are cheaper than wood pellets. The total cost of wood pellets is around 9 € per GJ. (Bergman, P. et al. 2011. p. 15)

7 ENERGY COMPANY EXAMPLES

The energy markets are changing and this offers opportunities for new companies. Although, this report mostly concentrates on integrated production in the forest industry, two energy companies are introduced in this chapter to highlight how the current possibilities can be taken advantage of.

The first company presented in this chapter is Topell Energy. This is because this report focuses on biocoal from all biofuels and Topell Energy is one of the leading companies in that field.

Chempolis is a Finnish company providing biorefining technologies and solutions for co-production of bioethanol, biochemicals and biocoal as well as co-production of non-wood pulp, biochemicals and biocoal. This company has been chosen to be presented here because it is innovative, Finnish and seems to have a promising future. Chempolis is also interesting in the sense that it is a biorefinery that concentrates in integrated processes and especially the production of transportation fuels.

Chemrec is a similar example and is thus covered more shortly. The purpose of these examples is to showcase that there already are companies providing solutions for turning traditional pulp mills into a biorefineries. The focus when looking into Chemrec is on the Chemrec process and the BioDME-project which is a great example of a successful research and development project profiting companies from different industries.

All of these companies are on markets with great growth potential. The competition is going to get more fierce in the future but for now all three companies seem to have good starting positions and if they keep open-mindedly developing and innovating the late starters may have a hard time catching up to these two.

7.1 Chempolis

Chempolis has been established in 1995. In 1996 the company made a pilot scale demonstration of its technology and 1997 successful paper machine trials were done with non-wood-based furnish. After ten years of development, followed the acquisition of the Chempolis Biorefining Park in 2006. In recent years Chempolis technologies have received recognition from respected authorities and the company has made licence agreements with Finnish companies and started a subsidiary in China. (Rousu, E. 2011. pp. 13-14)

In March 2012 a Finnish newspaper Tekniikka&Talous mentioned Chempolis as one of the most promising small size cleantech-companies in Finland. The program director of Cleantech Finland, Santtu Heikkonen, identifies Chempolis as one of the cleantech-firms with the best prospects of becoming a company with a turnover of more than 100 000 000 euros. (Heikkilä, M. 2012b. pp. 16-17)

7.1.1 Products and competencies

Chempolis provides sustainable solutions for the biomass, paper, biofuel, alcohol, sugar and chemical industries. The core products of the company are couple of third generation technologies for biorefining of residual biomass. Formicobio is used for the co-production of non-food cellulosic bioethanol, biochemicals and biocoal, and Formicofib for the co-production of non-wood papermaking fibers, biochemicals and biocoal. (Chempolis. 2012)

The expertise of Chempolis covers the entire processing chain from biomass to pulp and other end-products. The company has knowledge and experience in conceptual engineering, process and plant engineering, equipment design, supplying proprietary systems, and turnkey plant deliveries. (Chempolis. 2012) Chempolis provides technologies but also services and complete solutions. The offerings are based on Formico technologies: Formicofib, Formicobio and Formicochem. The company also provides Formico systems: Formicocont, Formicodeli and Formicopure, as well as engineering management, procurement management and commissioning. In addition Chempolis provides services like laboratory tests, pre-engineering work, plant optimisation and training. (Chempolis. 2012)

7.1.2 Technologies

Chempolis' technologies enable the co-production of papermaking fibres, bioethanol and biochemicals from non-wood and non-food biomasses such as straw, bagasse, corn stover and bamboo. The key technologies of Chempolis are the Formicobio and Formicofib technologies. (Chempolis. 2012) The Formico platform uses non-food and non-wood biomass to produce cellulose products like paper fibres, high value fibres and glucose ethanol, hemicellulose products like sugar and biochemicals, as well as lignin products like lignin, biocoal and nutrients (Anttila, J. 2012. p. 3).

7.1.2.1 Formicobio

Formicobio is a refining technology for the production of high purity non-food cellulosic fuel ethanol. It is an effluent-free low carbon technology which consumes less chemicals than traditional processes and generates its own energy. It also provides biochemicals as by-products. (Chempolis. 2012)

Formicobio enables cost-effective and sustainable production of transportation fuel from agricultural residues. The technology has no negative impacts on food production and it can provide additional income in rural areas. For example in Southeast Asian countries the sugar industry has a huge potential in bagasse residues which could be used to manufacture biochemicals and bioenergy. (Chempolis. 2012)

The Formicobio process is selective which means that optimised processes can be applied for each fraction and thus high conversion levels and pure products are achieved. The biosolvent and water circulation is closed which prevents the generation of waste. (Chempolis. 2012)

7.1.2.2 Formicofib

Formicofib refining technology is used to produce fibre for paper, board, packaging and hygiene products. It is also an effluent-free technology and it makes selective cooking possible. It has excellent bleachability without chlorine chemicals and it produces biochemicals as by-products. (Chempolis. 2012)

Pulp produced from non-wood raw materials with the Formicofib technology can be used in similar applications as current hardwood and non-wood pulps. Chempolis' Formicofib technology provides a cost-efficient and sustainable way to supply pulp for the paper industry in rapidly growing markets like China, India, and Thailand. It enables the use of inexpensive, local non-wood biomasses for the production of high-quality pulp. The solution is very competitive compared to either transporting dried wood pulp across the globe or producing non-wood pulp by inefficient and polluting old technologies. (Chempolis. 2012)

7.1.3 Markets

The headquarters of Chempolis are located in Oulu, Finland, but the target markets of the company are in Southern Asia. Chempolis' customers in Asia and Pacific region are served by the fully owned subsidiary Chempolis Biorefining Technology in Shanghai. Chempolis is expanding strongly in Asia. (Chempolis. 2012)

There are big opportunities for cleantech companies in China but it is generally a difficult market. The local companies have very low cost structure and are thus hard to compete with. India is also an interesting market for Chempolis. (Rousu, P. 2011. p. 11)

7.1.4 Research and development

Chempolis has been strongly focused on developing production technologies and has been granted more than hundred patents. Alongside its headquarters Chempolis has a biorefinery enabling the company to demonstrate to their customers the technologies they offer. The biorefinery also provides facilities for piloting research and development work. Chempolis has invested around 20 million euros in the plant. It is capable of processing 25,000 t of non-wood and non-food raw material per year. (Chempolis. 2012)

Chempolis is willing to invest in its innovation activities as its management believes in innovation being essential in order to deliver sustainable results. The mission of the company is to deliver technologies capable of refining biomass economically into high-quality products while minimising environmental impacts and maximising social benefits. By providing technologies that require less raw material, reduce water and energy consumption as well as decrease emission and waste Chempolis delivers benefits for its customers and stands out from its competitors. (Chempolis. 2012)

7.1.5 Sustainability

Biorefining non-wood and non-food raw materials, helps in preserving forest resources, reducing CO_2 emissions, and securing sufficient food for the growing population. It can also offer a new revenue stream for many rural areas. When renewable residual biomass is used for production, the production cycle is energy-efficient and the carbon footprint remains low. (Chempolis. 2012)

The CO_2 emissions of the transportation sector can be reduced by using bioethanol. This way also the sourcing of fuel can be secured as oil resources are declining and often located in politically unstable areas. (Chempolis. 2012)

Production of wood pulp consumes forest resources and long distance transportation of papermaking fibers causes CO_2 emissions. Unfortunately many processes that are currently used to produce non-wood pulp consume massive amounts of groundwater, as well as pollute waterways and cause CO_2 emissions. The Formico biorefineries are significantly more sustainable than their alternatives in social, environmental and economic aspects. (Chempolis. 2012)

Chempolis' Formico technologies enable higher revenues and reduced operating costs. The operating and investment costs are relatively low but the products are of high quality and their co-production improves the profitability. Local biorefining provides jobs and incomes to rural areas. Formico technologies use raw-materials that are not suitable for food production and thus don't affect the food supply. The products are locally produced and often used locally as well. The CO_2 emissions and other pollution to atmosphere and waterways are low and residual biomasses can be used for production which benefits the environment. The Formico technologies also help in preserving forest and water, as they do not use woody biomass as raw material and have low water consumption. (Rousu, E. 2011. p. 6)

7.2 Chemrec

Chemrec has 20 years of experience in the field of black liquor gasification. Its headquarters are in Stockholm and the development plant in Piteå, Sweden. (Chemrec. 2012) The company provides a process that turns traditional pulp mills into biorefineries. The installed Chemrec technology, a gasifier and a motor fuel plant, only need power and black liquor to produce motor fuels and chemicals. The Chemrec technology provides green liquor and steam back to the pulp mill part of the biorefinery. (Chemrec. 2010. p. 1)

The Chemrec process provides a way to convert low-value biomass into high-value renewable automotive fuels or chemicals. The highly efficient, integrated process provides 30-50% additional revenue for the mill. The Chemrec process can also help in increasing power generation and reducing fossil fuel use. (Chemrec. 2010. p. 1)

The process can significantly increase the cash flow and profitability of the pulp mill by enabling it to become a biorefinery. The Chemrec's black liquor gasification technology opens up new markets for mills, producing sustainable, low-carbon chemicals and fuels. (Chemrec. 2012) The products are produced efficiently and economically and they are nearly CO_2-neutral. Also the land use efficiency is higher than for most biofuels. The process can utilise forestry, agricultural or municipal waste streams. (Chemrec. 2010. p. 2)

7.2.1 Chemrec conversion process

The Chemrec process is based on high temperature, entrained flow gasification of black liquor. The product of this process is cooled high quality raw syngas which can be used to manufacture a number of different biofuels. (Chemrec. 2010. p. 2)

The components of Chemrec system are: an oxygen plant, a black liquor gasifier and gas cooler/steam generator, a plant for removing carbon dioxide and hydrogen sulphide from the raw syngas, a fuel synthesis plant, and a distillation plant. In the fuel synthesis plant the liquid fuel is synthesised from the syngas and in the distillation plant the fuel is purified. (Macdonald, C. 2009. p. 58)

Black liquor is a suitable biomass feedstock for biorefining because it is a liquid and it is available at existing industrial sites in large quantities. Because black liquor is a liquid it can be easily pumped into the pressurised gasifier. Liquid black liquor is also easily atomised into a fine mist that reacts very fast in the gasifier. The gasification of black liquor char is also faster than for other feedstock as its inherently high sodium and potassium content acts as a catalyst. (Chemrec. 2012)

Because of the characteristics of black liquor, the high temperature, entrained flow gasification principle can be applied for the process. The advantages over alternative gasification technologies include that it is rapid with low reactor volume, it needs less syngas clean-up, the carbon conversion is complete and has no tar formation and low methane content. (Chemrec. 2012)

Black liquor is such a great biomass feedstock for biorefining that in Chemrec system it is not burned in the conventional Tomlinson-type recovery boiler, even though the biomass boiler remains in the system to provide steam for the pulp mill process. The feedstock of the conventional boiler is switched to any kind of low-grade biomass and the black liquor is used for the production of biofuel. (LeBlanc, R. J. 2009. pp. 49-50)

The Chemrec process provides the pulp mill with the needed black liquor recovery capacity at the same time as it produces syngas for biofuel production. The infrastructure of the pulp mill guarantees the raw material supply, utilities, and provides the opportunity for net energy cost reduction. (Chemrec. 2012) For mills producing as little as 500 tons of black liquor solids per day it can be commercially viable to be turned into biorefineries with the Chemrec system. At the minimum capacity size a biorefinery mill would generate at least 32 million litres of green motor fuels a year. (Macdonald, C. 2009. p. 58)

7.2.2 BioDME -project

The BioDME -project consists of eight work packages and is financed by the participants, the EU and the Swedish Energy Agency. There are many companies involved from different industries. Chemrec and Haldor Topsøe have developed and built a dimethyl ether (DME) plant in Piteå. Other functions in the project are the development and building of DME trucks by Volvo Trucks and development of fuel injection systems for the trucks by Volvo Trucks and Delphi. Total is responsible for fuel and lubricant specifications and Preem for the distribution of the BioDME and the building of fuel stations in Sweden. The Energy Technology Centre in Piteå has assisted by providing technical expertise in the project. (BioDME. 2012)

Dimethyl ether has many applications such as propellant, power generation, fuel for heating and cooking or as transportation fuel. DME can be used as a fuel for the highly efficient diesel process. It has low exhaust emission and reduces noise levels of the vehicles it is used in. (BioDME. 2012) The BioDME pilot facility in Smurfit Kappa paper mill in Piteå, Sweden, was completed in 2010. The production capacity of the facility is 500,000 gallons per year. The produced BioDME is used in specialty converted trucks and operated by DHL, Green Cargo and Poten Logistics. (Sims, B. 2010)

The beauty of the BioDME-project is in the co-operation between companies in different stages of the life-cycle of the product. As many projects only focus on the development of production methods or on the attributes of the product or its use in a particular application, the BioDME-project entails all these aspects. It is a large scale project with large expectations but it also creates valuable links between organisations and that might be even more valuable for the participants than the objectives of the project.

7.3 Topell Energy

Topell Energy is a Dutch clean technology company which has developed a torrefaction process for the production of high value biocoal from woody biomass. The production principle and the properties of biocoal have been shortly explained in chapter 6.2 of this report. Topell Energy operates a commercial-scale production plant in Duiven, The Netherlands, and the company is an international provider of integrated torrefaction solutions. The torrefaction plant in Duiven will ultimately have a production capacity of 60,000 tons per year. (Topell Energy. 2012)

High hopes for more extensive use of biomass in energy production are expressed regularly. However, when untreated, biomass is expensive to transport, to store, and to combust or gasify. Also the amounts that can be combusted at a time in current coal-fired energy plants are limited. But by torrefying the biomass it can be made into a form that is cheaper to transport, store and combust as well as possible to use in much larger scale. (Topell Energy. 2012)

7.3.1 Production technology

Topell Energy has constructed a torrefaction plant with a maximum capacity of 60 000 t/a at Duiven in eastern Netherlands (Torftech Group. 2010). The plant uses TORBED technology and the company has plans to increase the production capacity of the plant to 80 000 or even 100 000 t/a in the future (Beckman, K. 2010). Topell Energy does not focus on all five areas in a torrefaction plant, but only in the third one in the middle of the process. This area consists of the biomass feed system, TORBED reactor system and product cooling. (Bergman, P. et al. 2011. p. 11)

The Topell Torrefaction System is efficient and flexible process. For the actual torrefaction phase, Topell Energy uses so-called TORBED reactor which has been developed by Torftech Ltd. (Newbury, UK) in 1998. The reactor consists of an empty cylindrical reactor chamber where an extremely turbulent environment creates a very intense contact between the hot process gas and the feed material, yielding an efficient and rapid heat-to-mass transfer. (Topell Energy. 2012)

The Topell Torrefaction System is a multi-stage process using a series of TORBED reactors to convert fibrous biomass into torrefied biomass (Topell Energy. 2012). It enables fast and homogeneous torrefaction at mild temperatures with 10-11 Mt/h systems. The system has high turbulence inside the reactor which causes intense contact between material and process air. The bed volumes are small and there are no moving parts inside the reactor. The Topell Torrefaction System has very fast reaction kinetics and efficient heat/mass transfer. Therefore the throughput times for specific processes are short. Other advantages of the system are that it is energy efficient, it can retain wide particle size ranges and the technology can be scaled up. The biomass is turned in to coal in only 90 seconds of torrefaction. (Post van der Burg, R. 2011. p. 3) The Topell Torrefaction System also makes it possible to precisely control the product specifications (Topell Energy. 2011. p. 6). After the multi-stage torrefaction process, the torrefied biomass is cooled and compacted. The energy dense torrefied pellet can then be stored and shipped to customers. (Topell Energy. 2012)

7.3.2 Markets

Besides selling TOP-pellets Topell Energy is also an integrated technology provider to torrefaction plants. The offering of Topell Energy includes inter alia engineering for Topell Energy Torrefaction System, delivery of key equipment for a Topell Torrefaction System, and installation and commissioning of the system. (Topell Energy. 2012)

The markets of the company are large and small-scale industrial heating, district heating and residential heating, co-firing of torrefied biomass with coal in for example steel production and applications of biomass for fuel production and gasification. (Topell Energy. 2012)

7.3.3 Environment

Many different raw materials can be used in Topell Energy Torrefaction System. Any woody biomass can be torrefied as well as various energy corps and agricultural waste streams. Possible feedstocks for torrefaction are for example woodchips, nutshells, rice hulls, straw, and bagasse. The use of by-products from other processes makes the production of biocoal environmentally friendly. (Topell Energy. 2012)

The CO_2-release in electricity production of coal is 706 g CO_2 per kWh and the CO_2-release from the fuel manufacturing of coal is in addition 54 g CO_2 per kWh. When using TOP-pellets, the CO_2-release from electricity production is considered to be zero and the CO_2-release from the fuel manufacturing of Topell pellets is 49 g CO_2 per kWh. This means that the total reduction of CO_2 when using Topell pellets instead of traditional coal is 94%. (Bergman, P. et al. 2011. p. 13)

Topell Energy is a member of the Dutch Torrefaction Association, which consists of a group of innovative companies which contribute to a cleaner environment through their focus on torrefaction. According to the Dutch Torrefaction Association torrefaction deserves social and political support, and the members of the association work together to create a nationwide awareness. The members jointly address questions from various stakeholders and provide information about the advantages of torrefaction. (Topell Energy. 2012)

8 INNOVATION MANAGEMENT IN THE FOREST INDUSTRY

The theories of chapter 2 are here connected to the forest industry. In this chapter, like in the previous ones, aspects connected to biorefining and bioenergy are concentrated on. The Finnish forest industry has a lot of companies differing in size, product and service range, future objectives, governance and management approaches, clientele, networks, internationality, and so on. It would be impossible to make such conclusions about the market that would apply to all companies in the Finnish forest industry, not to mention worldwide.

Here the focus is on companies that would have interest in biorefining business or would have an important role in the value chain of a biorefining product even if they would not themselves participate in producing or marketing it. We are looking at the situation from the perspective of Finnish forest industry, and even though it is facing similar challenges and changes as companies in some other countries, the conclusion made here cannot be generalised to include them and those analysis would have to be made separately.

8.1 Characteristics of innovation management in the Finnish forest sector

The Finnish forest industry has been strongly focusing in its innovation activities on cost-effectiveness and improvement of short-term competitiveness. This has been achieved mostly through process innovations though here it's important to notice that often a process innovation affects the manufactured items of the product line and in turn product improvements require changes in the process (Pesonen, P. 2006. pp. 58-59).

In the 2000s especially the largest companies have gained interest in business innovations and businesses outside their core business are developed for instance in venture-units (Pesonen, P. 2006. p. 59). Unfortunately despite the venture-unit activity there have been very few companies that have started in this industry since the 1990s. In the middle of the 2000s there has also been a switch from technology push to market pull which can be seen in the increase of customised products and solutions (Pesonen, P. 2006. p. 59).

The biggest obstacle in the Finnish forest industry companies' innovation management is the so called innovation paradox, which basically means the conflict between the pursuit of cost-effectiveness and long term innovation actions. Radical innovations usually require a long development process, risk-taking, big investments and a lot of courage. But on the other hand cost reductions and efficiency improvements are the best way of improving profitability, and profitable operations are crucial to getting investments for among other things the needed long term innovation activities. This situation with two conflicting objectives and the former strong focus on one side over the other is very problematic and troublesome. (Pesonen, P. 2006. p. 62)

8.2 Innovation processes in the Finnish forest industry

The organisational structures that guide the innovation activities of a company can be either centralised or decentralised. This means that there can be either just one research centre with all the activities, or several R&D units and/or departments. In large companies the structure is usually decentralised. (Pesonen, P. 2006. p. 59) Only in the resent years the companies have started to outline specific innovation strategies for themselves. Pekka Pesonen reports in his publication, from 2006, called in English "Innovation Management and its Effect in Forest Industry", that none of the nine representatives from Finnish forest industry companies that he had interviewed, had admitted that their firm had a defined innovation strategy (Pesonen, P. 2006. p. 64). The resent change shows that the management has interest in developing the innovation mechanism of their companies, but that the process requires much more than just outlining an innovation strategy. The implementation of a new and effective innovation culture, -management, -tools and -knowledge requires determination, willingness to truly change and courage to start thinking differently and from another perspective.

One comprehensive innovation process cannot be outlined for all companies of the forest industry. All organisations should have defined their processed to suit them in the best possible way. The process should be described step-by-step and should have defined functions to bring order and efficiency. (Pesonen, P. 2006. p. 60) There are defined frameworks like the Stage-gate model, which has been presented in section 2.2.6, that can be implemented to get a structured innovation proses and effective idea and innovation portfolio management system.

Obviously, one framework cannot be used in all units and functions in one form, so it must be scalable like the Stage-gate model is. The implementation must be carefully contemplated and as it's described in the theory part this might turn out to be quite challenging. As it has been, also to the forest industry firms that have tried. One major problem in implementing any kind of companywide innovation structure is the common outlook that the innovation activities are not included in the engagements of all company members but are the responsibility of the R&D function only (Pesonen, P. 2006. p. 60).

Many companies have initiative systems used to collect ideas from inside the company and in some those systems could even be used to get ideas from the closest partners. Unfortunately these systems have often shortcomings and are not utilised as well as they could be. The ideas are collected from the company and recorded somewhere but they are not regularly viewed. The decisions are made by a certain group of people from inside of the company and experts from outside are rarely used. Often the initiative system is not even companywide and even if it is, all employees are not actively encouraged to use it. The best ideas are usually rewarded which does act as an incentive but is certainly not enough to create an innovative atmosphere to the company. (Pesonen, P. 2006. p. 64)

After the first idea-stage the companies continue to stages of selection, concept testing, and development, as it is explained in chapter 2.1. If the management of the idea-stage is sloppy, it hinders the following process, no matter how well it is organised.

The principles of project portfolio management seem simple and self-evident: reviewing all projects, making sure they meet business plans and are align with the strategy of the company and provide real value. Still project portfolio management is used very shallowly in so many firms that evidently would need its help. In these cases it usually is the implementation of project portfolio management that has failed. (Pennypacker, J. & Retna, S. 2009. p. 3)

When a company is shifting a portion of its resources from an old product to a new one it is facing a risk, as the old product is already selling while the success of the new one is uncertain. This problem is especially prominent in a case of a radical product innovation. When bringing new products to the market one also needs to take to account that the customers might at first resist the change. (Pesonen, P. 2006. p. 61) In business to business operations this can be helped by including the most important customers into the R&D and letting them have their say about the product before it’s brought to the market.

Because the product development cycles have been relatively long and the amount of innovations made has been low especially prior to the 1990s, the atmosphere in Finnish forest industry companies is not very innovative as fast changes have not been required until very recently (Oksanen, J. et al. 2010. p.40). The atmosphere is not going to change quickly and the role of the management and company leaders is very important in making this transformation happen. As it has been mentioned in the theory part of this report people often get unsettled by change (Pennypacker, J. & Retna, S. 2009. p. 13). The structural change of the forest industry has been spiralling out of control as huge amounts of people have been laid off and the atmosphere in many working environments is most probably fearful as the continuity of the operations is uncertain.

Uncertainty can lead to competition between different units or even individual employees in the company and that can hinder the co-operation between people and result in a situation where different knowledge is not transferred within the company from a department to another. This significantly hampers the innovativeness of the organisation. Of course competition is not always a bad thing and the competitiveness can be used for the advantage of the firm by conducting for example innovation competitions within the company. The importance of co-operation between different departments and units is especially important in large projects (Pesonen, P. 2006. p. 66).

8.3 The increasing importance of co-operation

For many companies of the Finnish forest industry the difficulties in shifting to new ways of innovation management come from their history. The development efforts that have been made in the Finnish forest industry have mostly sought to improve cost-effectiveness and the short term profitability of the company. In the mature business environment the companies have focused on getting the shareholders and financiers the fast returns that they seek. (Pesonen, P. 2006. p. 62)

Now that the industry is in a transition the companies are looking for high value products and radical innovations that would guarantee them a good starting position for the future. When thinking of biorefining, it's easy to see that the innovations will spring from the interfaces of different industries and knowledge areas. This is generally considered to be one of the most important mechanisms in producing radical innovations. And this will require interaction and co-operation with other organisations: companies, universities, governance, clients and so on.

The companies use market researches and constant co-operation with key customers for market monitoring. In addition they use the services of different design and consult firms as well as co-operate with universities. The most important sources of ideas, according to the company representatives, are the forest cluster, other industries and of course customers. (Pesonen, P. 2006. p. 63) Even in project portfolio management there are many stakeholders with different roles and responsibilities. In order to get a project going a sponsor is often needed to promote the project and help to get funding for it (PMI. 2006. p. 16). He or she needs to have a good understanding of the industry but does not necessarily have to be an employee of the company. As the Finnish forest cluster is wide and extends to many different organisations it might be very beneficial for companies to utilise these kinds of sponsors also from outside of the company.

The most important stakeholders in a project are usually from within the company or a group of companies and research organisation working together according to formal contracts which outline the responsibilities of each party. Vendors and business partners are often very important for the project portfolio management process as they have different knowledge bases and outlooks on things. Also the role of interaction with customers can be very valuable during the research and development project. (PMI. 2006. pp. 17-18) The Benecol case, introduced in chapter 8, demonstrates well the role of different partners in one successful R&D project that combined knowledge from few completely separate industries. It also showcases a great example of a situation where a forest industry company has been a part of a successful development project resulting in and product innovation for another industry.

Also the production of bioenergy can be seen as one good example of co-operation between the forest industry and another industry. The forest sector has expertise in the upstream actions of the value chain but lacks knowledge on processing the material into energy and on delivering the products to customers. This knowledge can be acquired through co-operation with the energy industry. (Pätäri, S. et al. 2008. pp. 168-169) Even though all logic suggests that in this situation co-operation would be of great benefit some companies have chosen not to do so.

Lack of trust towards other companies is the most important thing holding back small and medium sized companies from creating networks (Etelä-Karjalan liitto. 2008. p. 15). Large companies often build their relationships so that their involvement becomes vital to the partner. These situations can often end up badly for the smaller company and they are not willing to take a similar risk again. Even if the partnership is otherwise working well the one-sidedness of the relationship tends to undermine innovation (TEKES. 2008. p. 4). An other problem in the networking in the Finnish business field is that the small and medium sized companies don’t necessarily recognize companies that could potentially be great partners for them (Etelä-Karjalan liitto. 2008. p. 15).

9 COMPARATIVE INDUSTRIES

In this chapter the Finnish wood and paper industry is compared to some other industries in Finland: the metal industry and the chemical industry. Metal industry is the one with the biggest exports, covering over thirty per cent of the total exports of Finland. The exports of the wood and paper industry and the chemical industry are roughly the same size, about twenty per cent. (National Board of Customs, 2012a, p. 11)

The Finnish metal industry is interesting in its innovativeness and ability to adapt to change. That is why the viewpoint of this part of the report is in comparing the innovation athmospere of the forest indusrty and the metal industry. Also some of the most significant innovations made in the metal industry during the last few decades are looked at in order to help and demonstrate the differencies between the metal idustry and the forest industry.

Many of the changes and trends effecting the business environment of the Finish forest industry are global and have their affect also in other industries. The industry comparison between the Finnish wood and paper industry and chemical industry concentrates on these changes and the ways they affect these two industries. Also the ways in which the industries perceive the changes that are happening and respond to them are compared.

The industry comparisons are followed by the Detroit Three -case, which showcases an example of a situation where an union bargaining system and an union cartel have affected the performance of companies that have given their employees great benefits and once the business conditions have changed have had hard times competing with such companies that have lower labour costs. The Detroit Three case may seem political but that is not its purpose. Instead it is an example of an industry struggling with structural change.

9.1 Metal industry

Here the metal industry is considered to include metal processing, basic and primary metal, machinery and metal product, vehicle, and electrical engineering industries. In Finland the business is mostly focused on manufacturing machinery, equipment and appliances for business customers. It can be seen from figure 5 below, that from the Finnish industry field the metal industry is clearly the one with the biggest exports. Also its effect on employment is significant (Oksanen, J. et al. 2010. p. 24). The exports of metal, machinery and vehicle industry products by Classification of Products by Activities, CPA, have increased five per cent from 2010 to 2011. This is mostly due to slight improvement in the economy and overall business circumstances. It can be seen from the picture that the only field in which exports have decreased in this period of time has been electrical and electronic industry products. (National Board of Customs, 2012b, p. 10)

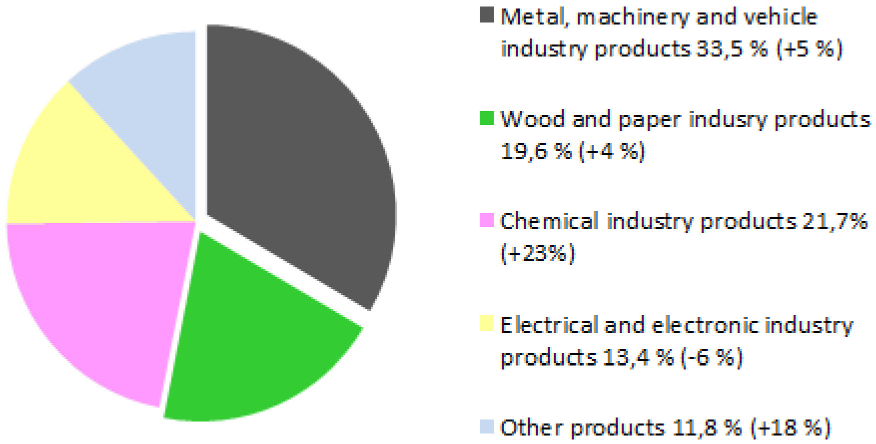

Figure 5. Exports by product category 2011: Metal Industry and Wood and Paper Industry. (National Board of Customs. 2012a. p. 11)

If compared in gross value of production the clearly biggest sub-industry in the Finnish metal industry is machinery and equipment. On second place is metal processing and on third metal products (not including machinery and equipment). (Oksanen, J. et al. 2010. p. 28)

9.1.1 The innovation atmosphere of Finnish metal industry

In the middle of the 20th century the war reparation deliveries added to the demand of the Finnish metal industry. This was also the time that the first direct public development supports were given for R&D activities. After the war reparation deliveries the metal industry was oriented to domestic markets which protected the industry from the international economic fluctuations. Industry and export diversification started to be considered in the 1960s. The difficult times after the war had sparked some very long-term products and solutions like the flash melting method of Outokumpu. (Oksanen, J. et al. 2010. pp. 24-25)

At those times an open-mindedness for new methods and technologies as well as the ability to adapt quickly to changing circumstances sparked. Companies are characterized by low corporate hierarchy and a relatively small number of companies which has supported the rapid diffusion and adoption of new production methods and technologies. The industrial structure has changed rapidly and adapted flexibly over time. (Oksanen, J. et al. 2010. p. 25)

The breakthrough of container technology and integrated freight transportation system was a significant change in the 1970s. It was possible due to international standards and enabled a more widespread geographical decentralization of production, outsourcing and subcontracting. (Oksanen, J. et al. 2010. pp. 25-26)

During the last few decades Finnish metal products have been internationally profiled as technologically advanced products. Competitive advantage has been applied through R&D activities by creating new successful products, rather than by mass production, and this is what has created the need for continuous innovation. (Oksanen, J. et al. 2010. p. 26) This is one major difference compared to the pulp and paper industry where the most important products are particularly mass products benefiting for economies of scale.

The development of metal industry products has been characterized as problem-solving driven as it is solving problems for its customer and partner organisations which are operating in different industries. For example the forest and metal industries are in close co-operation with each other. (Oksanen, J. et al. 2010. p. 26)

The strong position of Finnish metal industry is based on successful internationalization. The competitiveness comes from own product development, strategic focus in business operations, the outsourcing of non-core business activities, and partnerships with fewer operators corresponding with a larger part of the supply chain, internationalization of operations and services as growing portion of sales. Also the relations between technological universities and metal industry have historically been close and concentrated more on practice than research. (Oksanen, J. et al. 2010. pp. 26-27)

Comparison between the amount of new companies started each year in the metal industry and the forest industry shows that the metal industry has better been able to adjust to new situations and to attract new businesses. In the forest industry the amount of new firms is much lower and has been dropping since 1995. (Oksanen, J. et al. 2010. p. 28)

9.1.2 Innovations of the Finnish metal industry

In the Finnish metal industry innovations have been created at a steady pace. In quantitative terms there have been most innovations emerging in the 1990s and 2000s. The same time period has been the most active also in the Finnish forest industry. The metal industry innovations can be separated to different categories. (Oksanen, J. et al. 2010. p. 30) The categories of Oksanen, J. et al. (2010. p. 31) are the following: (1) *Metallurgy and Materials*: metal processing and raw material-related technologies, (2) *Off-Road Machinery*: forest and agricultural machinery, (3) *Motors and Marine Engineering*, (4) *Transport and Containers*: technologies related to the transportation of people or goods, (5) *Forest, Paper and Energy*: metal industry technologies related to the forest industry, (6) *Crushers and Drilling Machines*, (7) *Other metal products*: consumer-oriented products. From this categorisation it is easy to see that the forest industry represents an important customer to the metal industry. The Forest, Paper and Energy group is completely oriented towards the forest industry and also the Off-Road Machinery group obviously contains solutions made particularly for the forest industry. But the other groups as well might contain products for the forest industry or logistic solutions serving it.

The focus of product development in the metal industry is clearly in providing machinery, equipment and means of transportation for its customers. In the time period from the beginning of the 1900s until the 1960s and 1970s the production of consumer products was a relatively common in the metal industry. Since that the metal industry companies have mostly specialized in corporate markets. (Oksanen, J. et al. 2010. p. 31)

In general the innovations made in the metal industry have been quite significant. Oksanen et al. (2010. pp. 31-38) mention some of the ones considered most important. In Metallurgy and Materials the most important innovations of the last six decades are considered to be flash smelting process from 1947, as well as the NEO- and NEO-REM-magnets from the second half of the 1980s, which have further enabled more innovations. The NEO- and NEO-REM-magnets are used in elevators, marine engines and propellers, small electric automotive motors, mobile phones and wind turbines. In general most innovations in this category are quite new, and thus their significance is hard to measure. One of the promising products of the future is for example the VSF^{tm}-liquid extraction method. (Oksanen, J. et al. 2010. pp. 31-32)

The innovations of Off-Road Machinery are often also considered to be forestry innovations. As it has been mentioned before, many of the innovation in the forest sector are in fact made in the metal industry or at least in co-operation with it. In this category important steps have been the development hydraulics in the 1970s and, more recently, design and IT solutions. Challenges for the future are for example in cutting and collecting smaller trees such as eucalyptus. (Oksanen, J. et al. 2010. pp. 32-33)

In Motors and Marine Engineering the production of electrical and mechanical propulsion devices has created knowledge and know-how which in turn has led to an extensive network of subcontractors. The understanding of complex ice-breaker technologies has contributed to the existing propeller expertise. In this area there are few innovation considered to be very significant, but as they are not relevant to the topic of this report, they are not looked into. Also the transport and container category is fairly irrelevant, as most of its key innovations are related to elevators, hoists and cranes. In this category some important innovations are invented already in the 1940s. (Oksanen, J. et al. 2010. p. 34) Crushers and Drilling Machines are also a group that doesn't fall very well into the subject of this report. In this category the local conditions have had significant impact on the innovations made. Time wise the significant innovations are evenly spread from the 1960s until the 2000s. (Oksanen, J. et al. 2010. p. 37)

The Forest, Paper and Energy category is interesting as these innovations have direct impact on the Finnish forest industry. They are also a big and important part of the whole innovation ensemble of the Finnish metal industry. There are two time periods when there have been quite many important forest, paper, and energy related innovations: first in 1950s a few important innovations and between the middle of the 1970s and the middle of the 1990s a large amount of innovation considered very important by the expert group of Oksanen, J. et al. (2010. pp. 35-36 and 43) publication. The most significant reformations have been related to pulp production, energy production in the forest industry and paper machine technology. Most of these innovations have been made by engineering companies and a smaller part by forest companies. The forest industry has offered a demand oriented driver for the metal industry, creating specialised know-how usable in serving the domestic markets as well as markets abroad. Finnish innovations have had an important role in the paper and pulp manufacturing and over the decades engineering companies have been responsible for a significant part of the research and development activities of the forest industry. (Oksanen, J. et al. 2010. pp. 35-36)

To mention few of the most important innovations in the Forest, Paper and Energy category: recovery boiler by Tampella from 1950 and a recovery process of sulphate chemicals also by Tampella from 1968, a few important innovations by Jylhävaara Oy including a pulping proses from 1954, an automatic load control device of mass refiners from 1958 and a technology for the manufacture of mechanical pulp from 1976, as well as ozone bleaching and blending technique by Ahlström from 1993. In 1970s and 1980s Tampella and Ahlström were also active in the development of energy production of forest industry and at the same time Valmet Oy made some innovations considering paper machinery and paper-making technology. (Oksanen, J. et al. 2010. p. 36)

9.1.3 The innovative character of the Finnish metal industry

The technology of the metal industry has been changing through technology leaps. In the 1950s the technologies were based on mechanics and hydraulics. In the 1960s and 1970s the regeneration was aimed to create automated production through electrification and electronics. The next technology leap was created by information technology and data processing. Each of these leaps has created new knowledge and new businesses. (Oksanen, J. et al. 2010. p. 38)

By character the metal industry is integrative and solution searching. Interaction with the customers and close monitoring of changes in their business fields are extremely important as customers' problems are often the starting point for product development and thus bases for innovations. In many cases there is a mutually beneficial interdependence between the metal industry company and its customers. The challenging demand pushes the development further and engages the metal industry companies to innovativeness. Even though metal industry companies have increasingly own long-term research, the companies are characterised by problem and solution oriented innovation activities. (Oksanen, J. et al. 2010. p. 39)

The major difference between the forest industry and the metal industry is that the metal industry has been required to develop and change frequently. Its customer industries have demanded new technologies and solutions and even though cyclically the industry has been going forward by its own means. (Oksanen, J. et al. 2010. p. 39) The forest industry companies have not been forced to innovate as continually and they have in a way even been able to outsource some of their innovation activities. Also the products are different. For example in a pulp and paper mill the same product is produced in huge amounts. The economies of scale make the production profitable. But the metal industry company providing the paper machinery has to almost always tailor the product specifically for the customer (Oksanen, J. et al. 2010. p. 39). For a company that has to modify its products constantly also bigger changes come more naturally than to a company for which not only significant changes but also product modifications are fairly rare.

In order to achieve scale benefits in the manufacturing process of metal industry products standardization and fragmentation to smaller components are usually required. This is how different innovation paths and innovation families are formed around one initial innovation. Specialised expertise and know-how support continuous innovation. Company names and ownerships have been known to have changed without it having any immediate effect on the occurrence of further innovations from a single development project. In the industry there also is a significant co-operation network with suppliers and contractors, which grow as parts of global value networks, creating innovation and new business. (Oksanen, J. et al. 2010. p. 39)

9.2 Chemical industry

Here the chemical industry is inspected in the Finnish categorisation which includes also pharmaceuticals, paints and oil products, unlike some distinctions in other countries. From the production of Finnish chemical industry almost 75 per cent goes to export as such or as a part of another product. The main market is the European Union. Most of the import to Finland consists of raw materials. (Mäenpää, M. et al. 2010. pp. 22-23)

The following picture presents the Finnish exports in 2011 with Classification of Products by Activities, *CPA* (National Board of Customs, 2012b, p. 10). The exports of the chemical industry are very close to the exports of wood and paper products and have just recently exceeded the exports of the wood and paper industry products. The percentages marked in brackets show the change from the

2010 figure to the 2011 figure. As the exports of wood and paper industry have increased modestly the exports of the chemical industry have boomed, the growth being 23 per cent. Of course when looking at the growth per cents we must remember that during the recent economic downturn the production volumes dropped significantly and are now recovering. In the beginning of 2009 the production of chemical industry decreased with one fifth and the production of the forest industry with more than one third (Mäenpää, M. et al. 2010. p. 24).

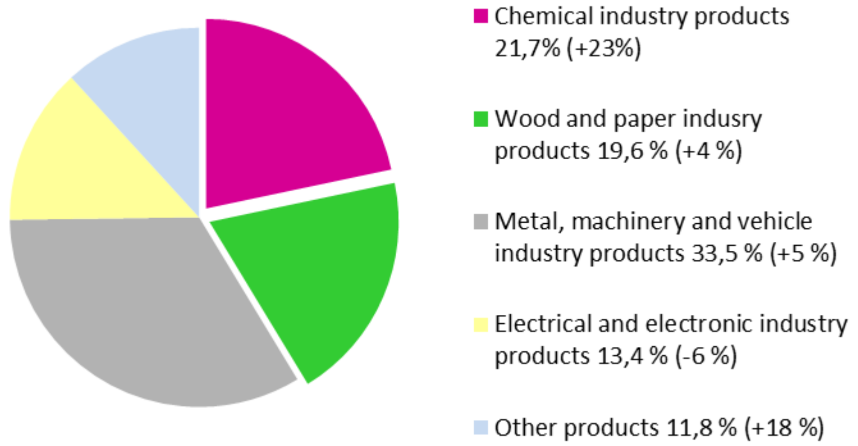

Figure 6. Exports by product category 2011: Chemical Industry and Wood and Paper Industry. (National Board of Customs. 2012a. p. 11)

In Finnish chemical industry the biggest segments are chemicals for industry use, pharmaceutical industry, paints and lacquer, detergents and cleaning products, and oil products. In total there are about 1400 companies in Finland but only few of them are globally significant. Compared to other sectors the chemical industry companies in Finland have more often foreign owners, but still most of the R&D funds come from within Finland. (Mäenpää, M. et al. 2010. pp. 25-26)

9.2.1 Global trends affecting the chemical industry

The biggest production area of chemical industry is Europe, but due to higher cost levels and slowdown in demand this is changing. The local operating conditions of the chemical industry depend on the same things as in forest industry: the proximity of customers and availability of cheap raw materials. (Mäenpää, M. et al. 2010. p. 13) The demand of chemical industry products is shifting more and more to the developing economies. Also the production is transferring nearer to the growing demand and into places with lower production costs. This means that the position of the European industry is getting weaker and China and India are where the growth happens. (Sikow, P & Saarinen, J. 2010. p. 4) Similar trends are detected also in the forest industry, in which the growth in Asia is accompanied with the growing production levels of South-America.

According to Mäenpää, M. et al. (2010. p. 30-31) the Finnish chemical industry is suffering from a rise in energy prices, long distance from raw material sources and high prices of raw materials, expensive workforce and relatively high tax rates. These things also affect the Finnish forest industry, except of course the distance form raw material sources when considering domestic woody materials. The raw materials from forests are also seen as an advantage in the chemical industry as well as the mineral-bearing soil in Finland (Mäenpää, M. et al. 2010. p. 30). An interesting thing to notice is that when talking about the chemical industry the collective bargaining system in Finnish wage bargaining is mentioned as an disadvantage, but the same thing is usually left out of consideration when talking about the forest industry, especially the pulp and paper industry.

The capital invested in the product facilities in Europe is keeping most of the existing manufacturing in place for now. In the European Union the competitiveness of the chemical industry has been improved by restructurings and saving measures. (Mäenpää, M. et al. 2010. p. 20) Many chemical industry companies in Finland have outsourced their R&D functions as it has been seen as the more cost-effective way to proceed. When doing so there is the risk that the R&D functions are not going to stay in Finland. (Mäenpää, M. et al. 2010. p. 26-27).

Concentration among the customers of the chemical industry has resulted in the customers favoring global operators. This has increased the pressure to grow or merge. (Mäenpää, M. et al. 2010. p. 20) Because of a broad shareholder base corporate arrangements like mergers and acquisitions have been common also in the past (Mäenpää, M. et al. 2010. p. 17). In the Finnish chemical industry the amount of recently established firms is very small, just like in the Finnish forest industry as well. Some of the underlying reasons affect all industries, like the lack of private equity investors and the lack of entrepreneur spirit. In Finland there also is a lack of chemical industry knowledge centres. (Mäenpää, M. et al. 2010. p. 30)

One significant trend affecting chemical industry, as well as the forest industry, is the amplification of environmental thinking. Environmentally friendly technologies offer business opportunities, and the European chemical companies seem to be quite willing to pursue them. Regulation and registration of chemicals adds its effect on things, as does emission trading. (Sikow, P & Saarinen, J. 2010. p. 9) Especially small and medium sized companies suffer from the complex regulations on national and EU level (Mäenpää, M. et al. 2010. p. 21). Mostly the regulations are seen as threats, but they do offer possibilities as well.

9.2.2 Transition in manufacturing and products

Price competition is intensifying in basic chemicals as it is in basic paper products in the forest industry. It seems that the production of these products will geographically concentrate in areas that are close to the raw material sources and where the price of the raw materials is low. Also lower oil and energy costs lure companies to certain regions. On the other hand in the chemical industry there is a trend that oil-based chemicals are replaced with alternative raw materials, in particular, with renewable and bio-based raw materials. (Sikow, P & Saarinen, J. 2010. pp. 6-8)

Roughly the products of the chemical industry can be divided to basic chemicals and specialty chemicals and services (Sikow, P & Saarinen, J. 2010. p. 10). Also pharmaceuticals can be seen as a separate market group, as their portion of the global market is nearly 30 per cent. Basic chemicals are produced in large scale and sold to industrial companies. In general basic chemicals are strongly affected by raw material and energy costs, and cost-competitiveness is on their part very significant. The operations are very cyclical and the growth is mostly in Eastern Europe and Asia. (Mäenpää, M. et al. 2010. pp. 13-14)

Fine and specialty chemicals have high added value and for most of them the demand is growing. The products can be for example chemicals used in electronics, different coatings or industry gases. (Mäenpää, M. et al. 2010. p. 14) In specialty chemicals and services the current trend is to combine service innovations and customer service approach. The companies in this area are often small and specialized, and R&D investments and innovations play a key role in their existence. Companies search for innovations from carefully selected areas. Usually the demand is not as strongly cyclical as in basic chemicals. (Sikow, P & Saarinen, J. 2010. p. 10)

The fact that the chemical industry in Finland is concentrated on basic chemicals is considered to be one of its most significant setbacks. The emphasis should be on speciality chemicals, and the development of new innovations and services. (Mäenpää, M. et al. 2010. p. 30) The growth of the chemical industry is generated through customer industries, and thus the environmental business and renewable forms of energy offer hope for new business areas. (Mäenpää, M. et al. 2010. p. 8)

9.2.3 Future opportunities

As it has been mentioned the growth of the chemical industry comes through its customer sectors from which the ones with the most growth potential: environmental business and renewable energy, new business opportunities in forest industry, machinery, construction and mining industries (including the metal industry), electronic industry, and pharmaceutical and food industry. There is a large growing potential in Finnish chemical industry but all directions can not be followed without hindering the competitiveness of the companies. The fragmentation and lack of big organisations is a problem, as usually only the big companies have the resources to heavily pursue new knowledge and markets. (Mäenpää, M. et al. 2010. pp. 33-34)

From the previously mentioned customer sectors the most compelling to Finnish chemical industry firms are environmental business and renewable energy, and new business opportunities in forest industry. From these the global business potential of environmental business and renewable energy is considered more significant. Also the Electronic industry and pharmaceuticals are considered to have large global business potential, but are not as attractive to Finnish companies. (Mäenpää, M. et al. 2010. p. 34)

Environmental business is globally one of the fastest growing industries and is thus understandably important. The forest industry is one of the most important customer segments of the chemical industry and has large potential in new applications. The role of wood in the forest clusters value chain could be much more versatile than what is currently is. (Mäenpää, M. et al. 2010. p. 36) Co-operation with the forest cluster and benefiting from the synergies requires trust between the parties co-operating, and as this is mentioned by Mäenpää, M. et al. (2010. p. 37) it suggests that the trust is not self-evident.

Wood consists of a wide variety of ingredients and compounds with offer great possibilities that have not yet been investigated. In this chemistry plays an important role (Mäenpää, M. et. al. 2010. p. 36). The BIOTULI-project combines successfully different science and technology fields including chemistry.

The metal industry is the biggest industrial sector in Finland. The chemical industry can provide applications and processes for example in achieving energy cost savings, recycling of metals and designing lighter building materials. (Mäenpää, M. et al. 2010. p. 37) There are also attractive business opportunities in the field of organic electronics like RFID-technology and OLEG-technology. There are also other opportunities like printed electronics that could be cheap mass-products. (Mäenpää, M. et al. 2010. pp. 39-40)

In order to be able to pursue these opportunities the knowledge in the chemical industry must become more diversified. The offering should be comprehensive solutions including services like consulting in environmental issues. Also new revenue models are needed. And very importantly, the customers and their needs should be well known as well as the interactions between the product, its user and the environment that it is used in. (Mäenpää, M. et al. 2010. pp. 42-43)

9.2.4 Co-operation: Possibilities and advantages

In Finland there is a strong and fairly cohesive forest cluster, but the chemical industry is scattered. As the Finnish forest cluster can be seen as one of the leading ones in the world and in the changing times it is very much intending to keep things that way, there is also an opinion that a single environmental business entity in the Finnish chemical industry should be formed to make Finnish chemical industry an international path-setter in environmental business and renewable energy. (Mäenpää, M. et al. 2010. p. 8)

One of the problems of the Finnish chemical industry is that the parties in the supply chain are not integrated enough and the production is not planned from the perspective of the end-customer. To mend this situation the traditional industry boundaries must be pushed. (Mäenpää, M. et al. 2010. p. 30)

As the chemical industry is shifting towards renewable and bio-based raw materials, it is especially in the Finnish circumstances considering the use of wood-based materials and thus moving closer to the forest cluster. Simultaneously, the forest industry is considering biorefining and production of high value products from which many in fact can be seen as chemistry products. As the two industries are getting closer to each other it is obvious that the opportunities for co-operation are getting bigger and more attractive. For example the chemical industry would benefit from the knowledge about wood as raw material and the raw material logistics of the forest industry and in return the chemical companies could offer knowledge about the chemical manufacturing processes and market expertise on high value and low production level products. The customers of the chemical industry are mainly companies. This means that the companies serve the end-customers and consumers via their customers. (Mäenpää, M. et al. 2010. p. 13) This means that co-operation already has an important role in the business. New business models often have a lower need of capital as they tend to have higher level of service or they use more subcontractors and have co-operation with different organisations inside the industry or back or forward in the value chain. (Mäenpää, M. et al. 2010. p. 17)

In Finland the chemical industry uses one fourth of its production itself. The same amount goes to the use of paper- and printing industry, which shows that there already is a significant connection between the chemical industry and the forest industry. (Mäenpää, M. et al. 2010. p. 13)

9.3 Case: Detroit Three

The drastic example of the Detroit Three shows how a strong trade union can hamstring otherwise competitive enterprises when they are in competition with non-unionized companies. A mutual mistrust between the Detroit Three (General Motors (GM), Ford and Chrysler) and the United Auto Workers (UAW) has resulted in interaction where the vast majority of communication is negotiation. This has created problems that increase inefficiency and deteriorate the competitiveness of the Detroit Three. (Robinson, L. 2008. p. A.11) Here the situation is compared to the Finnish forest industry and its trade union movement which is also described in the following chapters.

9.3.1 How “the Big Three” turned into the struggling Detroit Three?

Once, “the Big Three” were used as an example of American economic might. The BM-Ford-Chrysler oligopoly had emerged in the 1940s, and until the second half of the 1970s the three companies had virtually the whole American car market to themselves. United Auto Workers (UAW), the union representing the autoworkers in Detroit, had gained a dominating position over “the Big Three” in the middle of the 1930s and had a labour monopoly in American car factories. At this time, when UAW demanded benefits for its members the companies could just pass the costs on to the consumers. (Ingrassia, P. 2008. pp. 2-3)

The oligopoly however perished when foreign automakers started to build factories in America. First came the Japanese car companies like Nissan and Toyota and soon after them the German and Korean automakers. Most of these new factories were not organized by the UAW. (Ingrassia, P. 2008. p. 4)

At the same time there were some very bad decisions made at General Motors and the company was in trouble. It had simultaneously lowered the wages of workers and reinforced the bonus system of executives resulting in bad atmosphere within the company and dispute with the UAW. GM had also purchased new automated guided vehicles that were not working as they were supposed to and took a lot more time and money to implement than originally expected. (Ingrassia, P. 2008. p. 4)

Ford and Chrysler were doing well at the time. Chrysler launched the mini-van in 1984 which was an instant success and Ford managed to use its design knowledge for its benefit. The Gulf War recession affected all three companies, especially GM, but by the middle of the 1990s all three companies were doing alright. The SUV market was booming and the Japanese were not competing in that market at that time. In the beginning of the 2000s the Detroit Three were looking forward to what they thought would be a promising future and the companies were spending money accordingly. (Ingrassia, P. 2008. p. 4)

In 2005 the SUV sales were diminishing because of the soaring gasoline prices (due to Hurricane Katrina and growing oil demand in China and India). GM and Ford both lost over $10 billion in 2006 and Chrysler was sold in 2007 to Cerberus for about one-fourth of the price for which Daimler had originally purchased it.

(Ingrassia, P. 2008. p. 5) The resent recession has affected the companies very badly, but it’s important to recognize that the Detroit Three were in trouble even before the recession started (Ingrassia, P. 2008. p.1).

It is also worth noticing that GM, Ford and Chrysler are all competitive in foreign markets like Europe, South America and China. Of course, state franchise laws do differ between these markets and federal government’s Corporate Average Fuel Economy affects the market circumstances. Differing wage rates explain the difference in competitiveness to some extent but as foreign transplants pay well, and the UAW has had to give concessions in the recent bargaining the effect is not as big as one would think. So, the conclusion is that the most important difference between the Detroit Three and the foreign transplants is that the Detroit Three are unionized as the others are mostly not. (Robinson, L. 2008. p. A.11)

9.3.1.1 Describing the disharmony between the Detroit Three and the UAW

Until the last recession the UAW frequently threatened to or went on strike if the Detroit Three didn’t give in to their demands. Not so long ago the Detroit automakers paid their workers $70 an hour in wages and benefits. In 2007 the health benefits for retirees and active workers added $1,200 to the cost of every vehicle produced by GM. Also other benefits that UAW had managed to negotiate added to the cost of every car manufactured in Detroit. (Sherk, J. 2010. p. 22)

The collective bargaining agreement with the UAW has been, and still is, a very large and meticulous document and it is almost identical for GM, Ford and Chrysler. This is because the UAW is using so called pattern bargaining, which means that it is deliberately making the agreements as similar as possible. The collective bargaining agreement doesn’t only consider work rules, but also vitally important business decisions like selling and closing plants and starting spin-offs. This means that the companies have to negotiate with the UAW before they can make any major decisions. (Robinson, L. 2008. p. A.11)

Because every move has to be negotiated with the UAW, which interests are not necessarily in line with the needs of the company, all three enterprises need to maintain a large staff of lawyers, contact administrators, financial representatives and human-resources representatives just to negotiate with the UAW. Also the trade union itself needs to have the staff to do the bargaining with the Detroit Three. (Robinson, L. 2008. p. A.11)

UAW benefits, like retirement after 30 years of employment and the UAW Jobs Bank, have been adding to the cost of every car made in Detroit (Robinson, L. 2008. p. A.11). Although, the Jobs Bank has been recently cancelled there are still a lot of UAW benefits that are impairing the competitiveness of the Detroit Three (Sherk, J. 2010. p. 22).

9.3.1.2 The Jobs Bank

The Jobs Bank was created when the plants of General Motors were modernized to keep up with the competition. As the plants became more flexible and automated they needed less workforce. The UAW demanded that the company should keep paying to the workers displaced by the technology as then the workers would have job security and would easier adopt the new practices. Even though the union got its way and the idle workers of GM were paid most of their wages and benefits, the UAW continued to fight the plant closings. (IBD. 2009. p. PAG)

Due to the UAW Jobs Bank GM has paid to its former employees, for example, just at Buick City factory (that closed ten years ago) up to $85,000 a year. The idle workers have also had their health care coverage and continued to collect years of service toward their pensions. In addition to the Jobs Bank GM has spent huge amounts of money funding its pension and retiree health care obligations. And the non-union competition has of course been free of most of these costs. (IBD. 2009. p. PAG)

In 2009 the Investors Business Daily stated in an article called “Ax UAW ‘Jobs Bank,’ Save GM” that “While General Motors was losing billions, it was pumping billions into a union welfare system set up to pay workers not to work”. At this time the UAW was still fighting to keep the Jobs Bank as they felt that they had fought too hard for it to just let it go. (IBD. 2009. p. PAG)

9.3.1.3 Negotiations in 2011

The UAW and the Detroit Three are going to negotiate a new four-year contract this year (Terlep, S. 2011. p. B.3). The executives at the Detroit Three say that the companies cannot afford an increase in labour costs - at least not in the next agreement. The companies are prepared to pay bonuses or profit sharing, but want to keep the fixed (labour) cost as low as possible. On the other hand, the UAW members haven’t had a raise in seven years and most of them would prefer a wage increase to profit sharing. It’s hard to find a solution that would fit the workers’ aspirations as well as keep the competitiveness of the Detroit Three in a level that would ensure that any more jobs aren’t going to be lost. (Barkholz, D. 2011)

The UAW members are keen to recoup the benefits they have given up when the Detroit Three were in trouble. Especially employees of Ford seem to be willing to fight to get their way. In 2010 Ford workers refused concessions, including a no-strike clause. (Automotive News. 2010. p. 12) Ford has recently been profitable and even given substantial bonuses to its senior executives which is making the workers active to regain their former benefits (Barkholz, D. 2011). The situation of Ford is different from GM and Chrysler also because the UAW now owns stakes in the other two (Terlep, S. 2011. p. B.3).

9.3.2 The trade union movement in the Finnish forest industry

The Finnish collective bargaining system and its conditions have some exceptional features when compared internationally. First of all, in Finland an exceptionally large portion of employees are members of trade unions. An other interesting thing is that the government participates in confederation level negotiations. (Pentti, V. 2008. p. 19) While salary earners in Finland are well-organized employers' organization is not as common. However large companies are more organized than small ones. (Pentti, V. 2008. p. 21)

9.3.2.1 Negotiation system

Paperiliitto (the trade union of Finnish paper and pulp industry and paper processing industry workers) is founded in 1906 and in the beginning of 2010 represented slightly more than 43 000 employees. Paperiliitto belongs to the central organisation of Finnish Trade Unions Central SAK. Paperiliitto negotiates its collective agreements with two organizations representing the employers. Most members follow the agreement made with Metsäteollisuus ry. (Pentti, V. 2008. p. 23)

In the Finnish collective bargaining system the general level policies are first agreed at the central level. In these negotiations also the governments revenue and tax policies are taken to account. After this stage the trade unions and employer unions accept the agreement and make sectoral refinements. The agreements can be applied at the enterprise level within the provided framework and some practices can even be settled with an individual employee when making the contract of employment. Sometimes the central level negotiations don’t result in an agreement and trade unions and employer unions negotiate without those guidelines. Trade unions can also opt out of the centralized solution if they want. (Pentti, V. 2008. pp. 21-22)

Usually the collective agreement affects the parties that have made the agreement and of course their members. The agreement can also be generally binding, and then also the employers that are not in the union have to follow it. Wages that are agreed upon in collective agreements are minimum requirements. Due to local agreements and the multi-level system, wage increases at business level usually exceed the increases agreed on the general level. (Pentti, V. 2008. p. 22)

9.3.2.2 Average earnings and income trends

Between the fourth quarter of 2009 and the fourth quarter of 2010 the basic earning in the paper industry (here the paper industry covers all employees that are members of the Paperiliitto, or work in such tasks that they could be if they wanted) has increased 0,9% (from 1612 cents/hour to 1626 cents/hour). The earnings for regular working hours have increased in the same time period 1,1% (from 1734 cents/hour to 1752 cents/hour) and the earnings for real working time have increased 1,5% (from 1956 cents/hour to 1986 cents/hour). These increases are in fact a bit lower than the average figures for all industries (1,3%, 1,8% and 3,2%) and the change is smaller than for example in the technology industry, the chemical industry and the sawmill and panel industry. The change in the earnings has been less than average in for example the joinery industry and the energy industry. (SAK. 2011. pp. 1-2)

So, on these bases one could assume that the paper industry workers have made concessions and maybe they have. But, when the actual earnings are compared, not the percentages, it's evident that the small difference between the average growth-per cent and the one of the paper industry is not going to lower the wages of the paper industry workers to the average level any time soon. The average basic earning of an industry worker in Finland has on the fourth quarter of 2010 been 1418 cents/hour and the earnings for real working time have been 1683 cents/hour. The same figures for a paper industry worker are 1626 cents/hour and 1986 cents/hour. The basic earning of a paper industry worker is 14,7% higher than the average and the earnings for real working time are 18,0% higher than the average. (SAK. 2011. pp. 1-2)

According to the SAK comparison on the average earnings and income trends between collective agreements, the paper industry is one of the best paid industries in Finland. Other well paid industries are the energy industry, construction (especially building technology industry) and the stowage industry. For example the sawmill and panel industry and the joinery industry don't reach the average level and the chemical industry and the technology industry are close to the average. (SAK. 2011. pp. 1-2)

In the collective bargaining agreement of the paper industry, that is valid from 8. April 2010 to 31. March 2012 (with changes made in 2011), the minimum period wage is from 29. March 2010 to 27. March 2011 790,49 € and after that 823,29 €. The increase is c. 4,15 % and that doesn't seem bad at all as the industry is struggling and the wages are even without any raise quite high compared to the industry workers average. (Paperiliitto. 2011. p. 46)

9.3.2.3 The collective bargaining agreements in the paper industry

Ville Pentti has examined the importance of employment in trade union negotiations in Finnish forest industry. He has compared the collective bargaining agreements of the Paperiliitto (the trade union of Finnish paper and pulp industry and paper processing industry workers) and the Metallityöväen liitto (the trade union of Finnish metal industry workers). (Pentti, V. 2008. p. 1)

The earnings level in the paper industry has increased faster than in technology industry in 1995-2006. In paper industry the inflation adjusted figure for the average annual earnings rose more than 32 per cent during that time period, when in technology industry it only rose less than 21 per cent. The productivity developments of the two sectors have been similar so that doesn't explain the difference. (Pentti, V. 2008. p. 39)

According to SAK there have been 13 517 paper industry workers in Finland in the fourth quarter of 2010. That is 2,1 per cent less than in the fourth quarter of 2009. The average change in the number of employees in all industry sectors has been -2,6 per cent. In technology industry it is -4,7 %, in the chemical industry -0,9 and in the energy industry -1,5. The number of employees has also increased in some industries like for example the sawmill and panel industry (1,6 %) and the joinery industry (4,8 %). (SAK. 2011. pp. 1-2) The paper industry workers have had more job security in this time period than an average industry worker. That might suggest that the trade union has made such concessions that the jobs have been saved. But many factories have been closed before 2009 and more closings have come after 2010 and more are probably to come.

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There have been far more changes in the bargaining agreements of the paper industry than in the technology industry agreements in 1995-2006. In the technology industry there have even been years when the wages have been agreed without any other contract changes. In the paper industry bargaining agreement, in 2005, there were significant changes that impaired the employee's position. The bargaining agreement of the technology industry, made in 2004, also impaired the position of the employee’s, but not as much as the paper industry agreement. (Pentti, V. 2008. p. 52)

The bargaining agreement of the paper industry in summer of 2005 is, from the workers and the trade unions point of view, obviously weaker than the agreements before that. The result can be due to the trade union wanting to preserve the jobs in the industry and giving therefor concessions, or it can be because the bargaining power of the trade union has decreased. It is likely that both things contributed to the result. In his study Ville Pentti came to the conclusion that the Paperiliitto did not voluntarily accept the changes and that suggests that its bargaining power would have decreased as the conditions in the environment had changed, and that is probably the main reason for the outcome of the negotiations. (Pentti, V. 2008. pp. 53-55) It’s important to notice that even if the bargaining power of the Paperiliitto has decreased from what it was in the early 2000s the trade union has still a strong position.

9.3.3 Conclusions about the Detroit Three -case

Finnish forest industry has undergone major changes in the last decade. Globalization has forced the Finnish mills to compete against the production units around the world, some of which operate in countries with much lower labour costs and a climate in which raw materials can be obtained more cheaply and efficiently than in Finland. Slowdown or even decline of the demand of certain paper grades has caused overproduction that lowers the selling prices and causes lower profitability and needs for adaptation. Finland has also joined the European Economic and Monetary union in 1999 which has eliminated the possibility of devaluation. Before that devaluation could be used as international competitiveness improvement factor for the industry. (Pentti, V. 2008, p. 1)

The Detroit Three have faced some of the same problems as the Finnish forest industry companies, most importantly globalization has had a major impact on the American auto industry. The power to affect or determine the selling price has decreased and the increasing competition has made it harder to survive. Like the Finnish forest companies also the Detroit Three have suffered from overcapacity and factories have had to be closed. In an environment of downsizing the cumbersome bargaining structure causes a lot of inefficiency (Robinson, L. 2008. p. A.11). It seems that there are two American auto industries, one that is doing well and another that is struggling (Ingrassia, P. 2008. p. 1). Despite the distress in the domestic market the foreign transplants are doing fairly well, both in the case of The Detroit Three and the Finnish forest industry.

In the Detroit Three -case we can see that the union had such bargaining power over the companies that it even got them to pay to workers who were no longer working. The fact that the UAW has persistently wanted to preserve all their benefits has worsened the situation of the Detroit Three to the point of desperation. Ville Pentti (2008. p. 29) states that when the interest compensation and bargaining power of the trade union are large the trade unions decisions have a strong impact on employment. Correspondingly if the union has low interest compensation or bargaining power the impact is small (Pentti, V. 2008, p. 29).

From this we can conclude that the UAW has had an extreme bargaining power and interest compensation.

Previously there has been a union cartel in both the Detroit three and the Finnish forest industry. An union cartel benefits its members at the expense of everyone else, and previously the costs of the benefits that the unions have negotiated to themselves have just been addressed elsewhere. But for this to be possible the union has to have a labour monopoly that forces the employers to consent. (Sherk, J. 2010. p. 22) When there is a labour monopoly it is critical for the manufacturing executive to get along with the union, as it would cause him major difficulties if he doesn't (Robinson, L. 2008. p. A.12). This helps the union get its way on the in the workplaces but there can also be more significant problems due to pursuing own interest.

In 1995 Timo Tyrväinen has introduced an insider-theory in which he states that when the union negotiates the agreement a certain in-group decides the conditions that everyone has to follow. According this theory the insiders are the leading people in trade unions that make the decisions and the ordinary members and non-members just have to follow the agreements made. Such situation can lead to a situation where the insiders with secure employment increase the wage demands so much that some of the unemployed people would be willing to work for a lower wage than the decided wage rate. If the contract is not generally binding the problem does not exist. The reduction of the general binding might contribute to the emergence of new firms when they would be able to compete with lower wage costs. (Tyrväinen, T. 1995, pp. 15-17)

Competition has generated the breaking of the union cartels in both discussed cases as the companies have no longer been able to charge above-market prices and due to the union demands have become less competitive than their competitors. In non-unionized companies jobs expand more rapidly and contract more slowly than in unionized companies. Especially quickly union jobs decrease in industries where the union wins the highest relative wages. It can even be stated that a union cartel is as harmful to the economy as a business cartel. (Sherk, J. 2010. p. 22-23)

From all this we can make the conclusion that unless the Paperiliitto starts making real concession it will end up hurting the industry and contribute to the manufacturing activities sifting abroad. The Finnish forest industry is going through a structural change and has a fair share of difficulties even without the union adding to them. Same goes for the Detroit Three. The wages and benefits that Paperiliitto has managed to negotiate during the success period of the Finnish forest industry are higher than the industry average and the other industries are having a hard time competing with their foreign competitors because of their cost structure. As we can see from the Detroit Three case the longer the union waits to make the concession the worse it gets for the companies and the stickier the whole situation gets.

10 BIOREFINERY PRODUCTS AND THE BENECOL-CASE

The possible products of biorefineries are multifarious. For example biofuels, food ingredients, preservatives, cosmetics, medicines and pharmaceutical ingredients, disinfectants, textiles, packagings, carbon fibres, composites, bio plastics, polymers, adhesives and detergents can be manufactured from various raw materials in various production methods. Even though the biorefinery concept is trendy and sounds new, there are multiple biorefinery products in different markets. Some of the best known Finnish innovations are xylitol (sweetener) and plant stanol ester (the cholesterol-lowering ingredient in Benecol-margarine). Both of these products are also so called functional foods, which means that they are food ingredients that prevent nutrition-related diseases and/or increase physical and mental well-being of consumers (Menrad, K. 2003. p. 181).

But often the first, and in some cases the only, biorefinery products one thinks of are biofuels like for example biodiesel. In this report we also consider the production of fuel, mostly concentrating on biochar. This is discussed in chapter

3.3 and in the company case-examples of Chempolis and Topel Energy, in chapter 8. Production of energy is an important aspect of biorefining as the pressure to find affordable non-fossil fuels to substitute the fossil ones is constantly growing due to efforts to prevent climate change and create sustainability.

Unfortunately a common opinion is that the production of just energy or a single biofuel is not very profitable, at least not in the Finnish conditions. This is not probable to change in the near future as it would require the emission rights getting way more expensive and/or the price of energy going way up, and/or the raw material and its logistics becoming incredibly cheap. Probably even a big change in any one of these things would not be enough to make large scale production of any biofuel highly or even moderately competitive compared to its fossil competitors. But if all of these things happen and there is green mindedness to support the changes, who knows. With this in mind, pilot manufacturing plants are built and tested. Largely thanks to political support, there already is a small market for biofuels.

But there is also the question if products with more added value should be produced out of wood instead of manufacturing just fuel. Of course this is not a problem if for example waste is used as a raw material. But when considering wood, there are many traditional wood and paper products that have higher added value than fuels. Is it not wiser to continue to produce them instead?

Surely it is so. And already energy is being produced as a by-product of these processes. So, how about making even more products? Larger integrates, that would produce the traditional products, energy and completely new biorefinery products with very high value added. Integrates that would combine different knowledge and technology as well as different business and revenue models.

This is how we get to the most exiting biorefinery products, ones like xylitol, plant stanol ester or vanillin. Or preservatives, pharmaceutical ingredients, disinfectants, polymers and so on. The BIOTULI-project focuses on antibacterial compounds, but that really is just one of numerous options to choose from. But, why is it that there aren't that many of these products produced in Finland? And why products that would seem incredibly successful do not succeed as well as one might think? There are Finnish innovations like xylitol and plant stanol ester, so where do we go wrong? Or are our expectations just too high?

10.1 Finnish innovation: Plant stanol ester (Benecol)

As it has been previously mentioned, both plant stanol ester and xylitol are functional food ingredients. Cholesterol-lowering functional foods, like Benecol, represent a science based field between the food industry and pharmaceutical industry (Ritvala, T. 2007. p. 1). Plant stanol ester is a good example of an innovation that has sparked from co-operation in the intersection of different industries. The process of cross-industry innovation search in the front end of the innovation process has been explained in chapter 2.4. It fits well into the mind-set of open innovation and is an efficient way to pursue new opportunities. The cross-industry innovation search is often faster and contains lower risk than the old-fashioned way of searching innovations due to among other things the vast amount of previously obtained knowledge and knowhow of partners involved. The innovation process in the Benecol-case doesn't follow exactly the process explained in the theory part, but contains many of the important factors of that process.

There is a distinct trend for functional foods and the food industry companies seem to have high expectations for these products. There are functional soft drinks, confectionery, dairy products, bakery products, baby foods and so on. Most functional foods concentrate on certain segments. For example the growth in functional dairy products has been impressive. The biggest market for functional foods is the USA, with an estimated market share of more than 50 per cent. Another important market is Japan. In Europe the interest for functional food is higher in Northern and Central Europe than in Mediterranean countries. (Menrad, K. 2003. pp. 181-182)

Next the innovation process of plant stanol ester and Benecol is explained in detail. That is followed by a chapter explaining the process of international commercialisation of the product and after that the current market situation of Benecol. Then the Benecol-case is tied to the other parts of this report as the successes of the innovation process and failures of the marketing and commercialisation are considered and reflected to other biorefinery products.

10.1.1 The innovation process of plant stanol ester and Benecol

The innovation process started with a Finnish chemical factory, Kaukas Inc. which was a part of a large pulp and paper concern. It refined sitosterol from the waste material produced in pulp production and looked for applications to utilise it. First Kaukas had an agreement with a medical company to sell the sitosterol to be made into a steroid-based pharmaceutical product, but those plans didn't realise, and they had to start searching for other possible applications. (Lehenkari, J. 2000. p. 57-58) Already in the late 1970s, research had shown that plant stanols were especially effective and safe in reducing serum cholesterol (Uusitalo, O. & Grønhaug, K. 2008. p. 186). Kaukas found out about the cholesterol-lowering effects and in the mid-1980s they contacted some medical scientists in hope to start producing cholesterol-lowering medical applications of sitosterol. Unfortunately, such pharmaceutical products of sitosterol were already available and they weren't especially effective. (Lehenkari, J. 2000. p. 57-58)

Kaukas was producing sitostanol in pilot scale when one of the medical scientists they had contacted proposed to Raisio Margarine Ltd. to use sitosterol and its modified form sitostanol in vegetable fat products. This was followed by a research period in 1989 as Kaukas provided the sitostanol for the laboratory to study its chemical characteristics. The problem they faced was that sitostanol is in crystallised form but as the research carried on they managed to get it to a form that easily mixes with vegetable fats. The promising test results of the product were published in 1992 and 1995. (Lehenkari, J. 2000. pp. 58-59)

At the early stages of the innovation process the development was performed along normal work routines. Additional funding or resources were not needed as the actors could utilise resources that were already there. The relationships between the actors were at this stage open and non-formal, and based on earlier connections and former collaboration. Since the commercial potential of the product was revealed a funding agency, the National Technology Agency of Finland (TEKES), funded expensive medical experiments and industrial development work in order to assure to the authorities of food control, consumers, board of directors and stockholders that the product was safe and effective and worth investing in. (Lehenkari, J. 2000. pp. 60-61)

Raisio got worldwide patents for its invention in 1991 and started producing Benecol margarine four years later (Uusitalo, O. & Grønhaug, K. 2008. pp. 186-187). In the meantime Raisio did longer tests with larger scale. For that it needed a new research partner. The North Karelia project, launched in 1972, had studied heart and coronary diseases in a large population group in Finland and was exactly the kind of large-scale testing organisation of international recognition that Raisio needed. The tests were carried out in three phases during 1993-1994. (Lehenkari, J. 2000. p. 59) The product was introduced to the Finnish public in 1995 and it became a great success (Uusitalo, O. & Grønhaug, K. 2008. pp. 186-187).

10.1.2 Aiming for the international market

Cholesterol problems are common in all industrialised countries and Benecol was also internationally recognised to be a great innovation. The use of margarine spread on a sandwich or in cooking could be turned into an action of daily health care (Haavisto, V. 2005. p. 7). In 1996, stock analysts valued the Benecol patents to 2 billion euros (Uusitalo, O. & Grønhaug, K. 2008. p. 187) and Raisio was the second most valuable public company on the Helsinki Stock Exchange, after Nokia (Lütolf-Carroll, C. & Pirnes, A. 2009. p. 167). Raisio had problems in keeping up with the demand, even though the product was much more expensive than ordinary margarine. The first plant stanol ester production plant, a prototype designed within the company, was completed in Raisio at the end of 1996. (Uusitalo, O. & Grønhaug, K. 2008. pp. 187 and 192)

Raisio got offers of co-operation from many companies and decided to start co-operation with the American McNeil Consumer Products Company, a subsidiary to the Johnson & Johnson group. The most important thing luring Raisio into the partnership was the huge market potential of the US. The first agreement was signed in 1997 and the product was supposed to be on the American market in 1998. Financial analysts considered the situation to be very good for Raisio as Johnson & Johnson group was at the time the biggest producer of health-related products in the world. (Uusitalo, O. & Grønhaug, K. 2008. pp. 187-188 and 192)

The innovation process of Benecol margarine was all along based on an alliance of medical scientists and industrial partners and that was working very well. But access to global markets is usually needed to exploit the commercial potential of any break-through innovation. This is especially important when the innovation originates in a small market like Benecol in Finland. To exploit the potential of a break-through innovation a company can built up its own global distribution network, sell out the rights of the innovation, or may lease it to others. It can also choose to co-operate with one or more global partners. The profit potential of these options differs and they have different resource requirements and risks. (Uusitalo, O. & Grønhaug, K. 2008. p. 181)

Raisio’s choice was to co-operate with one global partner: Johnson & Johnson group. The agreement that was outlined confirmed that Raisio would keep the entire production of plant stanol ester to itself and develop Benecol production and marketing in Finland and the neighboring countries. (Uusitalo, O. & Grønhaug, K. 2008. p. 190) According to the agreement, Raisio received a one-off payment for assignment of the license rights and would receive remunerations related to operative development and royalties for the sales of Benecol products and deliveries of plant stanol ester in USA (Lütolf-Carroll, C. & Pirnes, A. 2009.

p. 168). After the agreement was made, a market research by stock analysts forecasted excellent sales for Benecol in the USA, although Benecol-products were not even in the market there yet. Raisio believed that profit would be additionally made by selling the Benecol active ingredient, plant stanol ester, to other players in the food industry. (Uusitalo, O. & Grønhaug, K. 2008. pp. 187 and 190)

Hoping and believing that Benecol was indeed the dominant design in cholesterol lowering functional foods, and would make a worldwide monopoly, Raisio and Johnson & Johnson group were planning worldwide co-operation (Uusitalo, O. & Grønhaug, K. 2008. pp. 189-190). A final co-operation agreement was signed in 1998. The revised terms added most of Europe and Japan to the market of the Johnson & Johnson group, leaving just the Finnish market to Raisio. The two companies would co-operate in coordinating medical and clinical research and marketing, and do product development on project-by-project basis. (Lütolf-Carroll, C. & Pirnes, A. 2009. p. 168)

Functional foods including cholesterol-lowering products like Benecol are challenging regarding regulations, norms and consumer awareness of the relationship between food and health as they have medicine like effects and thus are a product in a field between medicines and food (Ritvala, T. 2007. p. 1). The Johnson & Johnson group submitted the Benecol margarine to the US Food and Drug Administration (FDA) as a dietary supplement rather than a basic food product without explicit health claims and the FDA rejected the dietary supplement claim. The FDA demanded clinical evidence of the safety and efficacy of the plant stanol ester. The clinical trials were time consuming and expensive, so the product was repositioned as a food product without health-related claims. (Lütolf-Carroll, C. & Pirnes, A. 2009. p. 168) The FDA approved the Benecol ingredient with the status of an ordinary food in 1999 and the US launch was made in the same year. But the sales were low and the long waiting time had given competitors time to enter the market. Unilever launched its cholesterol lowering margarine in Europe at the end of 1999. (Uusitalo, O. & Grønhaug, K. 2008. p. 189)

Benecol also had to compete with the other products of the Johnson & Johnson group for the attention and effort of salesmen and management. The product also suffered from the Not Invented Here syndrome, and was thus remaining in the shadow of other products of the Johnson & Johnson group. (Uusitalo, O. & Grønhaug, K. 2008. p. 191) Huge losses were made in the Benecol Division in 2000 and Raisio stated that the problem laid in the structure of the worldwide license agreement with the Johnson & Johnson group (Lütolf-Carroll, C. & Pirnes, A. 2009. p. 168).

When the South Carolina production plant of plant stanol ester was ready, it increased the production capacity to a level four times higher than in 1997 (Uusitalo, O. & Grønhaug, K. 2008. pp. 192-193). In 2001 the sales of cholesterol lowering spreads were disappointing and the industry was suffering from overcapacity of plant stanol esters and plant sterol esters. The raw material suppliers were still optimistic about their long-term prospects. (Krause, C. 2001) A study about the European market of functional foods by Klaus Menrad (2001, p. 183) supports this view by assuming that the cholesterol-lowering spreads like Becel margarine by Unilever and Benecol by Raisio will gain increasing relevance in the following years.

In 2005 sales of Benecol have reached 60 million and from that 90 per cent were exported to twenty countries. The US market accounted for only 5 per cent of the export. Some of the markets that were included to the worldwide exclusive agreement with Johnson & Johnson have been returned to Raisio. (Uusitalo, O. & Grønhaug, K. 2008. p. 195)

10.1.3 The situation of Benecol in 2011

In 2011, sixteen years after the launch of Benecol, the cholesterol-lowering food product markets are dominated by three brands from which Benecol is one. In its annual report for 2011 Raisio states that despite economically difficult times the sales have grown during 2011 in several countries like for example Great-Britain, Ireland and Greece. In Great-Britain the growth was due to a relaunch of the brand, and in Greece the launch of cholesterol-lowering feta-cheese. Most of the sales of Benecol products come from Europe and the sales stayed quite stable in 2011, although there were difficulties in some countries like for example Spain, Portugal and Poland. Benecol products were sold in 30 countries. (Raisio. 2012)

The biggest growth potential is considered to be in Asia and South America. The growth strategy of Benecol is based on sales growth in current markets and entering new markets in the previously mentioned regions. More specifically countries like Brazil, Russia, India and China are considered. The sales have been growing in the countries where Benecol has been recently launched like Indonesia, Columbia and Chile. (Raisio. 2012)

One of the most important events in previous years has been the approved health-claim about the plant stanol esters effect of lowering the risk of illness by The European Food Safety Authority (EFSA). In 2011, there was also a meta-analysis published proving that by increasing the daily intake of plant stanol ester one can achieve a larger cholesterol-lowering effect. (Raisio. 2012)

The FDA has suggested in 2010 that the term phytosterols should be adopted as inclusive of both plant sterols and stanols. Unilever which uses plant sterols in its Becel/Flora pro-activ range of heart healthy spreads is supporting the move but Raisio is objecting. Raisio states that Unilever’s take on the use of the term phytosterols is scientifically unfounded as there are differences in the molecular structures and metabolism of plant stanols and plant sterols. (Watson, E. 2011)

10.2 Analysing the successes and failures of the Benecol-case

An important explanatory factor of the successful innovation process of plant stanol ester and further the Benecol margarine is the synergy of competencies of the participants. These competences, the production capability of sitosterol, cholesterol research and research made on vegetable fats, had developed during a long period of time, and were able to be used to enable the development of the product in a very sufficient way. (Lehenkari, J. 2000. p. 64)

As it has already been mentioned the case can be connected to the theories of open innovation and cross-industry innovation search in the front end of the innovation process. Also the approaches of strategic foresight can be identified. All of these approaches are explained in chapter 2.5. In the innovation process of plant stanol ester, two approaches of strategic foresight are much more evident than others. Raisio’s approach is mostly network oriented as it successfully implemented informal information and kept building its network as the project proceeded. All parties including Raisio were in the beginning of the innovation process more or less involved in research. Many of the parties involved were research organisations which clearly had a science driven approach to strategic foresight. Kaukas on the other hand can be seen to have acted first on financial controlling bases but since starting to seek for a use for sitosterol it applied also a networking approach. (Mietzner, D. & Reger, G. 2009. pp. 281-283)

At the time of commercialisation Raisio lost its ability to make accurate foresight and it believed too much in the success that the media, stock analysts and other outside parties predicted for the product. Raisio should have been able to switch its approach from network and science oriented towards a more market driven approach. If the focus of strategic foresight would have been more on collecting and interpretation of customer and competitor data, the choices made at that time might have been different. (Mietzner, D. & Reger, G. 2009. pp. 281-283)

After the commercialisation of the product, the number of industrial and medical research partners increased considerably. The medical studies proved to be important in luring outside actors to support the project. Raisio became the link between the local and global network and made formal contracts with its partners. (Lehenkari, J. 2000. pp. 60-61) The management of Raisio has admitted that there were mistakes made in the forming of the contract between the Johnson & Johnson group. In retrospect the point of the whole co-operation can be questioned.

Benecol ended up being just one generic complementary asset among other Johnson & Johnson brands (Uusitalo, O. & Grønhaug, K. 2008. p. 193). It seems that after the initial hype and hope for a product with a dominant or even monopoly position on the market, the enthusiasm of the Johnson & Johnson group perished as the FDA approval was lingering out of reach, Not Invented Here syndrome was having its effect and the financial risks were realising. Also the US marketing strategy, including the customers' expectations, values and needs, wasn't carefully enough thought through (Uusitalo, O. & Grønhaug, K. 2008. p. 193).

The problems in the approval process of functional food in FDA shouldn't have come as a surprise for Raisio as it knew the challenges xylitol had faced in the FDA's testing (Uusitalo, O. & Grønhaug, K. 2008. p. 193). Still the wrong decisions were made and competitors given valuable time to come up with their own products.

If Raisio hadn't been a stock listed company it would have had much less publicity and less pressure from outside of the company. But as it was it got caught in the hype: stock analysts praising its innovation and opportunities, stock price rising, organisations lining up to co-operate with the company. And it selected its partner hastily and carelessly. Raisio overestimated the importance and likelihood of a worldwide monopoly for Benecol. The company had poor knowledge of the industry and didn't analyse carefully enough the consequences of formal co-operation with one globally dominating partner. (Uusitalo, O. & Grønhaug, K. 2008. p. 194)

Also in 2005 the lack of interest toward the product can be seen in the actions of Johnson & Johnson group. Some market areas designated to them in the worldwide contract were returned to Raisio and the sales in the US were very modest. Even though the US was originally thought to be one of the main markets, one with huge potential, the sales have remained low. In its annual report for 2011 Raisio concentrates clearly on other markets.

In correlation to the expectations for the success of the product, it seems that Benecol didn’t do very well. On the other hand, it is sold in 30 countries and the markets are expanding. For a company like Raisio this is quite well done and the active ingredient, plant stanol ester, is sold to different companies around the world and has been estimated to be one of the ten most significant nutrition innovations in the world (Raisio. 2012).

11 SUSTAINABILITY OF BIOREFINING

Sustainable development means that the needs of present are met without compromising the ability of future generations to meet their needs. Sustainable development can be seen to have three parts: environmental sustainability, economic sustainability and social-political sustainability. All these aspects of sustainability have to be met to achieve sustainable operations. All three aspects of sustainability are equally important, even though economics are the bottom line for industrial operations. (BIOPOL. 2009. pp. 13-14)

This chapter ponders more deeply on the socio-economic impacts of biorefineries, starting with impacts on environmental issues, regional development, and employment issues. The chapter about environmental issues focuses particularly on the use of life-cycle management in creating eco-friendly products and services and contains some examples of companies doing so. That is followed by a look into the impacts that a biorefinery often has on regional and rural development. After that the impacts on employment issues are considered.

The socio-economic impacts of biorefining are often hard to measure as many of the established biorefineries are set up in existing plants. Greenfield facilities are rare because biorefineries are still seen as risky investments. Also the learning curve can be shortened by establishing the biorefinery at an existing plant. (BIOPOL. 2009. p. 9) Biorefineries can also be quite different from each other. Their size, products, raw materials, technologies, capacities and many other things may differ greatly and thus the socio-economic impacts cannot be comprehensively investigated. However, this chapter is constructed to give an overview of the possible impacts and it includes many factors that should be taken to account when considering biorefining as an aid to the environmental changes affecting all industries and the structural change of the forest industry.

The impacts of a biorefinery have been assessed in the BIOPOL-project (Assessment of BIOrefinery concepts and the implications for agricultural and forestry POLicy). One of the eight companies that the BIOPOL-team has looked into has been further covered in this report. The Swedish Chemrec is one of the case-examples in the chapter 7. The other seven companies investigated by the BIOPOL-team are British Sugar, Greenmills, BioMCN, Domsjö, Biowert, Nedalco and Cargil/Cerestar. The Domsjö factory uses technology provided by Chemrec. (BIOPOL. 2009. p. 5)

During the BIOPOL-research most of these eight facilities were in pilot phase or operating full scale and planning a major scale up. The most common biorefinery type among these companies is the Two-Platform Concept, with the exceptions of Chemrec and Domsjö being Lignocellulosic Feedstock Biorefineries, Biowert a so called Green Biorefinery and Greenmills an other type. The companies use very different raw materials ranging from sugar beet to starch and black liquor. Also the products that are manufactured are quite different, although many of them concentrate on the transportation fuel market. (BIOPOL. 2009. pp. 7-8)

11.1 Impacts on environment issues

The sustainability of biorefining is often based on it consuming less resources than traditional processes used to produce industrial goods. Also the utilisation of unwanted by-products is common in many biorefinery concepts. (BIOPOL. 2009. p. 14) On the other hand, land use change can cause greenhouse gas emissions as farmers switch from one crop to another which binds less carbon or has other harmful effects on the ecosystem. (BIOPOL. 2009. p. 22)

Of course the agricultural land could also be used in a more efficient way. A research team has studied the land use in USA and concluded that by using a more land efficient approach an equal amount of food and animal feed could be produced while also providing much larger quantities of bioproducts and biofuels from the same acreage of land. According to the study large scale biofuel production can be successfully reconciled with food production while also accomplishing significant greenhouse gas reductions and promoting biodiversity. Resolving the food versus fuel conflict seems to be more a matter of making the right choices than hard resource and technical constrains. The most important driver would be showing to farmers, livestock producers and biofuel industry that the needed changes in land use patterns are economically attractive. (Dale, B. E. et al. 2010. pp. 8386 and 8388) This only leaves the question of whether to produce primarily biofuel or other bioproducts or biochemicals. For example products of renewable chemistry contribute several times more added value than fuel. (BIOPOL. 2009. p. 28)

The use of forest materials instead of fossil fuels would significantly reduce greenhouse gas emissions (Cuoch, G. 2006.) although the carbon neutrality of forest material can be questioned (Environmental Paper Network. 2011. p. 30). According to current calculation methods it is carbon neutral but this assumption is misleading and might be corrected as the calculation methods of greenhouse gases develop (Environmental Paper Network. 2011. p. 30). Biorefineries use different methods to handle their residues. This is an important matter in biorefining. Also water consumption must be taken to account. (BIOPOL. 2009. p. 24)

In the decision of whether to establish a biorefinery, the environment and sustainability often play a significant role. Nevertheless the decision is usually maid in order to capture a market opportunity that is seen by the investors, and thus the environmental things are hardly the main driver in establishing biorefineries. Environmental legislation can of course encourage an organisation to go to a certain direction. (BIOPOL. 2009. p. 9)

The indirect impacts on environment are hard to measure but some can be observed by looking at improvements in material processing or maximisation of electricity yields. Usually when two or more technological processes are combined in a plant increased yields, efficiency and lower costs can be achieved. Chemrec is a good example of improved electricity yield. (BIOPOL. 2009. pp. 25-26)

11.1.1 Using life cycle management to achieve better and more eco-friendly products and services

Life cycle management has been shortly explained in chapter 2.3. Companies use numerous different approaches to implement life cycle management in their operations. To support the implementation of these concepts and tools organisational and capability development approaches are very important. Often companies have begun using life cycle management to prevent pollution and decreasing the use of materials of concern. Many of the companies have also experienced some pressure from non-governmental organisations, civil society or tightened legislative initiatives. (UNEP / SETAC. 2009. p. 25)

Life cycle management is often used to save money and increase efficiency, but also to reduce energy and material use and to save water. It is also used to support key choices in technology, investments and product development. Often the most important objective is the cost-effective mitigation of environmental impacts. (UNEP / SETAC. 2009. p. 25)

Next there are some examples of companies using life cycle management to achieve more sustainable business procedures as well as better and more eco-friendly products and services. The companies have been selected so that they are from such industries that are in the focus of this report also in its other chapters.

11.1.1.1 Alcan Packaging

Alcan Packaging is a speciality packaging company that serves food and beverage, medical, beauty, pharmaceutical and tobacco industries. Gerald Rebitzer, Global Director of Product Sustainability at Alcan Packaging, states that one can have a competitive edge by ensuring that the products are environmentally and socially responsible. In Alcan Packaging all the key people are involved in sustainability efforts, unlike in some companies where just one department is responsible for the efforts made. Alcan Packaging aims at continual improvement and develops constantly their whole product portfolio. The R&D and sales and marketing community are very much involved. (UNEP / SETAC. 2009. p. 14)

In Alcan Packaging the sustainability agenda is largely customer driven, and the company partners with their customers to find solutions that consider social, environmental and economic factors. Sustainability and relative sustainability are measured with ASSET™ (Alcan Sustainability Stewardship Evaluation Tool). For now the benefits of measuring can not be presented in monetary terms. The network also extends to suppliers and outsourcing. Alcan Packaging has a Social Responsibility Directive that is applied to the company itself and its suppliers. The directive can cross borders and has an effect especially in countries that have dearth local legislation. (UNEP / SETAC. 2009. p. 15)

11.1.1.2 Dow Chemical Company

The Dow Chemical Company is a USA based global and diversified chemical company. In Dow the sustainability focuses on the consumer and is a logical extension of the process of providing such products and services as Dow does. The aspirations come from customers and the customers' customers and their hopes. Dow has seven ten year goals and a "cradle-to-grave" concept that highlights sustainability, including among other thing a strong lifecycle view. (UNEP / SETAC. 2009. p. 16)

There is a long history of environmental and sustainability thinking in Dow. It is encouraged that different groups would like to know where they are situated in terms of sustainability aspects and in which they should focus on. Everyone in the company should have an idea about the sustainability issues. On day-to-day level, the life cycle management is applied and initiatives contributing to ten-year goals are monitored. Communication is hugely important as it is the only way of making the sustainability issues part of the everyday actions. (UNEP / SETAC. 2009. p. 17)

11.1.1.3 Eskom

Eskom is a South Africa-based electricity utility. It is the largest one on the African continent and has a very large net maximum capacity. Gina Downes, the Chief Advisor, Environmental economics, says that all employees in Eskom are aware of the sustainability ethos of the company, although in a vertically integrated company like Eskom, people tend to focus mostly on their immediate area of responsibility. (UNEP / SETAC. 2009. p. 18)

In the energy industry a company can not perceive itself as a stand-alone entity, as the power stations do affect the communities nearby. It is also important to recognise that the power stations that are built now are going to be functional for the next 40-60 years. Eskoms long term planning functions seek to optimise the electricity supply over 25-30 year time horizons. Much of the environmental legislation of South-Africa is from the last decade, and new legislations are on their way. Before that, much depended on self-regulation. (UNEP / SETAC. 2009. pp. 18-19)

Eskom has a Climate Change and Sustainability Department that among other things assesses the implications of regulations and research initiatives. Eskom also has a Generation Environmental Management Department that deals with specific power stations and future projects. The environmental impact assessments are made by and independent consultants. (UNEP / SETAC. 2009. p. 19)

Sustainability efforts are often complex and require compromise. For example, in the area in which Eskom is operating, fresh water is relatively scarce. That is why Eskom has piloted a dry-cooling technology that requires less water. Unfortunately this technology is not quite as efficient and thus the power stations emissions are a bit bigger. Trade-offs like this show how it is not always easy to include life cycle thinking into decision making. (UNEP / SETAC. 2009. p. 19)

11.1.2 Why do companies use life-cycle management?

As we can see from the company-examples above, life cycle management can be used in different industries, companies, and regions. Life cycle management is used in many companies around the world, to mention few in addition to the examples above: 3M, Ford (Europe), United Technologies Corporation, Veolia Environment (UNEP / SETAC. 2009. pp. 11-24) and Borregaard (Bredal, T. H. 2010).

An important thing to notice is that the value chain takes to account more than just an individual organization: in fact it is connected to the entire supply chain, distribution networks, customers, end-consumers and the surrounding community. The ways that life cycle management is implemented differs depending on the needs and the structure of the company. It can be customer driven, like in Alcan

Packaging and Dow, or due to an important and long lasting role in a community, like in the situation of Eskom. Borregaard's life-cycle analysis has been made in order to identify the climatic and environmental burden imposed by its cellulose, ethanol, lignin and vanillin products and the analysis confirms the superior sustainability of those Borregaar products (Bredal, T. H. 2010). Despite the different reasons for life-cycle management, there is one major similarity in companies doing it. They all have their eye on the future. Life cycle management and sustainability efforts are not done just because they are the responsible thing to do. The efforts are done to ensure the present success of the company as well as the success in years to come: not only in the near future but beyond.

11.2 Impacts on regional development

The use of forest material improves the diversity and security of the energy supply of the nation and eases dependence on foreign fossil fuels (Couch, G. 2006). If the raw material that is used is produced locally it has a quite direct impact on the rural development. Also the imported materials have a slight effect on logistics, and have to be also stored but the impacts on rural and regional development are much smaller than if the raw material is local. Many biorefineries use waste as raw material, which would have to be managed in an other way if it didn't go to a biorefinery and this has an effect on the waste management. (BIOPOL. 2009. p. 11)

Most biorefineries seem to have a moderate impact on the rural and regional development. (BIOPOL. 2009. p. 5) The products of biorefineries, like natural fertilizers, can have an important role in sustainable production in agriculture. Natural fertilizers might even crowd out the usage of synthetic fertilizers, but on the other hand their production might also intense the cultivation of biomass and further increase the usage of synthetic fertilizers. (BIOPOL. 2009. p. 12)

The pilot phase in establishing a biorefinery is necessary in order to showcase and justify the scale-up later (BIOPOL. 2009. p. 8). During the scaling up process the biorefineries are usually looking for stakeholder structure that is easy to manage and this tends to mean that local entrepreneurs or farmers are not invited to purchase capital shares in the biorefinery. In the future this could be seen as one opportunity to strengthen the bonds with the local community but often the supply chain of raw material is such that this kind of link is not necessarily needed. (BIOPOL. 2009. p. 10)

11.3 Impacts on employment issues

Regional economies can be strengthened by biorefineries as they help to preserve high-paying jobs in rural communities (Couch, G. 2006). Many of the established biorefineries are set up in existing facilities, which complicates the measuring of the effect on employment as there are indirect employment effects and usually the addition of biorefining also helps to maintain current jobs. It very much depends on the factory, how much jobs it creates. Some only create a few dozen or less and in others the direct impact on employment can be a few hundred jobs. (BIOPOL. 2009. p. 10)

Biorefineries often need educated employees with specific knowledge and skills. The biorefineries can offer new interesting challenges for their personnel and may thus lure people to transfer from other companies into the newly established biorefinery. When the company employs from within other companies the employment rates of the region are not directly affected. The displacement effects might also be harmful for other companies on similar industries as they might lose valuable personnel. (BIOPOL. 2009. p. 17)

Biorefineries usually outsource research work and in many cases this does not create local benefits as they can use research centres and universities from an other region. The origin of the raw material that is used can have an effect also on indirect employment as people can be partly or whole time employed to provide (store and transport) the raw material. Even the biorefineries that import their raw material might have a slight effect on employment through logistics. (BIOPOL. 2009. pp. 11 and 18)

Increased automation and productivity often lead to reduction of jobs. However, growth in manufacturing output contributes to strong job growth in non-manufacturing sectors as the manufacturing sector needs inputs from other sectors of the economy such as business services. (BIOPOL. 2009. p. 20)

12 CONCLUSIONS

In this chapter the observations from the previous chapters are combined to provide a comprehensive view of the current situation of the Finnish forest industry in relation to biorefining. Also the future prospects are pondered on as well as the required resources needed to get into biorefining business are specified.

First the strengths and weaknesses of the Finnish forest industry, related to biorefining, are analysed in correlation to the theories presented in the beginning of the report. After that the factors that were discovered in the industry comparisons are further looked at from the perspective of what can the companies of the Finnish forest industry sector learn from the Finnish metal industry and chemical industry. This is followed by observations from the Detroit Three case.

This is followed by a reflection on how the needed changes in Finnish forest industry companies can be achieved for them to be able to successfully implement biorefining into their operations. The Benecol case is looked at from the perspective of what other starting biorefineries can learn from it. Also the success factors of the companies presented in the company examples in chapters 5 and 7 are analysed.

The opportunities biorefining can offer to the Finnish forest industry firms as well as the regional and economic benefits of biorefineries are contemplated in the last section of this chapter. Also a possible future objective about a bio-economy with multifunctional and diverse biorefineries operating in Finnish conditions is outlined.

12.1 The strengths and weaknesses of the Finnish forest industry in relation to biorefining

The Finnish forest industry has some major advantages in getting into biorefining business. They have excellent raw material logistics and the feedstock is sustainable and of high-quality. The forest cluster also obtains profound raw material knowledge and employs skilled research teams. The factories of the forest industry are mostly modern and well managed and the biggest companies are international and globally significant operators with facilities, employees and networks around the world.

The Finnish forest industry is respected and well-paid but it does not perform well when measured with cost competitiveness. Major reasons for that are the lack of high value added products and the increasing competition in the bulk product market. (Metsäteollisuus ry. 2009. p.9)

Although, the great history of the industry provides many of the current strengths listed before, it also causes many of the current weaknesses of the industry. The pulp and paper companies are used to making profit by producing massive amounts of relatively simple bulk products in a cost efficient way. The scale benefits have been important and thus the production capacity has been high. The focus has been on short timescale and the profitability has been examined by quarter.

12.1.1 The innovation capabilities of the forest sector

Occasional radical innovations and steady pace of incremental process innovations have ensured a leading position in the industry for the Finnish forest industry companies. The companies are recently shown interest in innovation activities by for example implementing project portfolio management systems and initiative systems, and even by creating specific innovation strategies. However, the research and development investments of the forest industry have been rather modes. This is worrying as companies should on the contrary focus on innovation activities and be able to take higher risks when confronted with high competition (Gibb, J. & Haar, J. M. 2010. pp. 884-885). The lack of R&D investments or their targeting to other countries can also negatively affect the technological development of Finland (Hetemäki, L. 2006. p.36).

Project portfolio management helps the companies to choose the right projects and to eliminate projects that do not serve the best interest of the company. The implementation of a project portfolio management system requires top-level commitment and co-operative environment. (Levine, H. A. 2005. p. 3) Because of the traditional focus on short-term profitability in the forest industry, the top-level commitment is not self-evident. Neither is the co-operative spirit as there are so many changes happening and people tend to resist change (Pennypacker, J. & Retna, S. 2009. p. 13). However, in order for the companies to enhance their innovativeness, they need to have efficient innovation management systems and protocols to guide the processes. The resources are limited and it is very important that the best ideas are recognised and the resources are allocated to the most promising projects.

As a part of sufficient innovation management companies need to practice strategic foresight to determine the direction they want to go. This is not an easy matter, and in chapter 2.5 six different approaches are presented. Most companies combine some of these approaches and especially big companies can combine most of them. This does not necessarily mean that it is done better in them. The important things are that the information is specified and customised, integrated to strategic planning and operative business and implemented simply and efficiently. (Mietzner, D. & Reger, G. 2009. pp. 288-299) If the strategic foresight methods in the Finnish forest industry would have been in a better level, the structural change could possibly have been detected earlier and the measures to adjust to the change would have been more efficient. The implementation of strategic foresight also helps the project portfolio management as it provides a clear vision of what is the direction the company wants to pursue.

The Finnish forest industry companies have been and still are in close co-operation with the Finnish metal industry and the forest industry firms have been even able to outsource many of their innovation activities to the metal industry. In the Finnish metal industry an open-minded attitude for new methods and technologies has developed early. After the Second World War the war reparation deliveries added to the domestic demand of the metal industry and some very long-term products and solutions were invented. At that time the companies had low corporate hierarchy and the diffusion of new technologies was rapid because there were only a small number of companies. The ability to quickly and flexibly adapt to new circumstances emerged. (Oksanen, J. et al. 2010. p. 24-25)

The history of the Finnish forest industry is very different and the industry has relied much less on its innovativeness than the metal industry. The competitive advantage of the metal industry has relied on the ability to create new successful products which has brought up the need for continuous innovation. The forest industry in turn has been focusing on efficiency and scale benefits. The products of the metal industry are profiled as technologically advanced ones, but the forest industry has been depending on mass production. The forest industry and the metal industry both specialise in corporate markets but unlike the forest industry the metal industry is strongly problem-solving driven. There is often a mutually beneficial interdependence between the metal industry company and its customer. The innovation activities of the metal industry are characterised by problem solving and solution creation, although, the metal industry companies are focusing recently on long-term research as well. (Oksanen, J. et al. pp. 26 and 39)

Also the forest industry should change its focus from the short-term to the long-term. The forest industry has lost many of its former competitive advantages

(Hetemäki, L. 2006. p. 35) and it needs new ways to succeed. The shift from technology push to market pull has resulted in increased number of customised products and solutions (Pesonen, P. 2006. p. 59). In order to be able to produce these kinds of products the forest industry needs to embrace a similar view towards innovation as the one of the metal industry. Networking skills and atmosphere of open innovation are very much needed in the currently changing business environment.

12.1.2 Comparing the forest industry's response to the structural change to the response of the chemical industry

The exports of the chemical industry are roughly the same size as the exports of the forest sector in Finland, about twenty per cent each (National Board of Customs. 2012a. p. 11). The two industries are also affected by similar international changes like production sifting to countries with lower raw material prices and labour costs, increasing prices of energy, amplification of environmental thinking, and intensifying price competition. In both industries restructurings and saving measures have been made in Finland during the previous years. In Finland both industries also suffer from relatively high raw material prices, expensive workforce and relatively high tax rates. (Mäenpää, M. et al. 2010. p. 13, 20-21, and 30)

Also the future opportunities for the two industries are quite similar. For both of them the development of high value added products is essential and bioproducts are on the agenda. The chemical industry aims at forming a strong cluster like the Finnish forest cluster already is.

When comparing the two industries it is clear that there are some major differences. For the forest industry the raw material is a starting point for product development and innovation whereas the chemical industry is searching for new, environmentally friendlier, raw materials. The chemical industry produces so called bulk products as does the forest industry, but it also serves many special niches. This makes it more solution oriented and adaptable. From the publications of the two industries one can easily see that the chemical industry is looking more to the future while the forest industry is trying to hold on to its primer glory. For the chemical industry the changes present more of an opportunity and to the forest industry a threat. In fact the opportunities and threats are quite similar for the two industries and the difference is mainly in how they are looking at the situation.

As it has been stated in the theory part of this report, the organisational culture has significant impact on the innovativeness and renewal capacity of an organisation (TEKES. 2008. p. 4). As the forest industry has not been very innovative in the past, it can be concluded that its organisational culture does not especially promote innovativeness. In addition to the innovative culture an organisation also needs networking skills. In current times, especially when thinking about concepts that combine knowledge from different fields, like biorefining does, it is very beneficial for an organisation to understand the possibilities of open innovation. The forest industry companies cannot acquire all the needed knowledge from inside the company. The Benecol-case, in chapter 10, is a good example of a research and development project that has been conducted in co-operation with companies from different industries.

The paper and pulp industry and the chemical industry are already connected as the chemical industry provides raw materials for the pulp and paper making processes. In biorefining the situation could be the opposite as a pulp and paper mill could provide raw material for a biorefinery which would produce a variety of chemicals and other products. Even if the biorefinery would be a part of the pulp and paper mill and the forest industry organisation, knowledge about the chemical processes is needed and co-operation with a chemical industry company could be a great way of acquiring that.

12.1.3 What can be learned from the Detroit Three -case?

The Detroit Three have faced some of the same problems as the Finnish forest industry companies. Most importantly globalisation has had a major impact on the

American auto industry. The power to affect or determine the selling price of the products has decreased and the increasing competition has made it harder to make profit. Like the Finnish forest companies also the Detroit Three have suffered from overcapacity and factories have had to be closed.

In an environment of downsizing the cumbersome bargaining structure causes problems (Robinson, L. 2008. p. A.11). There has been a union cartel in both the Detroit three and the Finnish forest industry. A union cartel benefits its members at the expense of others, and previously the costs of the benefits that the unions have negotiated to themselves have just been added to the cost of the products. (Sherk, J. 2010. p. 22) Competition breaks the union cartel and prevents adding the costs to the product price. In the globalised forest industry this means that the benefits given to the employees are negatively affecting the profitability of the companies.

The important thing to notice is not so much the impact of union activity or even the high labour costs affecting the profitability. The point is that the case companies have not been able to predict the changes in their environment. They have too long trusted in their leading position in the market and wrongly assumed that things will stay the same. They have made incremental innovations to improve their efficiency and maintained their lead in that way for a period of time. But as they have enjoyed the luxuries of market leadership the environment has changed and now they have to do the same to survive in the increasing competition.

12.2 How to successfully implement biorefining in traditional forest industry?

Biorefining means sustainable processing of biomass into a range of marketable bioproducts and energy (Mäkinen, T. 2011. p. 3). A huge amount of different chemicals can be obtained from woody biomass (Niemelä, K. 2008. p. 11). Also the spectrum of possible product applications is enormous. Among these could well be the high value added products that the forest industry is seeking to improve its profitability.

Biorefineries are a luring option for the forest industry as the existing pulp mills can be developed into forest biorefineries. The biorefinery concept allows paper companies to maximise their value creation from the resources brought to the mills and to produce multiple products like biochemicals, biomaterials and biofuels simultaneously in an efficient process with fewer inputs and multiple outputs. (Thorp, B. 2005. pp. 35-36)

In order for the forest industry companies to be able to achieve the benefits the biorefinery concept has to offer, they must adopt a new innovative and customer focused strategy. In every part of the company its products and operations need to be seen in a new way. The process starts with generating new revenue streams. The value added products need to be developed in a market driven innovation process in co-operation with organisations with complementary knowledge bases. (Thorp, B. 2005. p. 38)

As totally new products are often created in the interface of different industries the cross-industry innovation process for the fuzzy end of the innovation process, explained in chapter 2.4, is a great tool in creating new fusion innovations (Gassmann, O. & Zeschky, M. 2008. p. 103). To be able to do this sort of thing the forest industry companies would have to have access to other knowledge disciplines. This in turn requires co-operation.

12.2.1 What can be learned from the Benecol-case?

From the perspective of other biorefineries, there are positive and negative things from which to learn in the Benecol-case. The innovation process of plant stanol ester and Benecol was very effective and the synergy of the different research fields and know-hows was used beautifully to create a new and truly innovative product. The co-operation between the different parties was well managed and their roles were clear. The importance of co-operation and the effectiveness of innovation in the interface of different industries have been talked about in the theory part and are well demonstrated in this case.

But just as important as to learn from others successes is to learn from their mistakes. The Benecol case shows that a well-managed and successful innovation process does not guarantee a further success for the product. The marketing strategy is ever so important in order to exploit the commercial potential of a break through innovation. Global markets can be accessed in different ways but the right choice must be made carefully to suit the product, the company (and its partners and other stakeholders) as well as the prevailing market conditions. Co-operation played a significant role in the innovation process of plant stanol ester, but it is just as crucial in the global commercialisation of the final product.

When an idea or an innovation captures the interest of media there is the danger of a hype forming around the phenomenon or a certain innovation and that is exactly what happened in the Benecol-case. The promise of greatness clouded the judgement of the decision makers and resulted in hasty decisions. This is a danger that has to be taken to account when dealing with innovative products that raise the interest of media. For example biochar, the biofuel that this report concentrates in, has been talked and written about a lot recently. There is definitely a hype around it, which is currently true in the case of many other biofuels as well. But the commercial breakthrough of biochar and many other biofuels can still be far in the future, and they may not ever fully meet the current expectations of their future commercial value.

When a company from a small market is trying to commercialise a product globally it can go about it in the same way as Raisio did in the Benecol case. The opportunities a big company can offer are certainly luring. But co-operation with a much bigger organisation has risks that Raisio didn't take into account. The co-operation was in a way one-sided as the product was much more important to Raisio than to Johnson & Johnson group which hadn't even been involved in the innovation process. There hadn't been former co-operation between the two companies so the mutual trust had to be built through formal contracts. Raisios previous partnerships were conducted with parties that were not competing with Raisio, which were interested and benefited from the research and in which the contacts were more or less based on personal networks.

The co-operation with Johnson & Johnson group was handled badly, due to lack of experience in this type of partnerships and a rush to commercialise the product in the big US market. Lack of adequate intellectual property rights (IPR) expertise and badly prepared market strategy are, sadly, such mistakes that can be easily made in small and medium-sized companies operating inside one small country or region. It is also common that former difficulties in co-operation with big global firms make companies reluctant to form such partnerships again. This is very relevant in the Finnish forest industry which is dominated by a couple of global companies.

12.2.2 Main points and success factors of the company examples

The conclusions about the company examples of Borregaard and Arizona Chemical, as well as Chempolis and Chemrec and Topell Energy are presented next. In the part about Topell Energy also the business opportunity of biocoal is considered.

12.2.2.1 Borregaard and Arizona Chemical

Borregaard and Arizona Chemical are great examples of working biorefineries. Both of them produce multiple products from which some have large added value. Both of these companies have started as pulp mills thus proving that pulp mills can in fact be transformed into working and profit making biorefineries.

Arizona Chemical has been operating for a really long time which proves that biorefineries are not as such a recent phenomenon. The wide range of products and variety of different markets and end-products of Arizona Chemical are incredibly impressive.

Often the expression “future forest biorefinery” is used when referring to biorefineries where biomass is fractionated into material streams which are then processed into different materials or chemicals (Mäkinen, T. 2011. p. 4). But how is that a future biorefinery when there already are such facilities operating in full scale? Biorefineries may be trendy but they are not a new phenomenon.

In both, the Borregaard and the Arizona Chemical case, two things are worth noticing. First of all, innovation: both companies highlight their innovativeness and it shows in their R&D functions and further in their product portfolios. Arizona Chemical is one of the companies using Robert G. Coopers Stage-gate model in its innovation management (Stage-Gate International. 2008. p. 4). The model has been explained in chapter 2.2.6. Second of all, both companies are keen to show how sustainable they are. The image of these companies is fresh, environmentally friendly, and innovative. And their future looks bright, even though competition is expected to increase.

12.2.2.2 Chempolis and Chemrec

Chempolis and Chemrec are both equipment providers. The business idea in them is quite similar, although, their markets are different and their technologies use different raw material. Both companies are very much engaged in research and development. They both have a rather green image but in fact the environmental friendliness of their products is largely connected to the sustainability of the raw material that is used in the process, and that is something that a technology provider cannot choose. However, the products of Chempolis and Chemrec certainly enable the production of renewable bioproducts.

Chempolis is a great company example when considering biorefineries in Finland as the company is Finnish. Although, its markets are mostly in Asia the company proves that the needed knowhow to design biorefinery processes exists in Finland.

The BioDME-project of Chemrec is interesting as it contains companies from different industries. They are working together to cover the whole life-cycle of biofuel used in specially modified Volvo trucks. (BioDME. 2012) This kind of cross-industry co-operation is potentially very productive. Even if the outcomes of the project are not particularly special, the companies learn from each other and create relationships that can be incredibly useful at some other time.

12.2.2.3 Topell Energy and biocoal as a business opportunity

Topell Energy is a Dutch clean technology company which has developed a torrefaction process for the production of high value biocoal from woody biomass (Topell Energy. 2012). The company seems to be doing quite well while other ponder whether the production of biocoal is profitable.

The main issue in the profitability of biocoal is the price of raw material and the chosen torrefaction and pelletizing process. By integrating the production to a power plant or a pulp mill, synergies and better efficiency can be achieved. In the future biocoal can become more profitable if some or a combination of following things happen: the price of electricity raises, government subsidiaries are issued, the price of raw material decreases or there are major increases in the availability of raw materials.

12.3 Opportunities and future prospects

The things that are affecting the opportunities in biorefining can be divided to five groups: environmental, economical, technological, political, and social. The climate change and other environmental factors favour biorefining, especially when it reduces the use of oil and fossil fuels. The economic factors are ultimately the ones that determine if something is worth doing in a business sense. Technological factors determine whether it can be done and how efficiently. The social and political factors have mostly indirect impacts, although political measures can be used to prohibit something and social factors can affect the availability of workforce or the sales of consumer products.

Sustainability contains environmental, social and economic sides discussed in chapter 11. To determine the environmental impacts of a product the life-cycle management approach can be used (UNEP / SETAC. 2009. p. vii). It is explained in chapter 2.3. Biorefining has mostly good impacts on the social and environmental aspects of sustainability. The economic impacts seem also very promising but at the moment biorefineries are still perceived to be risky targets for investment (BIOPOL. 2009. p. 9).

Biorefining agrees well with green thinking and the thought of low-carbon bio economy and would have also image benefits for the Finnish forest industry, which is not currently perceived to be especially innovative or environmentally friendly. But most importantly biorefining offers new products and revenue streams as well as better profitability. However, Finland is not the only country going through a structural change, neither the only place where biorefining is considered. Nevertheless, the Finnish companied do have some definite advantages like for example the excellent knowledge base, modern production facilities and good raw material supply (Metsäteollisuus ry. 2009. p. 9).

The structural change is altering the business field of forest industry. It remains to be seen how well the Finnish companies are going to be able to adapt. It is certain that the Finnish forest industry possesses all the needed resources for integrated biorefining. The problem is not in the technology or even the financing; it is in the old ways of thinking and seeing the industry. The opportunities in biorefining are huge but in order to be able to utilise those opportunities the industry needs to change its thinking patterns and business models. The companies must be able to tune themselves into a more innovative zone. Success also requires risk taking.

The risks can be minimised and the whole transformation can be eased by utilising various innovation management methods but the most important thing is to have an open-mind and ambition.

13 SUMMARY

The forest industry is currently going through big changes. Overcapacity, mature market conditions in main markets and low-cost production in market areas with growth are causing the prices of traditional paper products to decline. In the Finnish business field the relative importance of basic industries is going to get weaker in the future, partly because of companies moving their operations to countries with cheap labor and raw materials, as well as closer to the clients. Some of the future perspectives are the increasing importance and development of services, the significance of environmental issues and getting along with scarce resources.

Biorefining might be a way to keep the pulp and paper production in Finland as the biorefinery concept allows the mills to maximise their value creation from those resources that are brought to the site. In a biorefinery multiple products like biochemicals, biomaterials and bioenergy can be produced in an efficient manner. These products would of course require new business models but they could also create new valuable revenue streams.

Some of the possible biorefinery products have high added value as others can be profitably manufactured because of the efficient production methods. Biofuels are a current topic but in fact a biorefinery can produce products with much more added value. The products of a biorefinery can be used in end-products like biofuels, food ingredients, preservatives, cosmetics, medicines and pharmaceutical ingredients, disinfectants, textiles, packagings, carbon fibres, composites, bio plastics, polymers, adhesives and detergents. Different products require different knowledge about for example the production process, logistics and market conditions. In order to obtain this knowledge co-operation is needed.

The forest industry is not the only industry with interest towards biorefining. For example a business partner from the chemical industry or the energy industry could be of great benefit for a forest industry company planning to start a biorefinery. Cross-industry co-operation would also boost up the innovative spirit in the companies involved.

In order to survive from the structural change the forest industry companies need to invent new ways to utilise their knowledge and resources. Biorefining would be a good direction as a biorefinery can be constructed piece by piece giving the organisation time to adapt. But the process must be started by thinking through the new revenue models. The atmosphere in the industry can change but not overnight. It is important to go forward and to adapt to changes: to innovate and to be able to take risks when the times are difficult. There already are successful biorefineries operating, so it can be done. Few of these companies have been examined in this report. They prove that biorefining is not a thing of the future. Instead it is a viable business opportunity of today.

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