Value Chains for Renewable Materials in the Nordic Region

Opportunities & Challenges Towards a Sustainable Bio-based Economy

Master of Science Thesis in the Master Degree Programme
Management and Economics of Innovations

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Executive Summary

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There is an increased consciousness and activeness about environmental and sustainability issues, which expects to drive the demand for renewable products and materials in the future. On the market there is a great interest to figure out what capabilities renewable materials can offer for existing and new markets. There are many projects on-going and planned within the field of renewable material, and this trend is extra clear in the Nordic region. Industries and academia raising the priority and development of economically and technologically feasible biorefining concepts to value added products are currently in progress. In able to see the relations between the actors involved in the value chains and to analyse the different structures a mapping is needed. The Nordic countries covered in the thesis are Sweden, Norway Finland and Denmark. The scope includes companies, projects, universities and research institutes that utilise renewable materials based on forest, marine biomass and/or agriculture, with production or research related to biochemicals, biomaterials or biofuels. Open interviews have been conducted with both academic researchers and company representatives. The thesis outlines the institutional aspects for renewable materials, including directives, policies and research programs, and strategies for a bio-based economy in the future. Through full use of raw material the biomass resources can be more efficient used. In a biorefinery approach you must be able to steer the process in order to create an optimised product mix. When including biomass feedstock the dependency on fossil fuels decrease and the flexibility increases. Through utilising biomass new products will be possible to create with new functionalities and performance, which open up innovation possibilities. If the renewable products could be better in terms of performance parameters or if considering the total cost of ownership, they would become very competitive in the future.

Keywords: *Renewable material, value chain, biofuel, biomaterial, biochemical, bioenergy, sustainability, bio-based economy, institutional economics, forest, marine biomass, agriculture, chemical industry.*

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Many thanks, and have an interesting reading!

Gothenburg, 31th of May 2013

Gustaf Lundgren

Definitions of Concepts

Concept	Definition
Bio-based economy	Enable increased use of biomass in the different sectors of society through sustainable production. Aim to reduce the carbon footprint and the use of fossil raw materials. An increased value added of biomass to the economy, minimized energy consumption and utilization of nutrients and energy from the final products.[1]
Biogas	Gases arising from the anaerobic fermentation of biomass and the gasification of solid biomass. The biogases from anaerobic fermentation are composed principally of methane and carbon dioxide. Biogases can also be produced from thermal processes of biomass.
Biopolymers	Polymers based on biomass feedstock. Cellulose and proteins are examples of biopolymers, in which the monomeric units are sugars and amino acids respectively.
Biorefinery	Sustainable processing of biomass into a spectrum of products and energy. Aims at full conversion of biomass into higher value products, e.g. fuels and chemicals. Seeks to optimize product or by-products flows similar to conventional oil refineries.
Black liquor	The spent cooking liquor from the kraft process when digesting pulpwood into paper pulp removing lignin, hemicelluloses and other extractives from the wood to free the cellulose fibres.
Dissolving pulp	The bleached wood pulp or cotton linters that has high cellulose content, also called dissolving cellulose. This pulp is used to manufacture various cellulose-derived products.
DME	Stands for dimethyl ether and is an organic colourless gas.
Economical sustainability	To make it possible to use available resources to their best advantage, through promote the use of resources in a way that is both efficient and responsible, and thus provide long-term benefits.
FAME	Fatty Acid Methyl Esther (FAME) can be refined from the most vegetable and animal oils and fats, for example raps oil, soya bean oil, palm oil, fish oil and used frying oil.
Fossil resources	Biomass that has undergone a physical/chemical change in thousands/millions of years, e.g. crude oil, gas and coal.
Marine biomass	Aquatic biomass, for instance microalgae, macroalgae and seaweeds.

[1] Formas (2012). *Swedish Research & Innovation Strategy for a bio-based Economy*, pp. 9.

MFC	Micro Fibrillated Cellulose which is a material composed of nanosized cellulose fibrils.
PAN	Peroxy Acryl Nitrate
RME	Raps Methyl Esther is one example of FAME.
Sustainable development	Brundtland definition: 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'[2]
Value chain	The process for how the resource base is refined to an end product, and which actors that is active in the different steps.
1st generation biofuels	Mature technologies for the production of bioethanol from sugar and starch crops, biodiesel and renewable diesel from oil crops and animal fats, and biomethane from the anaerobic digestion of wet biomass.
2nd generation biofuels	Are novel biofuels or biofuels based on novel feedstock. Generally use biochemical and thermochemical routes that are at the demonstration stage, and convert lignocellulosic biomass to biofuels.

[2] United Nations (1987). *Our Common Future: Report of the World Commission on Environment and Development*, pp. 41.

Table of Contents

1. Introduction

In the current European energy policy EU-members are required to meet by 2020 a target of 20 per cent renewable resources in the energy supply and 10 per cent renewable energy resources in the transport sector.[3] The second requirement corresponds to a replacement of approximately 50 billion litres of fossil transportation fuels. This calls for increased use of renewable resources in the energy system and the European Council have presented a long term target for the European Union and other industrialised countries of 80 to 95 per cent cuts in greenhouse gas emissions by 2050. A keystone to accomplish this is biomass, which is expected to account for 56 per cent of the renewable energy supply in the EU27 by 2020. In the EU the overall target for renewable energy is higher than anywhere else in the world. One challenge in the future is the world's increasing population, implying greater demand for food. This puts pressure on to find renewable resources that does not compete with food production.[4]

Throughout the year's major investments have been made in infrastructure, which requires continuously access to fossil resources. But the world's usage and dependency on fossil resources leads to emissions of for example carbon dioxide (CO_2), sulphate dioxide (SO_2) and nitrogen oxides (NO_X). These emissions affect the environment negative in several different aspects, for example in terms of global warming and air pollution.[5]

Oil is and has been an important resource base, for instance for different value chains of plastics and fuels. The development of the world's economy in terms of GDP and oil consumption has historically speaking correlated tightly, and economic boom has implied higher demand for oil.[6] Moreover, natural gas is that fossil resource assumed to have the largest reserves, for instance extracted *shale gas* from the shale structures in the ground. In the U.S. new technology for exploiting shale gas is expected to eliminate the need for importing natural gas for energy, plastic and petrochemical purposes for several decades. Shale structures are also covering large areas of Europe, Asia and Middle East, but have so far not been exploited in any bigger scale.[7]

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[3] European Parliament and the Council. (2009) *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.*

[4] European Commission. (2010) *Energy 2020 A strategy for competitive, sustainable and secure energy.*

[5] Rogner, H.-H., D. Zhou, R. Bradley. Crabbé, O. Edenhofer, B.Hare, L. Kuijpers, M. Yamaguchi. (2007) *Introduction. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.*

[6] International Energy Agency. (2012) *The IEA Oil Data System Energy Statistics* http://www.iea.org/media/workshops/2012/trainingmoscow/Session3Reece.pdf

[7] The Royal Swedish Academy of Sciences. (2011) *Kemi – den gränslösa vetenskapen.*

In the society, generally speaking, there is an increased consciousness and activeness about environmental and sustainability issues. This expects to drive the demand for renewable products and materials in the future. On the market there is a great interest to figure out what capabilities, both in terms of economic and environmental aspects, renewable materials can offer for existing and new markets. Why will it then be a demand for more sustainable products? Some examples of thoughts about the future from three global companies;

IKEA - *We have taken a stand for fewer and safer chemicals. We have banned PVC from our products and lead in mirrors, dramatically reduced formaldehyde from lacquers and glues, and we never use optical brighteners in IKEA textiles.*[8]

SCA – *We deliver sustainable solutions with added value for our customers based on safe, resource-efficient and environmentally sound sourcing, production and development.*[9]

H&M - *Adding sustainability value to our products is an important way to further strengthen our customer offering.*[10]

As can be outlined from the three quotations above sustainability and environmental issues are important, which creates a demand for renewable materials leading to a transformation in the industry. There are many projects on-going and planned within this field and this trend is extra clear in the Nordic region. Industries and academia raising the priority and development of economically and technologically feasible biorefining concepts to value added products are currently in progress. A development towards renewables is to be favoured if the dependency on fossil resources is to be replaced with a renewable in the future. Industrial end products of renewable materials include for instance biochemicals, biofuels and biomaterials. Example of potential customers for renewable products are; private persons in terms of biofuel for cars, chemical companies in terms of bioethanol as base for producing other chemical compounds, biomaterials and fibres in terms of furniture and retail companies.

Where are the ‘green value’ and which incentives exist for involving in value chains of renewable material? A green image is good, but gives rarely more value on long term except for being a pioneer and gets the image of leading an innovative and sustainable development. More important, the renewable end

[8] IKEA. (2013) *People Planet Positive* http://www.ikea.com/ms/en_GB/pdf/people_planet_positive/People_planet_positive.pdf

[9] SCA. (2013) *Sustainability Effect* http://www.sca.com/en/Sustainability/Sustainability-Effect/ambitions-for-the-future/

[10] H&M. (2013) *Sustainability H&M Conscious* http://about.hm.com/AboutSection/en/About/Sustainability/HMConscious/CEO-Message.html#cm-menu

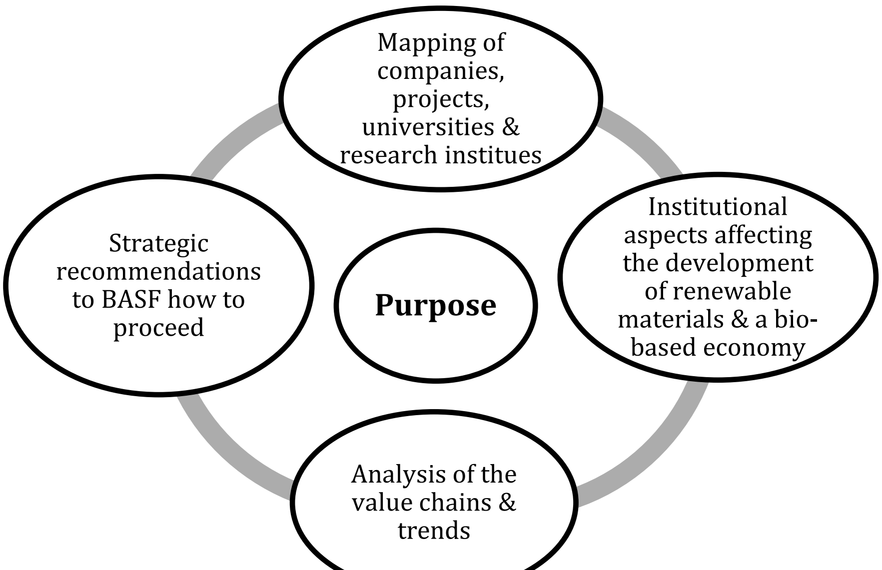
products or intermediates must be competitive in terms of functionalities and performance parameters and matching the customer's requirement. Several involved actors affecting the value chain structure and design of renewable materials as for instance institutional actors as politicians and financing research councils, market and surrounding businesses, research institutes and universities.

The thesis has been conducted in collaboration with the chemical company BASF (Badische Anilin- und Soda-Fabrik) at the department of Regional Market Development Europe North and the author has been located at BASF's Gothenburg office. BASF is the world's largest chemical company with over 110 000 employees and is headquartered in Ludwigshafen, Germany. In order to address and manage this new upcoming market within renewable materials, knowledge and market intelligence is needed about the involved actors. BASF has an interest in what the trend might be in the future in the Nordic region and which companies that is leading this development. This thesis is based on what companies, universities and research institutes are pursuing and planning in the future.

1.1 Purpose & Research Questions

In able to see the relations between the actors and to analyse the different value chains of renewable materials a mapping is needed. The Nordic countries that are covered in the study are Sweden, Norway Finland and Denmark. Only companies, projects, universities and research institutes that utilize renewable materials based on forest, marine biomass or agriculture are included in the scope of the thesis. The value chain starts with the renewable material and includes the refined product in terms of biochemicals, biomaterials and biofuels. The thesis purpose is fourfold, see figure below.

Figure 1.1 –*The thesis purpose.*



The thesis research questions are the following:

RQ1. *Which companies, projects, universities and research institutes are active within the field of renewable materials in the Nordic region?*

Selection criteria's for the mapping is that actors should have research or production related to forest, marine biomass or agricultural in at least one of the following product categories; biochemicals, biofuels and biomaterials.

RQ2. *How will the institutional aspects affect the development of renewable materials and a bio-based economy?*

The institutional aspects include directives, policies and research programs with focus on renewable materials. Also, strategies for a bio-based economy in the European Union and the Nordic region are covered.

RQ3. *In what ways can the value chains be illustrated for the different renewable materials?*

This includes where in the value chain the actors are positioned and how they are connected.

RQ4. *What strategic recommendations can be given to BASF and how should they proceed in the future?*

What does identified trends and activities related to renewable materials in the Nordic region mean for BASF with respect to technological and economic aspects.

The four research questions supports and complements each other in order to fulfil the thesis purpose. RQ1 builds up the empirical data for the thesis which is needed to answer RQ3 for illustrating the value chains. Further, RQ2 institutions and the institutional aspects is a key aspect to include, for example directives and national policies, since they are central for the development of value chains for renewable materials. By answering RQ1, RQ2 and RQ3 the thesis lays a stable ground in order to address RQ4.

1.2 Delimitations

The thesis does not include wind-, sun-, hydro- and nuclear power as energy sources; instead the focus is put on bio-based feedstocks and materials. Further, all companies, projects, universities and research institutes in the Nordic countries that utilize renewable material is not included and the thesis is delimited to the leading and most important from the authors point of view. Moreover, the concept of value chain is not applied on the institutional actors and it is not the author's intention to illustrate those relationships. Instead, the different institutions are used to see how they affect the development of renewable materials towards a bio-based economy in the future.

1.3 Outline

To answer the research questions and address the thesis purpose the following disposition is applied. *Chapter 2* outlines the theoretical framework that builds up an academic and research based perspective, focusing on value chains structure and the role of institutions when addressing environmental problems. This is followed by the methodology *Chapter 3* where a description of selected instances and methods are provided. Also, a table is presented which summarises what will follow in *Chapter 4-6,* namely the companies, projects, universities and research institutes that are active with respect to the different countries and renewable feedstock.

Furthermore, in *Chapter 7* the institutional aspects, including directives and policies, are presented. This sets the boundaries for the development of renewable materials and a bio-based economy. This is followed by analysis of market and value drivers for renewable materials in *Chapter 8.* Further, in this chapter trends are identified and analysed, and challenges and opportunities towards a bio-based economy are discussed. The thesis is concluded with strategic recommendations in *Chapter 9* and how BASF should proceed in the future in the field of renewable materials in the Nordic region.

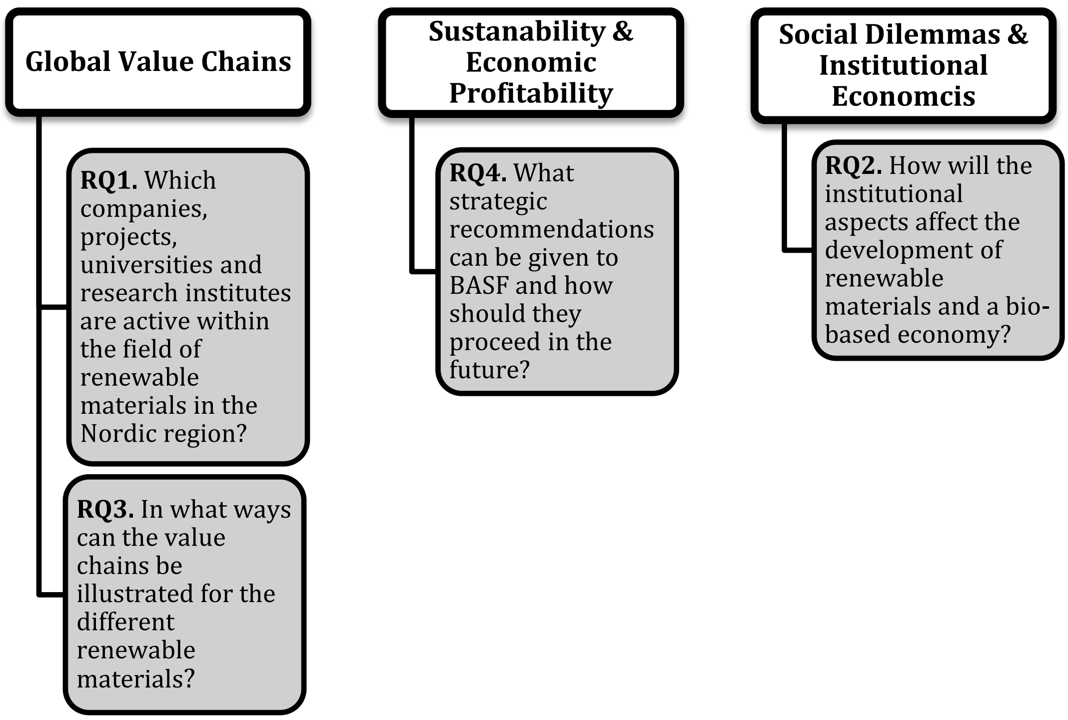
2. Theoretical Framework

There is limited research that has investigated value chains for renewable materials in the same approach as is the case in this thesis. Therefore, the theoretical framework is constructed of research that has a connection to the investigated area, and the three most appropriate theories have been selected. First, theories regarding *global value chains* are presented and those are related to answer RQ3.

Secondly, theories regarding *sustainability* and how *economic profitability* affects companies addressing sustainability issues are presented. These aspects are considered since when providing strategic recommendations both sustainability and economic profitability are important to consider for having higher legitimacy in the strategic recommendations. Through combining both sustainability and economic profitability success can be achieved.

The third theory comprises *social dilemmas* and the role of *institutional economics*. Institutions have an important role to play for how a sustainable bio-based economy can be accomplished enabling companies to successfully address environmental problems. These theories relates to RQ2 and the role of institutions for the future development of value chains for renewable materials and a bio-based economy. In the figure below the relationship between the theoretical framework and the thesis's research questions can be seen.

Figure 2.1 – *How the theoretical framework supports the research questions.*



Source: Author's own illustration

2.1 Global Value Chains

Theory regarding Global Value Chains (GVC) describes the organisational and social structure of the global economy and its dynamics of a specific product or service. Since the mid-1990s, the notion has interested several scholars and policy makers which have implied an expanding body of GVC literature. Five different patterns have been identified.

- *Markets;* firms and individuals trade products to each other with little interaction beyond exchanging goods and services for money. Price works as a central governance mechanism.
- *Modular value chains*; products/services are supplied according to customer's specifications. Often nonspecific equipment is used implying that the investments are spread over a larger customer base.
- *Relational value chains;* network governance with mutual dependence regulated through trust. Since mutual dependence and trust takes long time to build up, the cost of switching to new partners tends to be high.
- *Captive value chains*; small suppliers tend to be dependent on larger, leading buyers. These types of networks are characterized by a high degree of monitoring and control by the lead firm and dominant lead firm.
- *Hierarchy;* vertical integration, i.e. the transactions takes place within the own firm. Gives high degree of control but less flexibility since the market is not used.

The patterns and effects of GVCs tend to vary in specific industries and places, and because of this research often has a sectorial or geographic focus.[11]

2.2 Sustainability & Economic Profitability

Theories relating to how economic profitability relates to companies that wants to solve environmental problems have been chosen since it are key aspects in the transformation towards a bio-based economy. Economic profitability determines which value chains that will foster and those that diminish in a longer perspective. Today's economic activity is unsustainable from an environmental point of view.[12] Since firms are one of the most powerful problem-solving organizations in society, researchers have been studying how firms can profit by addressing environmental problems.[13]

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[11] Gereffi, G. Humphrey, J. & Sturgeon, T. (2005) *The governance of global value chains - Review of International Political Economy.*

[12] Intergovernmental Panel on Climate Change, IPCC. (2007) *Climate Change - Impacts, adaptation and vulnerability.*

[13] Horbach, J. (2008) *Determinants of environmental innovation – New evidence from German panel data sources.*

While there are cases where firms have profited from addressing environmental problems, there is no simple linear relationship between firms' environmental and financial performance.[14] One explanation for why it is problematic for firms to build a business case is that although firms may often be in a position to create value by addressing environmental problems, they often struggle to capture a large enough share of that value for themselves and their shareholders.[15]

2.3 Social Dilemmas & Institutional Economics

Social dilemmas and institutional economics constitute the theoretical framework when analysing the institutional aspects. In connection to the raised importance of sustainability this theories have engaged many researchers, and several Nobel Prizes in Economics have been awarded in this field the recent years. Institutions have and will have a great impact on the value chains of renewables and are therefore a suitable theory to include in the thesis theoretical framework.

Environmental problems often can be represented as social dilemmas and can be described as situations when the rational short-term interest of the individual is in conflict with the long-term interest of the collective.[16] Social dilemmas have been called by many names, for example 'public-good problems' and 'the tragedy of the commons'. The term 'institutions' has been referred as meaning 'the rules of the game'.[17]

Researches in the field of institutional economics have found that the existence of some types of formal and informal institutions can serve as solutions to social dilemmas. However, many of these findings have yet to be applied to the field of environmental strategy and the business case for sustainability. By leveraging and influencing the institutional rules of the game, firms may be able to appropriate a larger share of the value created from addressing environmental problems. As institutions exist and evolve at multiple levels this implies different strategies companies may use to increase the share they capture of the value created by addressing environmental problems.[18]

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[14] Porter, M. & Van der Linde, C. (1995) *Green and competitive: ending the statement.*
[15] Lankoski, L. (2000) *Determinants of Environmental Profit. An Analysis of the Firm-Level Relationship Between Environmental Performance and Economic Performance.*
[16] Ostrom, E. (1990) *Governing the Commons: The Evolution of Institutions for Collective Action*.
[17] North, D. (1990) *Institutions, Institutional Change and Economic Performance*.
[18] Williamson, O. (2000) *The new institutional economics: taking stock, looking ahead.*

To summarize, there is a growing interest how firms can create business strategies for addressing environmental problems, but so far no simple relationship between firm's financial performance and environmental performance has been outlined. Firms may often be in a position to create value by addressing environmental problems, but often struggle to capture a large enough share of that value. One reason can be explained by the concept of social dilemmas. For solving social dilemmas institutions and the theories related to institutional economics are central. As institutions exists and evolves at multiple levels different leveraging and influencing strategies can be used by companies to increase the share they capture of the value created by addressing environmental problems.

3. Methodology

In order to fulfil the thesis purpose and answer the thesis research questions an appropriate methodology is needed. The selections of companies and projects have been based on several criteria's. First, the companies and projects should utilize renewable materials based on forest, marine biomass or agriculture products. Second, the companies should have production or research related to biochemicals, biomaterials or biofuels. These selection criteria's has helped to structure the collected data and supported a time efficient work.

After the initial collection of data based on the above mention criteria's some companies and actors were selected. Particular considerations were paid to incorporate the leading and driving companies and actors. Furthermore, it was also considered to find companies that had research and production related to biorefining concepts, i.e. sustainable processing of biomass into a spectrum of products and energy which aims at full conversion of the biomass. In order to have representative data, attention has been paid to have actors from all the four Nordic countries and the three renewable materials. Through this described method the data was consequently refined.

The selected companies, projects, universities and research institutes can be found in the following three chapters which are separated on which renewable material that is utilized and on which Nordic country it originates from. The thesis has implied a large collection of data and mapping of the market for renewable materials in the Nordic region. A large numbers of companies, research institutes and other actors have been considered during the thesis work, see table later in this chapter.

For having a deeper insight in the area of renewable materials and future value chains, interaction with stakeholders is a key aspect. The author has therefore participated at two conferences during the work with the thesis. One conference was regarding marine biomass and organised by the *Nordic Algae Network* as a part of the *Nordic Marine Innovation Program* and constitutes of 22 partners from both industry and academia. The other conference was concerning *Forest Chemistry* which engaged stakeholders from Swedish forest- and chemical industry as well as institutional actors on both national and EU-level. Both conferences were held in Gothenburg during the spring of 2013.

Moreover, open interviews have been conducted with both academic researchers and company representatives in order to get deeper insights and a more focused collection of empirical data. The sample frame consists of researchers and company representatives, mainly based in Sweden, but many of them operate in international contexts. The selected interview objects are regarded to have an important role in the value chains of renewable materials and the future development.

The majority of the interviews have been conducted over telephone. One of the main advantages is the time reduction and it may also be more effective when asking sensitive questions due to the fact the interviewee is not physically present. However, one drawback is that you are not able to observe how the interviewees react with their body language to certain questions.[19] The academic researchers and company representatives that have been interviewed can be found in the References list. The used interview guide is attached in Appendix I

A degree of pre-testing of the interview questions was achieved during the first interviews and in this phase feedback was provided in relation to how well the questions were understood. The author could thereby see if questions were interpreted in the way that originally was intended and adjustments and clarifications were made.

To get an overview how the three following chapters are built up, see table below.

Table 3.1 – *Overview of the empirical data for the different Nordic countries.*

Country	Instance	Chapter 4 Forest	Chapter 5 Marine Biomass	Chapter 6 Agriculture	Summary
Sweden	Companies/Projects	16	5	9	**30**
	Universities	3	4	1	**8**
	Research Institutes	5	1	n/a	**6**
Norway	Companies/Projects	7	4	1	**12**
	Universities	n/a	2	n/a	**2**
	Research Institutes	4	3	n/a	**7**
Finland	Companies/Projects	10	n/a	4	**14**
	Universities	1	n/a	n/a	**1**
	Research Institutes	2	2	n/a	**4**
Denmark	Companies/Projects	1	3	9	**13**
	Universities	n/a	2	n/a	**2**
	Research Institutes	n/a	3	n/a	**3**
	Summary	**49**	**29**	**24**	**102**

[19] Bryman, A. & Bell, E. (2011) *Business Research Methods*.

4. Renewable Material - Forest

4.1 Introduction

This chapter provides a mapping of companies, projects, universities and research institutes utilizing renewable materials from the forest and corresponds to RQ1. In the European Union there are approximately 178 million hectares of forests corresponding to about 42 per cent of EU's total land area. About 133 million hectares, or 32 per cent, of the EU's land area is forests that are available for wood supply. The past 20 years, forests have increased by 5 per cent totally, which gives an approximately annual growth rate for the whole EU of 0.3 per cent. However, the annual growth rate varies significantly between nations and regions. EU's forests belong to many different bio-geographical regions and are adapted to a variety of natural conditions. Socioeconomically, they vary from small family holdings to state and company owned forests.[20]

In the Nordic countries the forest ownership is focused on the private side with a majority of private owners in all the four Nordic countries. Moreover, what is important to consider is how the growth rate vary significantly within the same country depending on geographical region, for example the difference between southern and northern parts of Sweden. The majority of the Swedish forest is located in the northern parts but it is also lower annual growth rate there compared to the southern parts. Moreover, there are significant differences and natural prerequisites and conditions between the Nordic countries as seen in the table below.

Table 4.1 – *Statistics of forest and the forest industry in the Nordic countries for 2012.*

	Sweden	Norway	Denmark	Finland
Land area (million hectares)	45.0	32.4	4.3	33.8
Forest land area (million hectares)	28.6	10.2	0.6	22
Annual growth (million m^3)	111	25.5	5.8	101.1
Annual outtake (million m^3)	80	10	2.2	70.9
Private individuals ownership	50 %	80 %	69 %	52 %
Private companies ownership	25 %	4 %	8 %	8 %
State ownership	17 %	12 %	23 %	35 %
Other ownership	8 %	4 %	n/a	5 %
Forest sectors part of GDP	12 %	0.8 %	3.67 %	17.2 %

Sources: Swedish Forest Agency, Norwegian Institute of Forest and Landscape, Danska Riksskogstaxeringen, Finish Forest Research Institute.

[20] European Commission Eurostat. (2011) *Forestry in the EU and World.* http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-31-11-137/EN/KS-31-11-137-EN.PDF

4.2 Sweden

Companies & Projects

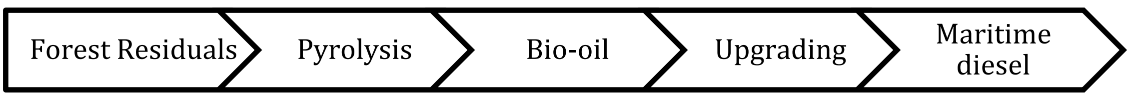
BillerudKorsnäs

BillerudKorsnäs is a producer of fibre based packaging materials. They have identified two areas of opportunity in the future; bioenergy and new materials. Within bioenergy they have a project regarding pyrolysis oil and received SEK 300 million EU funds from the NER300 Program. They will develop a new type of energy source, 'green bio-oil', which is pyrolysis oil from forestry residues. A full scale production plant will be integrated at the mill in Skärblacka, outside Norrköping.[21]

This plant will be the biggest in Europe for producing pyrolysis oil. In Finland two similar plants exists, but they are substantially smaller (see Chapter 4.3 Fortum and Green Fuel Nordic). BillerudKorsnäs has authorization to produce 200 000 tonnes/annually of pyrolysis oil and it is estimated to reach full production by the end of 2015. There is extensive research on-going by several actors focusing on how pyrolysis could be upgraded. In a short perspective they see the green oil to be used as energy source for industry instead of fossil oil. In a longer perspective value chains of the green oil could go into transportation fuels and marine diesel. BillerudKorsnäs thinks that the sulphur directive from the European Commission (delimits sulphur content to 0.1 per cent in fuels) that will be in place 2015 for the marine industry will have a great importance, since the green bio-oil is free from sulphur.

However, research is needed how the bio-oil could be upgraded to diesel and the technological progress will determine how the market will develop. In the figure below a potential value chain for the green bio-oil is illustrated. However, at this moment the value chains are unclear because the market is still unexploited.[22]

Figure 4.1 – V*alue chain for the green bio-oil.*



Source: Anders Persson, Project Manager Strategic Development, BillerudKorsnäs, interview.

[21] BillerudKorsnäs. (2012) *EU Awards BillerudKorsnäs 314 million.* http://billerud.com/en/Media/Press-releases/2012/EU-awards-BillerudKorsnas-314-million-within-framework-of-NER300-Programme/

[22] Anders Persson. (2013) Project Manager Strategic Development, BillerudKorsnäs, interview

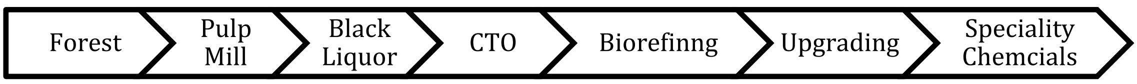
Holmen Biorefinery

Holmen Biorefinery Development Centre identifies and develops new business ideas and products from forest and forestry residuals. They focus on businesses within biofuels, biogas, materials, and chemicals. Research and development is currently in progress within biofuel for transportation and it is for instance investigated how biomass could be gasified and synthesized.[23] The forest industry is in transformation due to digitalisation, and hence less demand for newsprints. One way to face this transformation is to engage in new activities in unexploited areas, for example green chemicals. Holmen have rest streams of hemicellulose (including glucose, mannose and xylose as the most important building blocks), lactic acids, terpene and unsaturated fatty acids. Their waste-streams are well characterized with carbohydrates constitute the main part which could be used for production of biogas and micro bacterial processes. Holmen investigates the possibilities to produce bulk chemicals from their stream as furans, methanol and 1-metyl, and in the future they want to deliver directly to the chemical industry in the early stages of the value chain.[24]

Arizona Chemical

Arizona Chemical is a producer of chemicals based on refined tall oil. They aims to optimise the value chain of forest based products by converting tall oil based chemicals from pulp and paper mills to valuable end-products. Arizona has customers in a wide range of industries, for instance fuel additives, lubricants, glues, coatings and cosmetics.[25] They have the biggest fractioning and upgrading capacity in the world for the products Crude Tall Oil (CTO) and Crude Sulphate Turpentine (CST). Both CTO and CST are renewable resources from the forest.[26] The emissions from the biorefinery in Sandarne, Sweden, and the products CTO and CST corresponds to 80 000 tonnes of CO_2 which is 25 per cent of the emissions that is generated from the petrochemical equivalent.[27] In the figure below one value chain of CTO biorefining towards the market of speciality chemicals is illustrated.

Figure 4.2 - *One example of value chain Arizona Chemicals operates in.*



Source: Arizona Chemicals. (2013) *Presentation at Forest Chemistry conference.*

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[23] Holmen. (2013) *Biorefinery Development Center.* http://www.holmen.com/en/Products/Raw-material/Energy/Holmen-Biorefinery-Center-HBC/

[24] Jörg Brücher. (2013) Project Manager Biorefinery, Holmen Energy, interview.

[25] Arizona Chemical. (2013) *About us.* http://www.arizonachemical.com/en-GB/About-us/

[26] Arizona Chemical. (2013) *Sustainable solutions globally.* http://www.arizonachemical.com/en-GB/

[27] Arizona Chemicals. (2013) *Arizona in Sweden* http://www.arizonachemical.com/sv/Sandarne/

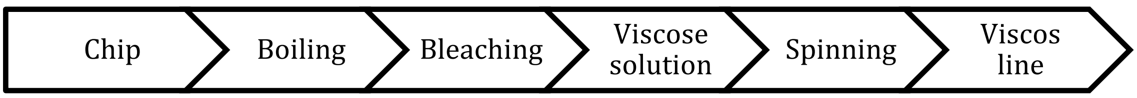
SEKAB
SEKAB is one of Sweden's bioethanol companies and import, produce and refine bioethanol to fossil free green chemicals and biofuels. Moreover, they develop the 2nd generation bioethanol production based on forest cellulose at a demonstration plant in Örnsköldsvik called *Etanol Piloten*. The demonstration plant is funded by the Swedish Energy Agency, EU and SEKAB, and is owned by a holding company consisting of the Universities of Umeå and Luleå together with SEKAB.[28]

SEKAB plans to increase the production of cellulose bioethanol to 50 000 m^3. Approximately 1 billion SEK is a new plant estimated to cost. This plant would have a biorefinery approach, which except from bioethanol would produce biogas and lignin, thus utilizing 80 per cent of the energy in the forest material. Research regarding break down of cellulose to sugar and ferment it to ethanol has been on-going for several years. A big challenge has been to decrease the price on enzymes that cuts the cellulose into sugars, another challenge has been to develop efficient yeasts.[29]

MoRe Research
MoRe is a competence and equipment provider to their customer's biorefineries and they work together with pulp and paper mills that want to create more value from their waste streams and rest products.[30] They have a pilot plant that can be used for producing viscos from wood. MoRe is unique in Europe to have a complete chain of pilot machines under the same roof. They can thus offer customers project the whole value chain, from raw material to finished viscos line.

MoRe's customers are dissolving producers and different research projects, and they have noticed an increasing interest from pulp mills how they can increase value creation by converting the dissolving process towards this field. In the figure below an illustration of MoRe pilot machines can be seen representing one value chain towards viscos from forest based material.[31]

Figure 4.3 - *MoRe pilot machines within the value chain towards viscose.*



Source: MoRe Research. (2013) *Biorefinery pilot plants.*

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[28] SEKAB. (2013) *About us - Demo Plant.* http://www.sekab.com/about-us/facilities/demo-plant
[29] NyTeknik. (2012) *Etanol plant in Örnsköldsvik might be shut-down.* http://www.nyteknik.se/nyheter/energi_miljo/bioenergi/article3396783.ece
[30] MoRe Research. (2013) *About Biorefinery.* http://www.more.se/default.asp?ML=12293
[31] MoRe Research. (2013) *Biorefinery pilot plants.* http://www.more.se/default.asp?ML=12703

Domsjö Fabriker & Aditya Birla Group

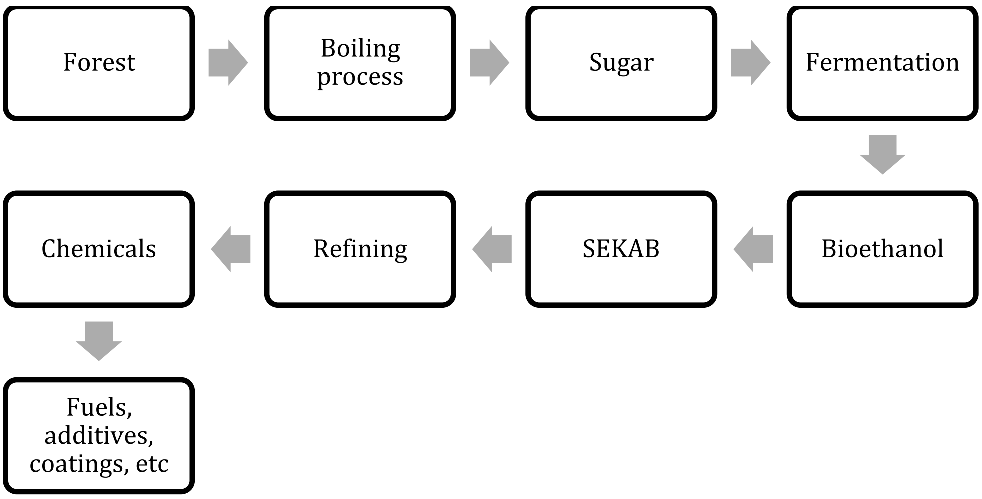
Domsjö is Sweden's biggest producer of biogas and has in total 5 per cent of the total gas production in Sweden. More products that Domsjö produces are carbon acid, bioenergy, bioresin and lignin. They foresee strong drivers for sustainable products that over time will create new markets, and they have new Indian owner, Aditya Birla Group, who have shifted the focus towards textiles. Domsjö Fabriker and Aditya Birla Group operate in synergy in the value chain towards textiles and this highlights new opportunities for pulp mills how the dissolving pulp can be exploited in new markets than the traditional, see value chain in figure below.[32]

Figure 4.4 – V*alue chain towards textile from dissolving pulp.*

Source: Domsjö Fabriker. (2012) *Presentation at the biorefinery conference.*

From Domsjö Fabriker's boiling process sugar is obtained and the sugar is fermented with bakery yeast to bioethanol. The bioethanol is after refining delivered to SEKAB where it is further refined to chemical products and biofuels. The yearly production of bioethanol from Domsjö is 14 000 tonnes. The bioethanol is produced from forest, and is thus 2nd generation bioethanol. They want through product development reach market segments where the bioethanol has higher value. In the figure below the value chain for bioethanol is shown and how it through refining can be used.[33]

Figure 4.5 – *Value chain of the bioethanol from Domsjö Fabriker.*



Source: Domsjö Fabriker. (2013) *Products bio-ethanol.*

[32] Domsjö Fabriker. (2012) *Presentation at the biorefinery conference.*
[33] Domsjö Fabriker. (2013) *Products bioethanol.* http://www.domsjo.adityabirla.com/

SCA

SCA is the biggest private forest owner in Europe with 2.6 million hectares, and the annual outtake corresponds to 50 per cent of SCA's total wood supply. SCA works along the whole value chain and their operations include forest to finished hygiene consumer goods that is sold to retail stores, production of solid wood based products and pulp and publication papers.[34]

SCA believes it to be a necessity to have political incentives for biofuels to make it economical feasible, but maybe not needed for plastics and materials. They are doing a pre-study performed by the SCA R&D Centre were they are evaluating direct sources (e.g. turpentine, bark) and potential sources (e.g. lignin compounds, wood extractives). They foresee value enhancement through cost reduction by energy and combustion and utilizing derivate for further refining to for instance green chemicals. In the SCA R&D Centre they have a broad focus towards biofuels, biomaterials and bioplastics and in the future SCA aims to produce more than bioethanol from cellulose.

SCA see a trend in lignin applications for carbon fibres and are involved in a project with Innventia that comprises the main actors of the Swedish forest industry. As today, most of the lignin is burned for energy purposes, but SCA regards more value could be extracted from lignin if refining it. However, more research is still needed before it can become commercialised, maybe 5-6 years. One obstacle is to get the lignin pure enough and at an even quality, but through the *LignoBoost* technology that issue is now solved. SCA monitors and track how it goes in the U.S where the LignoBoost technology has been implemented in a Domtar pulp mill.[35]

Göteborg Energi GoBiGas

GoBiGas, Gothenburg Biomass Gasification, is the name of Göteborg Energi's large investments in biogas production by gasification of forest and forestry residuals. The purpose with GoBiGas is to show the gasification technology in commercial scale and has been acknowledged as one of the projects that have been granted funds from the EU's NER300 program. Moreover, SEK 222 million in financial aid has been granted from the Swedish Energy Agency. In 2020 GoBiGas expects to deliver biogas equivalent of 1 TWh. It represents about 30 per cent of current deliveries in Gothenburg or fuel to 100 000 cars. GoBiGas will produce biomethane by thermal gasification of forest residues.[36]

[34] SCA. (2013) *SCA forest products at a glance.* http://www.sca.com/en/About_SCA/SCAs-business-and-operations-worldwide/SCA-Forest-Products-at-a-glance/

[35] Christian Kugge. (2013) Project Manager SCA R&D Centre, interview.

[36] Göteborg Energi. (2013) *GoBiGas Project.* http://www.goteborgenergi.se/English/Projects/GoBiGas__Gothenburg_Biomass_Gasification_Project

Focus so far in the project has been to build up the plant and it is estimated to be fully operational by the end of 2013. Due to the fact that biogas is not cheap to produce compare to fossil gas they are lobbing for political incentives that will drive the demand for greener biofuels. One political incentive that they track closely is one regarding how the cars will be fossil-free by 2030 in Sweden. They know that the biogas could be used for chemical production and they have been in frequent contact with the chemical cluster in Stenungsund, since they have a vision to become fossil free by 2030, *Sustainable Chemistry 2030*. But so far the biogas is too expensive which makes in not economical feasible to switch from fossil gas to biogas, except from having the environmental gaining, and hence less climate impact.[37]

Preem

Preem is the biggest oil company in Sweden and has refining capacity of 18 million m^3 of crude oil per year, which corresponds to 80 per cent of Sweden's refining capacity and 30 per cent of the Nordic refining capacity. Preem has refining activities in Lysekil and Gothenburg on the west coast of Sweden.[38] Preem has as one business objective to increase the part of renewable material in their products. The refinery in Gothenburg is first in the world to produce diesel based on residual products from the forest, *Evolution Diesel*, which is a world unique Swedish invention. Part of these activities involves using natural gas for producing hydrogen, which considerably reduce the CO_2-emissions from the refinery. In the refinery oxygen, nitrogen and sulphur is removed by using hydrogen and catalysis. Preem's refining technology allows production of renewable diesel comprising renewable hydrocarbons that is identical to those of fossil diesel and can be drop-in directly in the refining process.[39]

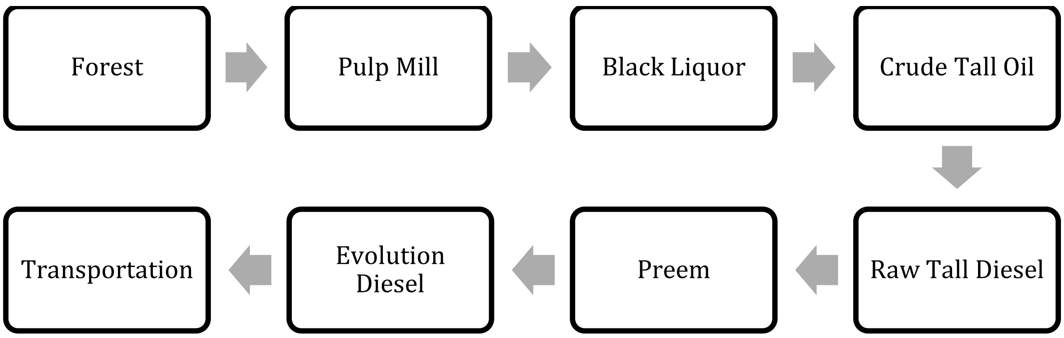
Preem only uses FAME made from RME, and the RME is produced in collaboration with Perstorp in Stenungsund. RME is mixed in diesel, in small portions up to 7 per cent of according to the European standards. Preem uses bioethanol and the European standard allows 5 per cent mix of ethanol in gasoline and Preem lobbying for to increase that part to 10 per cent.[40]

[37] Åsa Burman. (2013) Project Manager GoBiGas, interview
[38] Preem. (2013) *About Preem* http://www.preem.se/templates/page____1248.aspx
[39] Preem. (2013) *Evolution Diesel.* http://evolution.preem.se/
[40] Preem. (2013) *RME & FAME* http://www.preem.se/templates/page____9454.aspx

SunPine

SunPine is a 2nd generation biofuel company and is a pioneer in the value chain of crude tall oil towards renewable diesel. SunPine is owned by Sveaskog, Preem, Södra and KIRAM and is situated in Piteå. Around 2 per cent of the wood becomes tall oil and is refined from the black liquor, which is a rest product in the sulphate process when producing paper pulp. The crude tall oil is converted to crude tall diesel and then shipped to Preem's refinery in Gothenburg, see value chain below.

Figure 4.6 – *The value chain for crude tall oil from SunPine into Preem's evolution diesel.*



Source: SunPine. (2013) *Green diesel from crude tall oil.*

The tall oil has shown to be an interesting rest product and it contains lipid acids, hart acids and neutral compounds that are converted to crude tall diesel in vacuum. Tall oil that cannot be used for oil production is sold has heating oil to industries. In total SunPine produces around 100 000 m^3 raw tall diesel annually.[41]

SunPine has started collaboration with Lawter, a company within the Japanese Harima Chemical Group, for building a hart's acid plant close to the SunPine plant. It will be one of the biggest refineries for harts in Europe and it is planned to produce 20 000 tonnes of harts annually. Through this plant additional value from the crude tall oil is going to be utilized and areas of use are for example in glue and ink.[42]

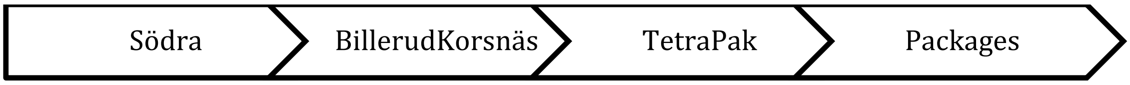
[41] SunPine. (2013) *Green diesel from crude tall oil.* http://sunpine.se/index.php?option=com_content&view=article&id=47&Itemid=54

[42] SunPine. (2013*) SunPine and Lawter building a harts plant in Piteå.* http://sunpine.se/index.php?option=com_content&view=article&id=65-sunpine-och-lawter-bygger-hartsfabrik-i-pitea&catid=35-news&Itemid=55

Södra

Södra is a co-operative society with 51 000 Swedish forest owners as members. A project with respect to material science that Södra has been involved in is *Woodi* aimed to develop a wood based diaper, a project done in collaboration with SCA and Chalmers. Another project is *Formulosa* aimed to developed new packages and materials, incorporated actors from different parts of the value chain. Chalmers was involved as project manager working together with all the actors, and VINNOVA funded the project. An illustration of where in the value chain the different actors are involved can be seen in the figure below.[43]

Figure 4.7 – *Value chain actors in the project Formulosa.*



Source: Camilla Rööst, Head of R&D Södra Innovation, interview

Södra Pulp Lab has a pilot facility in Värö and the patented biocomposite material *DuraPulp* has been developed there. Demand for renewable material is increasing and Södra have R&D activities for example within dissolving pulp to make textiles, biocomposites, and new materials from lignin and hemicellulose. One challenge for Södra is if the separation processes can be done more effective. If chemical industries want to have forest based material Södra thinks collaboration and joint work is needed if it is going to be a success story. To have a market breakthrough it must be a win-win situation. Price press on suppliers and asymmetrical power relationship will probably not work and one supplier cannot become too dependent on one big player. Within an established value chain actors can come and go and the roles are well-defined. However, within a new value chain everything is different and roles and responsibility for the different actors are unclear and uncertain.[44]

Södra made an investment recently in the LignoBoost technology developed by Chalmers and Innventia, which is a technology for refining lignin from black liquor. The technology makes the mill in Mörrum fossil free and gives Södra possibilities to focus on new biomaterials in the future. Södra also puts additional focus on textile pulp and started the production in December 2011 after a conversion of one of the two existing production lines. The plan is to convert another pulp line for textile pulp production. Their intention is to reach 170 000 tonnes per year of hardwood pulp for the textile market.[45]

[43] Camilla Rööst. (2013) Head of R&D Södra Innovation, interview.
[44] Ibid
[45] Innventia. (2013) *Södra invests in LignoBoost.* http://innventia.com/sv/Om-oss/Nyheter/Sodra-invests-heavily-in-bioenergy-with-LignoBoost/

Sveaskog
Sveaskog, owned by the Swedish state, delivers 10.6 million m^3 of wood to 170 customers and they have sales of approximately SEK 7 billion. They see a growing consumer demand for renewable materials, and forest biorefining can become the sustainable way to meet this demand.[46] Sveaskog supports research regarding pyrolysis, which is fast method for converting solid forest biomass to liquid green bio-oil. It is similar to the technology that BillerudKorsnäs is exploiting in the Skärblacka mill. Green bio-oil is one renewable material that can replace fossil heating oil for industry, and hence decrease the emissions of fossil CO_2 radically.[47]

Innventia & LignoBoost
Innventia is a R&D company based in Stockholm that works actively with new products and materials based on forest resources and is to 51 per cent owned by direct owners representing the forest industry (e.g. BillerudKorsnäs, Stora Enso, Södra) and the remaining part is own by a holding company and private investors. They regard pulp and paper mills to have good prerequisites for working as biorefineries in the future.

Innventia has a pilot plant in Stockholm for producing nanocellulose (MFC – Micro Fibrillated Cellulose) and was opened in 2011 with a capacity of 100 kg/day.[48] Further, they see lignin as a potential material for biophenols, biopolymers and carbon fibres.[49]

Chalmers and Innventia develop a technology called LignoBoost, which refine lignin from black liquor. The technology gives the possibility to increase the capacity in the pulp mill and improve the profitability if the lignin could be used instead of oil and natural gas for energy purpose. Lignin could also be raw material for high value products as carbon fibre. The technology has recently been bought to a Domtar pulp mill in the U.S, using the LignoBoost technology for commercial scale production.[50]

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[46] Sveaskog (2012) *Presentation at the biorefinery conference*.
[47] Sveaskog. (2013) *Pyrolysis oil increases the value from the forest.* http://www.sveaskog.se/press-och-nyheter/nyheter/2012/pyrolysoljan-okar-vardet-pa-skogen
[48] Innventia. (2013) *Demo and pilot Nanocellulose.* http://innventia.com/sv/Sa-har-gor-vi/Demonstration-och-pilot/Nanocellulosapilot/
[49] Innventia. (2013) *Pulp mills and biorefineries, Green chemistry.* http://innventia.com/sv/Det-har-kan-vi/Massatillverkning-och-bioraffinaderi/Gron-kemi/
[50] Innventia. (2013*) Pulp mills and biorefineries, LignoBoost.* http://www.innventia.com/sv/Det-har-kan-vi/Massatillverkning-och-bioraffinaderi/LignoBoost/

ForTex

ForTex is a project aiming to produce textile fibres from Swedish forest products in an eco- and cost-effective manner. The idea is to make use of the facilities and equipment available in today's pulp mills and to integrate this with facilities for fibre spinning. The project started in 2012 and is coordinated by SP. Project members are Södra, Kiram, H&M, IKEA, Innventia and SwereaIVF.[51] The background to the ForTex project is fierce competition from low cost countries and cheap, fast growing eucalyptus trees which forcing companies to search for new market segments and products. There is need for pulp and paper industry to search for new business opportunities and ForTex try to fill that role by making textiles from forest.[52]

Processum - Cluster

Processum was started in 2003 and has developed to a leading biorefinery initiative, both on a national and international level, and hosting the regional growth initiative *the biorefinery for the future*. Processum's main focus lies within R&D in the areas of biotechnique, inorganic and organic chemistry, and is an important hub for development of new products, energy solutions and fuels based on forest. Processum is owned by its member companies, for example; AkzoNobel, Domsjö Fabriker, Holmen, SCA and SEKAB.[53]

Processum has invested in a pre-treatment pilot plant for biomass which will be placed at MoRe in Örnsköldsvik. The investment is funded by several actors, for example, Umeå University, SEKAB, Domsjö Fabriker, MoRe and SP. This pilot plant is the first step in the process for producing green chemicals from biomass and is planned to be operational 1st of October 2013. Processum has since earlier invested in 11 pilot plants for enabling up-scaling of successful biorefinery concepts. In order to go from biomass to green chemicals several steps are required; (1) pre-treatment of biomass, (2) hydrolysis of cellulose to produce a sugar solution, and (3) fermentation. Umeå University wants to demonstrate potential future value chains in pilot plants. They collaborate closely with the cluster in Örnsköldsvik, which is important for having the biorefinery development going in the area. The university has a big chemical institution and that competence is needed in Örnsköldsvik.[54]

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[51] Innventia. (2013) *On-going projects*. http://www.innventia.com/en/Projects/Ongoing-projects/

[52] Åsa Östlund. (2013) *SP, Project member in ForTex, interview.*

[53] Processum. (2013) *About us*. http://www.processum.se/sv/processum/om-processum

[54] The Biorefinery for the future. (2013) *Pre-treatment plant for biomass.* http://bioraffinaderi.se/sv/framtidens-bioraffinaderi/media/nyhetsarkivet/888-pilot-foer-foerbehandling-av-biomassa?utm_source=Paloma&utm_medium=Newsletter&utm_campaign=Nyhetsbrev+fr%c3%a5n+Framtidens+Bioraffinaderi

In the figure below a value chain is illustrated which Processum has been evaluating in lab and pilot scale. Södra has also evaluated this and delivered to plastic producers. Moreover, Purac, a multinational corporation, has been in contact with Processum for evaluating poly lactic acids for bioplastics, see illustration of value chain below.

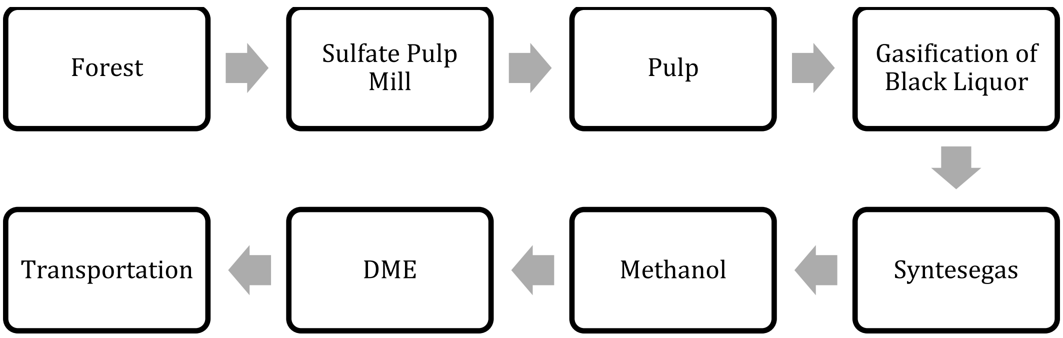
Figure 4.8 – *Value chain for bioplastics from cellulose.*

Source: David Blomberg. (2013) Research Engineer, Processum, interview

One obstacle as today is that the volumes of 2nd generation bioethanol are too small since it hard to have it economical feasible. Forest based bioethanol has almost commercial viable developed technology and due to the decrease in paper prints consumption the feedstocks are available. The interest for biorefineries in Sweden increases and has drawn a lot more attention from the chemical industry than Processum expected. They have focused on the bulk chemicals, since they consider it to be the best way to reach commercialisation stage.

Further, a project called *BioDME* was done in collaboration with several actors representing different stages in the value chain, for example TOTAL, Preem, Delphi, Chemrec, HaldorTopsøe and Volvo Trucks, and lasted 2008-2012. Volvo has manufactured and developed ten trucks that could have DME (dimethyl ether) as fuel. Chemrec in collaboration with HaldorTopsøe developed and build a plant in Piteå, Sweden. Preem was responsible for the distribution and building of fuel stations in Sweden and TOTAL were in charge of fuel and lubricants solutions. The BioDME project was financed through 7th Framework Program and the Swedish Energy Agency.[55] In the figure below the value chain for the BioDME project is illustrated.

Figure 4.9 – *The value chain evaluated in the BioDME project.*



Source: David Blomberg. (2013) Research Engineer Processum, interview

[55] BioDME Project. (2013) *Presentation - From Wood to Wheel*. http://www.biodme.eu/wp/wp-content/uploads/15Per-Salomonsson.pdf

In a report from the Swedish Royal Academia of Sciences it is proclaimed that methanol could potentially replace gasoline and DME could replace diesel. This should be done through gasification of black liquor or wood. R&D regarding gasification of black liquor has been on-going for a long time, but has not reach commercialization stage yet.[56] A research group in Denmark found the same conclusion last year, methanol and DME is what should be used, but it is highlighted the importance of strong political incentives and broad investments in R&D for market success.[57]

Sustainable Chemistry 2030 – Collaborative Project

Sustainable Chemistry 2030 (Hållbar Kemi 2030) comprises five companies in the chemical cluster in Stenungsund, namely AkzoNobel, INEOS, Borealis, AGA and Perstorp. They have a united vision that the cluster should be the centre for producing sustainable products based on renewable materials and renewable energy, and all plastics should be recycled. It is the companies own investment that will drive this transformation, but as support they have received financing from EU Regional Development fund.[58]

A project called *Skogskemi* (Forest Chemistry) is a collaborative project between the forest industries and the chemical companies in Stenungsund. The project is coordinated by Processum and is a part of the vision Sustainable Chemistry 2030. In a previous phase of the project different value chains have been brought forward and now in the next phase the three most promising value chains have been selected for in-depth study. The project has been financed by its member companies and VINNOVA, with a budget of total SEK 20 million for 2 years. The three green chemicals that will be study are the bulk chemicals butanol, olefin and methanol, which are considered to have long term conditions to become successful and result in demo plants driven by the forest and chemical industry. This selected value chains have partly been decided based on the demand for green chemicals in the cluster in Stenungsund, but also the technical suitability. Members in the projects are for instance AGA, AkzoNobel, Borealis, Chalmers, Domsjö Fabriker, Perstorp, Processum, SCA and SEKAB.[59]

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[56] NyTeknik. (2013) *Report from KVA - Put the efforts on methanol*. http://www.nyteknik.se/nyheter/energi_miljo/bioenergi/article3685351.ece

[57] The Swedish Royal Academia of Sciences. (2013) *News Biofuels.* http://www.kva.se/sv/pressrum/Pressmeddelanden-2013/biodrivmedel/

[58] Chemical Cluster in Stenungsund. (2013) *Sustainable Chemistry 2030.* http://www.kemiforetagenistenungsund.se/

[59] The Biorefinery for the future. (2013) *The collaborative project Forest Chemistry.* http://www.bioraffinaderi.se/sv/framtidens-bioraffinaderi/media/nyhetsarkivet/38-skogskemi-ett-gemensamt-projekt

Universities

Mid Sweden University ChemseQ

The company ChemseQ, connected to the Mid Sweden University, has got financial support from Länsstyrelsen Västernorrland, SCA and EU and they have projects regarding how to retain the value of the natural wood chemicals, instead of as today wasted in the mechanical pulp mill. They want to reduce costly process problems and quality issues created by hydrophobic extractives. Selectively separate the hydrophobic disturbing substances from the water and gain value. Problem caused by hydrophobic extractives are paper breaks, higher consumption of chemicals and water. ChemseQ has developed a concept to obtain minimal emissions of complexing agents to the recipient, but so far only developed in lab scale.[60]

Chalmers University of Technology

Chalmers's research is focused on lignin and it is there they see the greatest potential in the future. Chalmers has one project regarding cracking of lignin together with Metso, and they crack the lignin to monomers and chemicals. Chalmers evaluates biorefinery concepts, since they regard it to be a necessity if it is going to be economical and you need be able to steer the process towards the chemicals you want. As long as the oil is on today's levels the oil is too cheap to have profitable lignin processes, but if oil price increasing the lignin becomes more competitive. Lignin is one part of the black liquor and is approximately 40 per cent of the total black liquor. Researchers have been focused on replacing PAN (Polyacrylonitrile) with lignin in carbon fibre and reduce the cost for carbon fibres. Even though the quality might not be the same, their expectations are that it should be at least good enough for the most applications. Chalmers is the biggest research institute in Sweden with the field of forest and employees in total 130 people at different departments.[61]

Luleå University of Technology

A project called *Renewable Energy Project* is currently on-going and is led by Luleå University of Technology, LTU. Financial resources have been received from the Swedish Energy Agency (SEK 10 million in the first stage for 0.5 years and second stage 2.5 year SEK 50 million). In total, LTU planning projects for SEK 250 million. They want to produce green fuels from biomass and focus on black liquor gasification. Several industrial and academic partners are involved and the whole project is planned to finish 2017. A factory for producing green diesel, BioDME, is part of this project.

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[60] Mid Sweden University. (2013) *ChemseQ* advantages. http://chemseq.com/fordelar/

[61] Hans Theliander. (2013) Professor Chemical Engineering Chalmers University of Technology, interview.

A new company called LTU Green Fuels will intensify the research on green fuels through utilizing pilot plant for gasification of different bio products as synthesis gas and green fuels.[62] Furthermore, LTU is involved in a project for making plastics from green butyric acid from bio-based rest products from forest and agriculture and financing have been received from the Swedish Energy Agency.[63]

Research Institutes

The Swedish Technical Research Institute - SP

SP, a Swedish research institute, is in process of building up a new part of their organisation which they call *Bio economy*. In a pre-study they have investigated how the demonstration plant *Etanol Piloten* in Örnsköldsvik can be rebuilt to become a more broad facilitated research facility. SP wants to take over the demo plant from SEKAB and a decision is to be taken in summer 2013. Cellulose from forestry and agriculture should be fractioned to later be used for producing different kinds of green chemicals, everything from bulk chemicals to fine high value products. To get economy in such process SP regards it to be necessary to utilise all the different parts from the raw material and combine high and low value products.[64]

Wallenberg Wood Science Centre - WWSC

WWSC do research focusing on biomass material and processing and is financed with SEK 40 million over 10 years from the private Wallenberg foundation, and involves 60 people in total. Their opinion is that the polymeric structure of the wood components should not be destroyed, the material efficiency must be high and the energy demand should be low. Likely future scenario that WWSC foreseen is that today's chemical pulp mills will be modified, two alternatives. (1) Pre-processing step of the wood chips in order to extract hemicelluloses and lignin, or (2) smaller production process parallel to the existing paper pulp process. New materials from wood that they conducting research on are for instance lignin, hemicellulose, nanocellulose (MFC) and biocomposite.[65]

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[62] Luleå University of Technology. (2013) *LTU Renewable Energy Project.* http://www.ltu.se/ltu/media/news/Storsatsning-pa-fornybar-energi-1.100992?l=en

[63] Plastnet. (2013) *Plastics from green butyric acid.* http://www.plastnet.se/iuware.aspx?pageid=4080&ssoid=163201

[64] Kemivärlden Biotech. (2013) *SP Etanol Pilot Plant.* http://www.kemivarldenbiotech.se/iuware.aspx?pageid=792&ssoid=164600

[65] Wallenberg Wood Science Center. (2012) Presentation from Biorefinery Conference in Jönköping 2012.

Mistra Future Fashion

Mistra is a foundation for strategic environmental research in Sweden and has a project called *Mistra Future Fashion*. They have received SEK 40 million to research about sustainable fashion from 2011 to 2015. The fashion industry is global and far-reaching and the consumption of clothing continues to increase at a fast pace. The lifecycle of the textile industry affects people and the environment, especially the climate and water. The project involves several institutions and companies for example Chalmers, Copenhagen Business School, Stockholm School of Economics, Innventia, SP, H&M and Södra.[66] Cotton is pure cellulose, but one obstacle today is the presence of mixed textile materials, for example the viscos in cotton clothes. Within the industry there are a lot of projects in progress and there is an increased awareness. Recycling has become a trend in the industry and companies are becoming more active with communicating this to the customers. H&M has a goal that 50 per cent of the clothes should be made of 'green' fibres, either eco-cotton or recycled textiles. If recycling can be done in a greater extent it is substantial amounts of money that could be safe and great environmental benefits could be obtained.[67]

Skogforsk

Skogforsk, Forestry Research Institute of Sweden, is financed by the Swedish Government and is a central research body for the Swedish forest sector. The goal is to provide the forest industry with knowledge that contributes to profitable and sustainable forestry. The research includes forest technology, raw-material utilisation, environmental impact and forest bioenergy.[68]

The Swedish Forest Agency

The Swedish Forest Agency is the pulp, paper and saw mill industries branch organisation and are representing some 50 pulp and paper mills and around 140 saw mills. They have a vision called *Vision 2035,* that aims to double the production of the Swedish forest cluster measured in value, from SEK 50 billion to SEK 100 billion until 2035, and half of that growth should come from new products.[69]

[66] Mistra. (2013) *Ongoing research Mistra Future Fashion.* http://www.mistra.org/en/mistra/research/ongoing-research/mistra-future-fashion.html
[67] Åsa Östlund. (2013) Program Director SP Mistra Future Fashion, interview.
[68] Skogforsk. (2013) *About Skogforsk.* http://www.skogforsk.se/en/About-skogforsk/
[69] The Swedish Forest Agency. (2013) *Vision 2035 Ekoportal.* www.Ekoportal2035.se

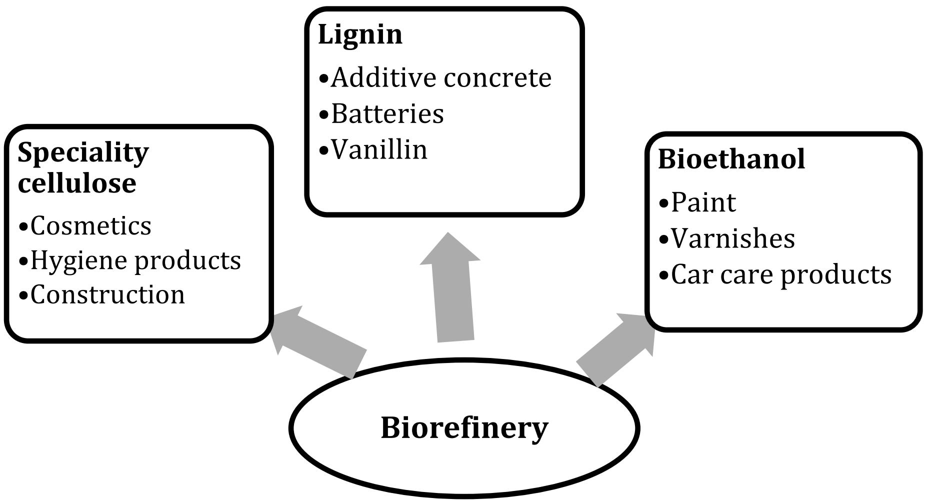
4.3 Norway

Companies & Projects

Borregaard

Borregaard is using forest for producing sustainable biochemicals, biomaterials and biofuels in a biorefinery approach. Some example of products that Borregaard produces are lignin, specialty cellulose and bioethanol, see figure below for example of products. The most important use for lignin based products is as an additive in concrete. Except for providing advantages in terms of strength and quality, the lignin also implies that the water and cement content of the concrete can be reduced. This contributes to a lower energy need and lower CO_2-emissions in the production of cement. Lignin is also the source of the flavouring agent vanillin. Most of the world's vanillin production is based upon petrochemical materials, and Borregaard is the only producer in the world to make vanillin from forest. Bioethanol is produced through fermentation of sugar in the wood and is 2nd generation biofuel.[70]

Figure 4.10 – *Example of products and application areas.*



Source: Borregaard homepage, the world's leading biorefinery.

The demonstration plant, called *Biorefinery Demo*, started preliminary operations in summer 2012, followed by normal operations in the 1st quarter of 2013. The plant relies on Borregaard's patented BALI technology.[71]

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[70] Borregaard. (2013) *The world's leading biorefinery.* http://www.borregaard.com/content/view/full/10231/(language)/eng-GB

[71] European Commision, BRIDGE2020. (2013) *Borregaard biorefinery demostration plant.* http://bridge2020.eu/news/2013/04/borregaard-inaugurates-biorefinery-demonstration-plant-in-sarpsborg-norway-2/

Nordic Paper

Nordic paper has four paper mills and two pulp mills, all located in Norway and Sweden. They are a manufacture of special paper for a wide range of applications and their two biggest categories are greaseproof and kraft papers. There is an increased awareness in the society about the toxic fluorinated substances used in many applications in contact with foodstuff or in household products. Nordic paper does not add any chemicals to their papers, and therefore are they suitable to use in connection with food products.[72]

STEM

In the project STEM it is evaluated how to produce micro fibrillated cellulose (MFC) and use it as stabilizers for emulsions to increase the understanding of the functionality. Emphases are laid on both emulsions of water-in-oil and oil-in-water applications and the project is partly funded by the Research Council of Norway. The project involves both industry and R&D partners. R&D-partners are Paper and Fibre Research Institute (PFI), Norwegian University of Science and Technology (NTNU) and SINTEF.[73]

Biorefinery Mid-Scandinavia

In the project *Biorefinery Mid-Scandinavia* PFI and Processum aim to create sustainable development and cooperation between Norwegian and Swedish research centres and industries in the biorefinery area through access to each other's pilot plants, experiences and networks. The project is financed with SEK 5.1 million of which half comes from the European Regional Development Fund through the program Interreg Sweden-Norway and the project period is 2012-2014. Furthermore, VINNOVA, as well as the county administration in Västernorrland, Sør-Trøndelag and Nord-Trøndelag, are providing funding.[74]

The Bio-Oil Refinery Project

The Bio-oil Refinery Project aim developing technology for producing and fractionating bio-oil components as a basis for a biorefinery producing green chemicals, transportation fuels and energy. Biomass liquefaction is done by fast pyrolysis and the technology is suitable for bio-oil production of wood waste materials. The project is a collaboration between PFI, Aston University and partners from industry. The project is managed by PFI and partly funded by the Research Council of Norway.[75]

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[72] Noridic Paper. (2013) *Our Paper.* http://www.nordic-paper.com/our-paper/

[73] Paper and Fiber Research Institue, PFI. (2013) *New Biomaterials project STEM.* http://www.pfi.no/New-Biomaterials/Projects/STEM/

[74] Paper and Fiber Research Institue, PFI. (2013) *Biorefinery Mid Scandinavia.* http://www.pfi.no/Biorefinery/Biorefinery-Projects/Biorefinery-Mid-Scandinavia/

[75] Paper and Fiber Research Institue. (2013) *Biorefinery project Bio-oil.* http://www.pfi.no/Biorefinery/Biorefinery-Projects/Bio-oil/

LignoRef

The project *LignoRef* aims to develop knowledge about processes for conversion of lignocellulose materials into 2nd generation biofuels and products. Processes include biomass pre-treatment, hydrolysis and fermentation of carbohydrates and thermochemical conversion of process by-products. The project R&D partners are the Norwegian University of Science and Technology (UMB), SINTEF, University of Bergen, NTNU and PFI.[76]

PROFIT

The *PROFIT* project objective is to develop technical solutions for bioenergy production and more profitable paper production by integrating a synthetic biodiesel plant and/or a pellet plant with the Follum paper mill at Hønefoss. Norwegian Industry and the Research Council of Norway fund the project. Xynergo is participating in the project and intends to establish a synthetic biodiesel plant based on low quality wood at Hønefoss. The R&D partners in the project are PFI and Chalmers.[77]

Research Institutes

SINTEF is the largest, independent and non-commercial research organization in Scandinavia and are multidisciplinary.[78] Within renewable energy they have activities within several areas and one of them is biorefinery. SINTEF is involved in R&D projects for making sustainable production possible of for instance 2nd generation biofuels, materials, bulk and fine chemicals. The research comprises biomass characterization, biochemical conversion, thermochemical and catalytic conversion and integration and optimisation of material and energy flows. SINTEF carries out research in close collaboration with the Norwegian University of Science and Technology (NTNU) and the University of Oslo (UiO).[79]

Moreover, SINTEF leads a Bioenergy Innovation Centre, *CenBio*, with the objective to develop the basis for a sustainable, cost-effective bioenergy industry in Norway to achieve the national goal of doubling bioenergy use by 2020. CenBio address the entire value chains of biomass, including forest, agriculture, and biodegradable waste fractions.[80]

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[76] Paper and Fiber Research Institue. (2013) *Biorefinery project Lignoref.* http://www.pfi.no/Biorefinery/Biorefinery-Projects/LignoRef/

[77] Paper and Fiber Research Institue. (2013) *Biorefinery project PROFIT.* http://www.pfi.no/Biorefinery/Biorefinery-Projects/Profit/

[78] SINTEF. (2013) *About SINTEF.* http://www.sintef.no/home/About-us/

[79] SINTEF. (2013) *Renewable energy – Biorefinery.* http://www.sintef.no/home/Environment/fornybar-energi/Biorefinery/

[80] SINTEF. (2013) *Project CenBio.* http://www.sintef.no/Projectweb/CENBIO/

Paper & Fibre Research Institute, PFI, is a research institute and working for instance with how fibres can be fibrillated into their smaller building blocks, micro fibrils. Micro fibrils can be utilised in products in a wide range of application areas, for examples emulsions, composites and packaging material. Another central application area is in composites where micro fibrils act as reinforcement to obtain improved mechanical properties.

Furthermore, PFI is involved in a project called *Fuel-ethanol from Nordic Wood* aiming to develop pre-treatment techniques reducing production costs for bioethanol from lignocellulose biomass. A second objective is to quantify the possibilities to reduce investment and operating costs by co-locating and integrating the bioethanol plant with existing industry infrastructure (pulp mills and oil refineries). Some of the R&D-partners in the project are Innventia, SINTEF and VTT.[81]

Furthermore, the *Norwegian Centre for Bioenergy Research* aims to contribute to the sustainable production and use of bioenergy, industrial innovation and research-based teaching. Priority areas for the centre include for instance bioresources, biogas and biofuel from various feedstocks, for example forest and agriculture. They have expertise within biomass production, sustainability assessments and enzyme technology. The centre is owned by the Norwegian University of Life Sciences (UMB), the Norwegian Institute for Agricultural and Environmental Research (Bioforsk) and the Norwegian Forest and Landscape Institute.[82]

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[81] Paper and Fiber Research Institue. (2013) *Biorefinery project Fuel Etanol from Nordic Wood.* http://www.pfi.no/Biorefinery/Biorefinery-Projects/Fuel-etanol-from-Nordic-Wood/

[82] Norwegian Centre for Bioenergy Research. (2013) *Bioforsk.* http://www.bioforsk.no/

4.4 Finland

Companies & Projects

St1

St1 is an energy company and has operations in Finland and Sweden. The vision of St1 is to be the leading producer and seller of CO_2 friendly energy and aims to develop and commercialise new modern solutions to reduce the transportation sector's negative environmental impact. St1 regards that the greatest potential for bioethanol production to be in materials containing cellulose and will start Finland's first bioethanol production from sawdust in Kajana, Finland, with sawdust provided from an adjacent sawmill. The sawmill produce approximately 80 000 m^3 sawdust annually, which will give an bioethanol production of 10 million litres/year. To get the production going investments of approximately € 30-40 million is needed.[83] Further, St1 produces bioethanol from waste and rest products from the food industry. The ethanol is called RE85 and is 100 per cent ethically and local produce with low CO_2-emissions and distributed to the present infrastructure of stations.[84]

UPM

UPM doing 2nd generation biofuels based on forest residual fully compatible with current diesel motors. Compared to traditional fossil diesel UPM's biofuels has only 20 per cent of the greenhouse gas emissions. UPM invested approximately € 150 million giving a production capacity of 100 000 tonnes (corresponding to 120 million litres of diesel) annually and is estimated to be in full production 2014. European market is driven by biodiesel and demand is expected to grow by 7 per cent yearly the next 10 year. It is likely that the global demand will exceed supply in the next few years. UPM has received financing from the NER300 Program and funds from the Finnish Government. UPM has developed a hydro treatment process in Lappeenranta, Finland, and hydro treatment piloting is done in cooperation with HaldorTopsøe.[85] UPM and VTT testing the biodiesel in Volkswagen cars during 2013.[86]

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[83] Forest Sweden. (2013) *St1 production of etanol from sawdust.* http://skogssverige.se/nyheter/st1-vill-tillverka-etanol-av-sagspan

[84] St1. (2013) *Locally produced etanol.* http://www.st1.se/narproducerad-etanol

[85] UPM. (2013) *Investor news EU awards NER300 technology grant for UPM.* http://www.upm.com/EN/INVESTORS/Investor-News/Pages/EU-awards-NER300-technology-grant-for-UPM%E2%80%99s-biorefinery-project-in-France-001-Tue-18-Dec-2012-16-05.aspx

[86] Globennewswire. (2013) *UPM and VYY initiate tests of wood based diesel using VW cars.* http://www.globenewswire.com/news-release/2013/04/26/541907/0/en/UPM-and-VTT-to-initiate-fleet-tests-of-wood-based-diesel-using-Volkswagen-cars.html

Moreover, UPM has MFC technology and know-how for producing nanocellulose. UPM think they will be a big company in the future in the market of advanced biofuels and they have set revenue target > € 1 billion annually. However, to reach the really big volumes of advanced biofuels improved technologies for converting lignocellulose to advanced biofuels are required.[87]

Green Fuel Nordic

Green Fuel Nordic is a biorefining company and produces 2nd generation bio-oil through pyrolysis from local forest biomass. The company is owned by the management team, personnel and an additional number of private equity investors. By more investments their ownership based will be expanded to institutional investors. They will be the first Finnish actor that will be using local renewable material to refine bio-oil on a commercial scale. The bio-oil is a liquid, low-carbon and sulphur-free that can directly replace light and heavy fuel oil in renewable energy applications. In the upcoming years they aim to build several new biorefineries in Finland. The company was established in October 2011 and is headquartered in Kuopio, Finland.[88]

StoraEnso

StoraEnso is a global paper and packaging producing company located in more than 35 countries worldwide. Two main tasks have been identified by StoraEnso connected to biorefinery development: (1) Isolate and reuse the valuable blocks and (2) scale up to commercial success. StoraEnso Biorefinery division is focusing on biofuels, lignin materials, micro materials and functional biochemicals. StoraEnso has been working with a variety of lignin applications, for instance as replacement in expensive materials, platform in chemical applications, fibre modification and the use of fibre fragments in non-traditional materials and chemicals. They have also been researching regarding lignocellulose residuals from other industries and how combinations of new value streams could reduce cost and increase the value.[89] Moreover, StoraEnso has a pre-commercial plant in Imatra, Finland, for producing nanocellulose (MFC) and invested approximately € 10 million.[90]

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[87] UPM. (2012) Presentation at the Biorefinery Conference in Jönköping 2012.

[88] Green Fuel Nordic. (2013) *News Bio-oil low-sulphur maritime transport.* http://www.greenfuelnordic.fi/en/page/23?newsitem=2

[89] StoraEnso. (2013) *Biorefinery business platforms.* http://www.sari-energy.org/PageFiles/What_We_Do/activities/worldbiofuelsmarkets/Presentations/BiorefineryPlatforms/Timo_Heikka.pdf

[90] StoraEnso. (2013) *StoraEnso makes ground-breaking investment.* http://www.storaenso.com/media-centre/press-releases/2011/05/Pages/stora-enso-makes-a-groundbreaking.aspx

Since summer 2012 StoraEnso has been producing dissolving pulp aimed for the textile market at one plant, Uimaharju, Finland. The plant has two lines with a capacity of 450 000 tonnes. One of the lines, with a capacity of 150 000 tonnes, has been converted towards dissolving pulp instead. The market price for dissolving pulp is higher than for the conventional pulp, and the demand is expected to rise since the need for clothes increases as the world population growths.[91]

Forest BtL

Forest BtL is a company owned by Finnish Vapo Corporation and they provide knowledge in raw material procurement chains and integration of 2nd generation biofuel processes enabling large investment projects. They utilize the Biomass-to-Liquid technology (BtL) in where the raw gas obtained from the biomass (forest) by gasification is conditioned and processed into an ultra-clean synthesis gas with only two residual components left prior to the fuel synthesis; carbon monoxide and hydrogen. These react to form crude bio-oil, which can be refined into liquid biofuels.[92]

Furthermore, Forest BtL builds a production site in Kemi that is planned to be in commercial operation for production of biodiesel and naphtha by the end of 2016. The plant will have a gasification capacity of 480 MW and an annual output of about 130 000 tonnes of biodiesel and naphtha by using about 1.5 million tonnes of wood. The project will be funded by the European Union's NER300 program.[93]

Fortum

Fortum is an energy company and has invested in pyrolysis technology and building a bio-oil plant integrated with the Joensuu heat and power plant in Finland. Through this investment production of electricity and district heat and 50 000 tonnes of bio-oil per year is enabled. The bio-oil raw materials will include forest and forestry residues. The new technology has been developed in a joint cooperation project between Fortum, Metso, UPM and VTT as a part of TEKES *BioRefine Program*. Metso will supply Fortum with the bio-oil production plant and with raw material. The new bio-oil production plant is scheduled for start-up in the autumn of 2013.[94]

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[91] Forest-Based Sector. (2013) *Technology platforms Dissolving pulp provides completely recyclable textiles.* http://www.forestplatform.org/en/dissolving-pulp-provides-completely recyclable-textiles

[92] Forest BtL. (2013) *2nd generation technology.* http://forestbtl.com/2nd-generation-btl-technology/

[93] Chemicals-Technology. (2013) *Forest BtL and Linde biomass gasification.* http://www.chemicals-technology.com/news/newsfinland-forest-btl-oy-linde-dresden-biomass-gasification

[94] TEKES. (2013) *BioRefine Fortum bio-oil plant.* http://www.tekes.fi/programmes/BioRefine/Current+topics/Fortum+Joensuu+en?type=news

Vaskiluodon Voima

The energy company Vaskiluodon Voima has the world biggest gasification plant for biomass. Metso has built the plant and the Finnish Government has provided € 10.8 million in investment support and the whole budget for the project is € 40 million. The plant is seen as an important step to favour domestic biomass for electricity and heat production in Finland.[95]

Neste Oil

Neste Oil is an oil company and has recently started to use tall oil pitch (a residue produced by tall oil refiners) as a feedstock for refining into traffic fuel. They successfully tested tall oil in commercial refinery operations in March-April in 2013 and are now ready to begin using it on a continuous basis. Fuel refined from tall oil will be distributed to stations in Finland and they aims to use significant quantities of tall oil pitch in the future. Finnish tall oil refiners produce around 100,000 tons of tall oil annually as a residue. This represents a further step in their strategy of extending the feedstock base and increasing the use of waste and residues. Neste Oil doubled its use of waste- and residues-based inputs in 2012, and the volume of renewable diesel refined from these materials was equivalent to the annual fuel consumption of some 740,000 cars last year.[96]

Ahlstrom

Ahlstrom has business within the area of high-performance, cellulose fibre-based materials. They have products within for instance filters and food packaging. Recently, Dow Chemical, an American MNC, has entered into a collaboration agreement to use Ahlstrom technology for nonwoven fibre in drinking water applications. Dow will incorporate Ahlstrom's high-performance, breakthrough filter medium into a new set of drinking water purification products.[97]

Finish Bioeconomy Cluster - FIBIC

FIBIC is one of the six Strategic Centres for science, technology and innovation in Finland. FIBIC offers businesses and research organisations new way of in close, long-term cooperation build future, sustainable bio-based economy concepts. FIBIC strategic target is to double the value of forest cluster products and services from the 2006 levels up to 2030. At least half of the value will come from products and services that were not yet in production in 2006.

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[95] Papernet. (2013) *World biggest gasification plant of biomass* http://www.papernet.se/iuware.aspx?pageid=346&ssoid=164892

[96] Neste Oil. (2013) *Uses tall oil pitch to produce traffic.* http://www.nesteoil.com/default.asp?path=1;41;540;1259;1260;20492;20993

[97] Ahlstrom. (2013) Products fibre composite food nonwovens. http://www.ahlstrom.com/en/products/fiberComposites/Pages/Foodnonwovens.aspx

Future Biorefinery (FuBio) is one of the three strategic focus areas of FIBIC. The main objective of FuBio is to establish Finnish globally competitive knowledge platforms within the field of forest biorefinery. FuBio is focused on development of novel value chains, in which forest and forestry residuals are refined into materials and chemicals.[98]

Universities

Aalto University has developed a method that makes it possible to use microbes to produce butanol from forest biomass. Butanol is particularly suited as a transport fuel because it is not water-soluble and has higher energy content than ethanol. Most commonly used raw materials in butanol production have so far been starch and cane sugar but starting point in the Aalto University study is to use lignocellulose from forest biomass. Further, it has been studied how to successfully combine modern pulp- and biotechnology, since Finland's forest industry provides good opportunities. This study is a part of the TEKES' *BioRefine Program* and TEKES is the Finnish Funding Agency for Technology and Innovation.[99]

Research Institutes

VTT, Technical Research Centre of Finland, is the biggest research institute in Northern Europe and conducting R&D, testing and information services to public sector and companies as well as international organisations. For instance, VTT develops biomass-based technology for the drop-in replacement of existing platform chemicals and also developing novel functional, bio-based chemicals and intermediates through the use of chemical conversion.[100] VTT supports development in packaging materials and bio-based chemicals based on forest biomass and agricultural side streams. Cellulose nanofibres can be used to develop completely new fibre-based products. Combining wood and other natural fibres with polymers and plastic processing technologies offers new market opportunities for biocomposites and natural fibre composites, which could be applied in for instance furnishing and automotive parts.[101]

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98 FIBIC. (2013) *About FIBIC.* http://fibic.fi/about-fibic

99 Aalto University. (2013) *News Chemicals and biofuels from wood biomass.* http://www.aalto.fi/en/current/news/view/2011-12-09-002/

100 Technical Research Centre of Finland, VTT. (2013) *Renewable process concepts.* http://www.vtt.fi/service/renewable_process_concepts.jsp?lang=en

101 Technical Research Centre of Finland, VTT. (2013) *Forest industry bio-focus on materials.* http://www.vtt.fi/service/forest_industry_biofocus_on_materials.jsp?lang=en

A new project called *Adcellpack* aims to develop new cellulose-based materials to replace oil-based materials in food packaging. For instance Carrefour and VTT are partners in this project and research how to create a thermoplastic wood-fibre-based packaging material. The challenges are finding the right barrier properties and an adequate elongation of the material. *Adcellpack* is a two-year project that started in November 2012 and has a budget of € 1.4 million, funded by the EU 7th Framework Program.[102]

Metla, Finish Forest Research Institute, is the main forest research institution in Finland and one of the biggest forest research institutes in Europe. Metla is a governmental, sectorial research institute, subordinate to the Ministry of Agriculture and Forestry. Metla's duties are defined by the law to promote through research the economical, ecological, and socially sustainable management and use of forests.[103]

4.5 Denmark

Due to the natural prerequisite as can be seen in table in the very beginning of this Chapter, Denmark's area for forest is limited and the annual outtake is low in comparison with the other Nordic countries.

The Danish Forest Association - DFA

The Danish Forest Association, DFA, is the Danish forest owners' national policy organisation. The objective for DFA is to promote the political and professional interests of the Danish forest owners and to promote such forestry, which has the ability to protect the nature values of Danish forests. DFA provides, among many other things, information on wood- and non-wood markets, political supervision of the interests of forest owners and general information to the public on forests and wood. DFA owns the international wood trading company DSH-WOOD.[104]

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[102] European Plastic News. (2013) *EU project looks at cellulose based packaging.* http://www.europeanplasticsnews.com/subscriber/headlines2.html?cat=1&id=2627&q=EU+project+looks+at+cellulose-based+packaging

[103] Metla Finnish Forest Research Institute. (2013) About Metla. http://www.metla.fi/metla/index-en.htm

[104] Nordic Forestry. (2013) *The Danish Forest Association.* http://www.nordicforestry.org/facts/Denmark.asp

4.6 Summary Forest

Between the different Nordic countries both similarities and dissimilarities can be identified, with respect to the various value chains. First, what should be highlighted are the differences in the areas of focus and the number of actors active. Due to natural prerequisites, Denmark's land area available for forest production is limited, and thus less activity compared to the other countries.

Further, as outlined in the table 4.1, private individuals owns the majority of the forest feedstock and large volumes are mainly available in Sweden and Finland. One similarity between Sweden and Finland, worth to be highlighted, is the similar future vision for the forest industry. The Swedish Forest Agency aims double the value by 2035 from SEK 50 billion to SEK 100 billion and half of the growth should come from new products. The Finnish Bioeconomy Cluster FIBIC's strategic target is to double the value of forest products and services from the 2006 levels by 2030.

Sweden, Norway and Finland all have strong, broad and well-established research institutes supporting the industry, in particular VTT in Finland, Innventia in Sweden and PFI in Norway. The institutes are broad and active in the development of innovative value chains based on forest feedstocks.

Moreover, many big companies see the market within pulp and paper industry diminishing, mainly within newspaper print. Therefore an underlying pressure exists to find new markets and applications to not get stuck in useless investment facilities and equipment that has required large investments. The existing production platforms offer opportunities for developing biorefinery concepts through new innovative value chains. One example of this is the shift in pulp mills towards the textile market. Large actors as Domsjö Fabriker, Södra and StoraEnso have converted plants to produce dissolving pulp aimed for viscos and textile value chains.

Furthermore, lignin is a big part of the tree and large amounts of rest products containing lignin is produced in pulp mills. Through the LignoBoost technology it is technical possible for pulp mills to refine the lignin to use it in new value chains towards for instance carbon fibres. If utilising lignin the cost for carbon fibre could be lowered, hence making it economically feasible in value chains towards automobile industry. Example of actors evaluating lignin for carbon fibre applications are for instance SCA, StoraEnso, VTT, Innventia and Chalmers.

Micro Fibrillated Cellulose (MFC) is another interesting area that potentially offers new markets through innovative value chains. Several actors as for instance UPM, VTT and StoraEnso evaluate MFC technology and applications.

Moreover, green bio-oil is another forest value chain that recently has given increased interest, and large investments in pyrolysis plants have been made. One underlying driving force is that mainly forest residuals are utilised, and thus not compete with traditional forest value chains. In this stage the bio-oil is aimed to be used as industry oil for heat and energy purposes. However, the focus is set on developing value chain for upgrading the bio-oil to transportation fuels, particularly aimed for the maritime sector. That is because the bio-oil is sulphur free and a EU directive in place 2015 delimiting sulphur content to 0.1 per cent in maritime fuels which forcing the industry to search for alternative fuels. Example of actors involved in value chains of green bio-oil is BillerudKorsnäs, Fortum and Green Fuel Nordic.

Further, thermal gasification of forest residuals is a value chain Göteborg Energi GoBiGas and Vaskiluodon Voima are involved in and evaluating. The thermal gasification aims both towards biofuels for the transportation sector, as well as biogas as a replacer of natural gas. One similarity between Sweden, Norway and Finland is that they all have broad-facility value chain activities within the biofuel and bioethanol area, with several actors on the market. Within this field several value chains exists as for instance St1 bio-ethanol produced from sawdust, UPM biodiesel from forest residuals and Neste Oil's use of tall oil pitch. Also activity exists through co-production of fossil and renewable materials as a method for green blending and one example is tall oil from SunPine into Preem's value chain of transportation diesel.

A summary can be seen in the table below and examples of companies, projects, universities and research institutes that operates within different areas.

Table 4.2 – *Summary of material from forest.*

Area	Sweden	Norway	Finland
Biofuel/ Bioethanol	SEKAB, Domsjö Fabriker, Preem, SCA, LTU, BioDME	Borregaard, LignoRef	St1, UPM, Neste Oil, StoraEnso, Forest BtL, Aalto University
Tall-oil	ArizonaChemicals, SunPine		Neste Oil
Biogas	Göteborg Energi GoBiGas, Domsjö Fabriker	Norwegian Centre for Bioenergy Research, SINTEF	Vaskiluodon Voima, Forest BtL
Green Bio-oil (pyrolysis)	BillerudKorsnäs, Sveaskog	The Bio-Oil Refinery Project	Fortum, Green Fuel Nordic
Nano cellulose (MFC)	Innventia, WWSC	STEM, Paper & Fibre Research Institute - PFI	UPM, StoraEnso, Ahlstrom, VTT
Lignin Carbon fibres	Chalmers, SCA, Innventia, WWSC		StoraEnso, VTT
Viscose/Textiles	Domsjö Fabriker, MoRe, Södra, ForTex, SP		StoraEnso
Bio-plastics	Södra, SCA, Innventia, WWSC, LTU		VTT

5. Renewable Material - Marine Biomass

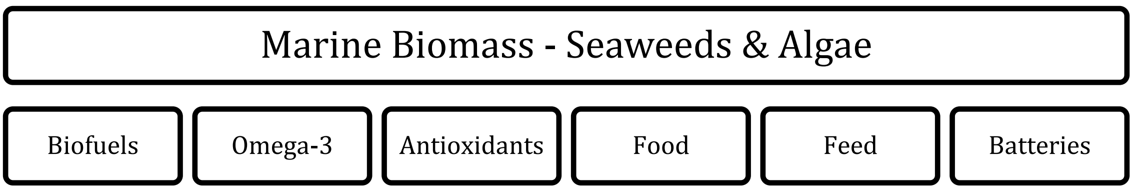
5.1 Introduction

This chapter provides a mapping of companies, projects, universities and research institutes and corresponds to answer research question 1. Selection criteria's has been based on renewable materials from marine biomass, mainly algae and seaweeds.

Marine biomass has potential as resource for several different areas, for example energy, chemicals, and ingredients for the food and feed industry. Industrial scale utilization requires intensive development of growth, harvest and conditioning systems that secure reliable supply of biomass.[105] Cultivation of algae for biofuel has one great advantage compare to cultivation of raps, corn, and other food crops. Algae's can be cultivated on unproductive land, and hence not compete with food value chains. Further, they grow very fast, capture carbon dioxide and uptake nitrogen and phosphor from the water. About 50 per cent of algae's weight is oil and due to the high yield algae provides an attractive fuel source since it has the potential to yield oil at an exponentially greater rate than other biofuels. However, 50 per cent is water and it's a challenging task to have effective separation processes.[106]

The most promising applications so far in the Nordic countries appear to be the exploitation of high value chemicals for health nutrition. Residuals after extraction may be used for anaerobic digestion and the resulting biogas injected into a gas grid. Other promising areas include replacing fishmeal in animal feed and a new and valuable source for omega-3, both for aquaculture and the omega-3 industry. In the figure below some examples of areas of applications are shown, and as can been seen the possibilities are broad facilitated.[107]

Figure 5.1 – *Examples of what marine biomass could be used for.*



Source: Author's own illustration

[105] Blue Bio Microalgae. (2013) *A Market Analysis*, pp. 10-11.
[106] The Swedish Technical Research Institute SP. (2013) *Algae cultivation.* http://www.sp.se/sv/index/research/algae_cultivation/sidor/default.aspx
[107] Blue Bio Microalgae. (2013) *A Market Analysis*, pp. 3.

5.2 Sweden

Companies & Projects

AstaReal

AstaReal is a biotechnology company based in Gustavsberg, near Stockholm and was established in 1994. They produce an additive from algae for animal feed, containing astaxanthin. The company uses algae to produce large amounts of astaxanthin, which is then refined down to a deep red powder. This powder is then for instance fed to chickens so that they produce eggs with a more colourful yolk, or as fish feed for giving salmon red colour in the meat. Astaxanthin is a strong antioxidant and has several positive health effects as for instance reduce oxidative stress. Pigment from algae is attracting considerable interest as an alternative to chemical-based colouring agents.[108]

Nordic Paper

Oil from algae that is cultivated in wastewater in pulp and paper plants can serves as a base for sustainable production of biodiesel, bioplastics and lubricants. A pilot plant involving these issues is being built at Nordic Papers facilities in Bäckhammar for testing the technology. VINNOVA, a Swedish state funding agency, has invested SEK 4 million, and the total budget is SEK 8 million. SP, a Swedish technical institute, coordinates the project and it has a duration of three years. The water that can be obtained in the middle step will give the algae the nutrients that they need for growing and cultivate. The algae are harvested through flocculation or filtering, and the oil is extracted. Rest products as proteins and carbohydrates aimed to be used for other purposes. In this project several more actors are involved, as for instance Perstorp, Chalmers, Simris Alg and Lantmännen.[109]

Umeå Energi

Umeå Energi doing big scale testing with algae cultivation in four big pools and the algae's is going to be feed by sewage from the city's municipal water treatment plant. Carbon dioxide, nitrogen and phosphor will be obtained from the power and heat plant. Algae support the plant to clean its emissions and to create an energy rich biomass, which could for instance be used for biodiesel production. Research has been in progress since 2007 and the Swedish University of Agriculture Science, SLU, coordinates the project together with Umeå Energi. Financing has been obtained from Sweden Energy Agency and this algae plant is the biggest in Sweden.[110]

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[108] AstaReal. (2013) *About AstaReal.* www.bioreal.se

[109] Energinyheter. (2013) *Algae project receive funds from Vinnova.* http://www.energinyheter.se/2013/01/algprojekt-f-r-pengar-fr-n-vinnova

[110] Energinyheter. (2013) *Algae cultivation at Umeå Energi.* http://www.energinyheter.se/2012/07/algodling-vid-ume-energi-ger-eko-i-v-rlden

Simris Alg

Simris Alg is situated in Simrishamn and focuses on food, feed and health production by utilising algae. The company was founded in 2010 with Almi and Innovationsbron as their main funding partners. Simris Alg has 2000 m^2 greenhouses and 150 m^2 new laboratories, and full commercialisation of algae cultivating for its omega-3 is planned in 2014-2015.[111] Besides being sold in stores as health supplement, the omega-3 will be added to functional foods and infant formula. Their first products omega-3 rich algae extracts are expected to launch during late 2013.[112]

Marin Biogas

Marin Biogas is a company located in Stenungsund and wants to produce biogas from cultivated and harvested ascidians. When the marine biomass is digested it produces a renewable biogas. Positive environmental aspects, when harvesting the ascidians, are a net uptake of nutrients from the sea for a low cost per removed kilogram of nitrogen and phosphorus. The rest product can be used as a fertiliser for agriculture. Marin Biogas has an international patent pending concerning the cultivation technology.[113]

Universities

Uppsala University has research on-going to make polymer battery made of cellulose from algae, called *Algae battery*. These kinds of batteries are expected to become cheaper, simpler, and also metals-free and thus safe to throw away after use. A low manufacturing price, in combination with a flexible structure making it possible to bend, will give several new applications are some of the expectations.[114]

There is an on-going collaborative project with *KTH* and *Chalmers* under the name *Formas Centre for Metabolic Engineering*, and it has received € 3 million from the research council Formas. They research how butanol can be produced from cyanobacteria's. Researchers at KTH argue that the production needs to be improved hundredfold before it becomes commercially viable. Some cyanobacteria able to extract nitrogen from the air and thus do not need any fertiliser. Moreover, researchers have plans to develop fuels from cyanobacteria that are more energetic, and could therefore be appropriate for aircraft engines.[115]

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[111] Simris Alg. (2013) *About Simris Alg.* http://simrisalg.se/

[112] Algae Industry Magazine. (2013) *Swedish algae company wins environmental award.* http://www.algaeindustrymagazine.com/swedish-algae-company-simris-alg-wins-environmental-award/

[113] Marin Biogas. (2013) *Our Idea.* http://marinbiogas.se/varide.php/1_var-ide

[114] Miljönytta. (2013) *Cellulose based batteries.* http://miljonytta.se/framtid/cellulosa-baserade-batterier/

[115] KTH Royal Institute of Technology. (2013) *Make fuels from bacteria's.* http://www.kth.se/en/aktuellt/nyheter/gor-bransle-av-bakterier-1.370530

Within *Chalmers* there are several research groups dedicated to marine biotechnology. At the department of Industrial Biotechnology research regarding biotechnological processes for production of chemicals, fuels and materials with the help from microorganism and enzymes. Research has recently started regarding microalgae and is done in collaboration with SP and University of Gothenburg. Moreover, the chemical cluster in Stenungsund is working together with Chalmers researcher regarding how algae could be utilized for chemical production.[116]

Blue Bio is a part within the EU Interregional Program IV-A in the Kattegat and Skagerrak region. The project had duration of two years and was finished in the beginning of 2013 and University of Gothenburg and MareLife have been the main partners. The goal with Blue Bio was to find sustainable ways of exploiting the marine environment and to expand the potential for the industrial use of algae.[117]

Blue Bio regards the final market for algae based products to be in the field of biofuels, but in order to finance the investments needed for bigger production sites high value products are needed, as for instance omega-3. As main advantage when utilising algae is the cleaning of water and the uptake of carbon dioxide. Moreover, cultivating algae in wastewater is an area that has attracted strong interest, and many projects are driven on research level. However, it is a big obstacle to overcome the trouble to get the industry involved in projects and to have them co-finance. Institutional initiatives in forms of directed investment and support to research will also be needed since the economic climate does not favours this kind of risky investments. The research is needed to be given stability through long-term conditions and financial support.[118]

Research Institutes

The Swedish technical research institute, SP, is a knowledge provider in several areas. Within the area of marine environmental technology SP have on-going activities with in the three following areas; (1) antifouling, (2) microalgae for bioenergy and (3) bio prospecting of marine substances. They do several projects in collaboration with University of Gothenburg. Further, within the field of microalgae close collaboration is done with Chalmers, and evaluating the whole value chain from cultivation conditions to energy analysis when using biofuels.[119]

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[116] Västra Götalands Regionen, Gothenburg University & Chalmers (2012) *Maritima kluster Västra Götaland,* pp. 32.
[117] Blue Bio Project. (2013) About Blue Bio. www.bluebio.org
[118] Camilla Pettersson. (2013) Project Manager Blue Bio, interview.
[119] The Swedish Technical Research Institute SP. (2013) *Algae cultivation.* http://www.sp.se/sv/index/research/algae_cultivation/sidor/default.aspx

5.3 Norway

Companies & Projects

Statoil & Wintershall

In the field of microalgae Statoil is doing research regarding cultivation and processing of algae and has on-going collaborative projects with several U.S partners. Regarding macroalgae they are investigating the use of seaweed as a feedstock for biofuel production.[120] Moreover, Wintershall and Statoil are evaluating fungal residues to improve oil recovery. Since December 2012, Wintershall have been testing a new method in the extraction of oil where biopolymers act as a thickener when the substance is injected into the reservoir. When the water is thicker, it will press out the oil. Wintershall has along with its parent company BASF taken several patents on the biopolymer technology.[121]

Indbiotech

Indbiotech, Industrial Biotech Network-Norway, wants to bring together academia and industry crossing boards between the different industrial biotechnology sectors, research disciplines and geographic areas and thus form a coherent network. The network was established in June 2012 and aims to inspire innovation and knowledge distribution in the area of biorefining and industrial biotechnology. The main sponsors of the network are Innovation Norway, The Research Council of Norway and SIVA.[122]

CO_2BIO

CO_2BIO is an innovation network of actors from the research area and industry and was established in 2011. The objective is to develop new profitable business based on the existing operations at Mongstad. They will establish a pilot plant for production of omega-3 rich algae biomass and to conduct research projects in order to develop the whole value chain. The pilot plant expects to be established in 2013.[123]

Pronova Biopharma

Pronova is a healthcare company providing preventive care and treatments focused on safe and efficacious lipid therapies, and is a pioneer in the omega-3 industry. As of January 31, 2013 Pronova is part of BASF.[124] Pronova are monitoring the process and cultivation techniques that Simris Alg is utilising. BASF, who recently bought Pronova, only buy fish oil from monitored fisheries.

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[120] Blue Bio Microalgae. (2013) *A Market Analysis*, p. 30.
[121] Wintershall. (2013) *Small fungus with a big impact on oil production with biopolymer* http://www.wintershall.com/en/media-library/detail/media/a-small-fungus-with-a-big-impact-oil-production-with-biopolymer-14.html
[122] Indbiotech. (2013) *About Indbiotech.* www.indbiotech.no
[123] CO_2BIO. (2013) *About CO_2BIO*. www.co2bio.no
[124] Pronova Biopharma. (2013) *About Pronova*. http://www.pronova.com/about-pronova/category131.html

Pronova uses very little of the fish oil which is being produced and Pronova hopes that technologies which BASF has available will massively reduce their use of crude oil. Pronova is one of the business partners in MabCent, Centre for Marine Bio-prospecting. The centre aims to develop high value marine bioactivities and drug discovery based on extracts from marine organisms in the artic environment.[125]

Universities

NTNU, Norwegian University of Science and Technology in Trondheim, has on-going commercial activity related to microalgae cultivation as feed for aquaculture. They are doing big scale research projects related to omega-3, bioenergy and cultivation units for algae. One big challenge identified is the light with too few hours during wintertime which makes the cultivation inefficient. Cultivation of algae could produce 5-7 kg/m^2 day, which would imply large areas of land needed. NTNU has on-going projects with University of Life Science Ås, University of Tromsö, CO_2Bio and SINTEF. One new project they planning to start is related to cultivation of seaweed for making biofuels.[126]

UMB Ås, University of Life Sciences, is focused on higher education and research within environmental and biosciences. Bioforsk and NOFIMA are located at UMB Ås. Several microalgae projects are running at UMB, for instance feed for salmon and cod, immune stimulants in feed and hydrogen gas production from algae.[127]

Research Institutes

SINTEF together with *NTNU* has competence within marine algae and bacteria, and how they can be applied into different systems. By doing bio prospecting they work to find suitable organisms from both a health and an environmental perspective.

NOFIMA is the Norwegian Institute of Food, Fishery and Aquaculture, the largest institute for applied research within the fields of food, fisheries and aquaculture. NOFIMA has recently entered into a strategic alliance with Alltech, one of the world's largest animal health and nutrition companies. Moreover, Alltech has one of the world's largest algae production facilities.[128]

Bioforsk is in progress of developing know-how in aquatic plant cultivation with particular focus on cultivation of algae, but also other aquatic plants are investigated.[129]

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[125] Blue Bio Microalgae. (2013) *A Market Analysis*, pp. 23.
[126] NTNU. (2013) *Biotechnology Marinebio.* http://www.ntnu.edu/biotechnology/marinbio
[127] Blue Bio Microalgae. (2013) *A Market Analysis*, pp. 18.
[128] Ibid
[129] Bioforsk. (2013) *Research areas arctic agriculture.* http://www.bioforsk.no/ikbViewer/page/en/research-area?p_document_id=97740

5.4 Finland

Research Institutes

SYKE Finnish Environment Institute has collaborative projects on-going related to the use of marine biomass for energy purposes. The project *ALDIGA's* main goal is to design and validate an integrated concept of biowaste to energy based on algae and biogas production. They want to develop an efficient process requiring minimal energy and utilizing all the side streams generated in addition to the main fuel stream (biodiesel and biomethane). VTT has been involved and collaborated in this project by modelling and analysing side streams. Further, the project *LIPIDO* aimed to optimise algal culturing as a source for biodiesel production by looking at how conditions like light, temperature and nutrients affect the growth and lipid yield. Project partners were NTNU, University of Oslo, Ludwig Maximilian University LMU, and Icelandic Energy Research Institute IERI. The project lasted 2007-2010.[130]

SYKE also collaborates with industrial partners and one example is an algae research program with Neste Oil. This project was one part in Neste Oil's initiative for using algae oil as a raw material for producing NExBTL renewable diesel in the future. The focus is on testing the lipid production capacity of different types of algae and analysing how the quality and quantity of these lipids could be optimised. The project started in August 2011 and lasts for two years.[131]

The Technical Research Centre of Finland, VTT, is involved in several projects related to marine biomass and algae cultivation. Within energy they are doing projects related to fatty acids, as a raw material for renewable biodiesel, and projects including N-INNER LIPIDO, MicroFuel and ALDIGA.[132] Further, VTT are involved in a project called DirectFuel. The project aims to investigate volatile fuels and longer chain alkanes by biological conversion of solar energy through engineered cyanobacteria. The project is funded by EU and coordinated by the University of Turku. Except of VTT five universities and two companies that are participating in the project.[133]

[130] TEKES. (2011) *BioRefine Yearbook 2011.* www.tekes.fi/u/BioRefine_Yearbook_2011.pdf
[131] Neste Oil. (2013) *Neste and the Finnish Environment Institute to begin joint algae research.* www.nesteoil.com/default.asp?path=1;41;540;1259;1260;16746;18082
[132] Blue Bio Microalgae. (2013) *A Market Analysis*, pp. 18.
[133] The Technical Research Centre of Finland, VTT. (2013) *Energy research focus areas.* http://www.vtt.fi/research/ene/?lang=en

5.5 Denmark

Companies & Projects

AgroTech

AgroTech is a specialist in measurements of photosynthesis and optimisation of growth in higher plants, and they research about microalgae production. They are working together with partners on a number of projects, and AgroTech's role in the projects are for instance doing characterisation of the algae's climate needs for optimum growth by photosynthesis measurement, formula sheet for ideal nutrition for the algae and advice on commercial algae production.[134]

Algae Innovation Centre

The Algae Innovation Centre, financed by the EU's Regional Fund, Denmark's Business Innovation Fund and LOKE, conducting research on algae potential for different uses as energy fuels and chemicals. The centre aims to create a triple helix organization on a regional level and a national network of researchers, industries and politicians, thus create a strong cluster. The centre will make use of already existing infrastructure on the Municipality of Lolland of various testing and demonstration facilities. The partners in the project are Roskilde University and Aalborg University.[135]

Kalundborg Municipality

Kalundborg Municipality will build a new facility that will conduct research on how microalgae can be used for cleaning up industrial wastewater. The plant will be up and running in June 2013 and have received € 1 million from the EU. The plant will incorporate 10 photo bioreactors and has a production capacity of 10-40 kg dry biomass per day.[136]

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[134] AgroTech. (2013) *Investigating potential of microalgae.* http://agrotech.dk/en/projects/agrotech-investigating-potential-of-microalgae

[135] Algae Innovation Centre. (2013) *About the centre.* http://www.algaeinnovationcenter.org/eng/index.php?mod=main&top=0&parent=0&id=131

[136] Copenhagen Capacity. (2013) *Denmark establishes new micro seaweed facility.* http://www.copcap.com/Newslist/2012/Denmark%20establishes%20new%20micro%20seaweed%20facility

Universities

Aarhus University has a pilot scale cultivation facility with 12 land-based tanks of 2 m^3 each used for wastewater remediation. The facility can be used for other purposes than testing bioremediation, for instance in terms of comparing algal growth in different types of water, and an advantage is that temperature, salinity, pH and oxygen can be monitored in real time. Aarhus University will also cultivate brown algae in more than 1 hectare coastal waters the following two seasons, 2013 and 2014, and this is done in collaboration with Danish Shellfish Centre.[137]

The Technical University of Denmark, DTU, is involved in research projects that investigate how biodiesel can be derived from microalgae. If the production is going to be economical the cultivated algae must be done efficient and cost-effective and species that contains high yields of lipids must be selected. DTU studies a number of microalgae species that could be used for oil production and are looking at how they can be modified to have improved growth rate and enhanced lipid yield.[138]

Research Institutes

The Danish Technological Institute, DTI, leads the project *MacroAlgaeBiorefinery* and is a partner in *AlgaeCenter Denmark.* Further, DTI is also involved in the projects *BioWALK4BioFuel* and *EuroBioRef*. The later project includes algae among several other biomass feedstocks in a biorefinery concept producing a stream of various products from fuels to chemicals. DTI is mainly involved through project management assignments, analyses of the cultivation and harvesting conditions, thermal conversion of the biomass and quality characterising. DTI has facilities for physical, chemical and mechanical characterisation and a pilot plant for testing solid biofuels.[139]

AlgaeCenter Denmark is a consortium of the partners Aarhus University, Danish Technological Institute, Kattegatcentret and Ocean Centre Denmark and they are in process of setting up algae cultivation facilities at the Kattegatcentret in Grenaa Harbour. One project that is conducted in the centre is *Algae for biogas in Central Denmark Region*. The project aims to develop and implement new technologies through facilitation of knowledge sharing between industries, universities and technological institutes.[140]

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[137] Blue Bio Microalgae. (2013) *A Market Analysis*, pp. 14-15.
[138] Ibid
[139] Ibid
[140] AlgaeCenter Denmark. (2013) *About AlgaeCenter.* http://www.algecenterdanmark.dk/28968

Another project in the centre is the project *MacroAlgaeBiorefinery* that aims to develop new technologies in laboratory and pilot scale. Sustainable growth and subsequent conversion of algae to three energy carriers (bioethanol, biobutanol and biogas) and a high-protein fish feed supplemented with essential amino acids.[141]

Moreover, *BioWALK4Biofuel* is another research project that is included in the centre. The 7th Framework Program finances the project and aims to develop and demonstrate an integrated plant for use of organic waste and CO_2 from energy production plants. The waste will be used for the production of 2nd generation biofuel by cultivation of algae.[142]

5.6 Summary Marine Biomass

Marine biomass has potential as a feedstock for several different areas, for example energy, chemicals, and ingredients for the food and feed industry. One of the main advantages with utilising marine biomass that have been outlined is the capture of carbon dioxide and the uptake of nitrogen and phosphor from the water.

In all the four Nordic countries it exists research activities related to marine biomass, mostly with a focus towards biofuels and biogas. One pattern that could be outlined is R&D activity focused on biofuels and biogas through cultivation of microalgae, and those activities are mostly research projects. Many universities and research institutes are active in exploring these value chains, but also commercial actors as Neste Oil, Statoil and Wintershall are involved. One pattern that could be seen is that Denmark and Finland have their focus towards biofuels, while Sweden and Norway, on the other hand, are broader in their research activities and includes also value chains of omega-3 and antioxidants.

What could also be highlighted is the lack of clear value chain structures since most of the projects are carried out on R&D level. However some value chains can be outlined. One example is towards omega-3 fatty acids aimed for both food and feed, and one commercialised value chain by the company Simris Alg exists. Another example of a commercialised value chain is for antioxidants with the company AstaReal producing astaxanthin. However, except from these example few commercialised value chains exists and hence hard to see the value chain relationships between different actors.

[141] AlgaeCenter Denmark. (2013) *MacroAlgaeBiorefinery.* http://www.algecenterdanmark.dk/32697

[142] BioWALK4Biofuel. (2013) *About the project.* http://www.biowalk4biofuels.eu/

Furthermore, what has been noticed is the many projects are pursued in the Nordic region. But many projects are evaluating similar aspects or have similar project scopes. Most of the activities that have been identified in this thesis are carried out as research projects and their focus are similar in all the countries implying overlapping research.

See the table below for a summary of different actors in the Nordic countries, operating within different application areas.

Table 5.1 – *Summary material from marine biomass.*

Area	Sweden	Norway	Finland	Denmark
Biofuels	Marin Biogas, SP. KTH, Umeå Energi, Chalmers	Statoil & Wintershall, NTNU, SINTEF	SYKE Finnish Environment Institute, VTT, Neste Oil	DTU, AlgaeCentre Denmark, Algae Innovation Centre, DTI
Materials	Nordic Paper, Uppsala University			
Omega-3	Simris Alg	CO_2BIO, Pronova, NTNU		
Antioxidants	AstaReal			

6. Renewable Material – Agriculture

6.1 Introduction

This chapter provides a mapping of companies, projects, universities and research institutes. Selection criteria's has been based on renewable materials from agriculture and rest products and this chapter corresponds to research question 1.

The main agricultural areas in the Nordic countries are in Denmark, in south of Sweden and a belt from southwest of Finland through central Sweden. The agriculture sector in the Nordics is characterised by the memberships in the European Union of the three most important agricultural countries in the Nordic region, are namely Denmark, Finland and Sweden. During several years there has been an on-going structural change in the agricultural industry towards bigger and less actors. See table below for statistics of the agricultural sector in the Nordic countries.[143]

Table 6.1 – *Statistics of agriculture sector in the Nordic countries year 2012.*

	Sweden	Norway	Denmark	Finland
Land area (million hectares)	45.0	32.4	4.3	33.8
Arable land & gardens (million hectares)	2.6	0.8	2.5	2.3
Arable land & gardens (as % of land area)	5.8 %	2.5 %	58.1 %	6.8 %
Grain production (as % of arable land)	38 %	29 %	60 %	49 %

Source: Nordic Council of Ministers. (2012) *Nordic statistical yearbook 2012.*

[143] Nordic Council of Ministers. (2012) *Nordic statistical yearbook.* http://www.scb.se/statistik/_publikationer/AA9999_2012A01_BR_A16BR1201.pdf

6.2 Sweden

Companies & Other Projects

Xylophane

Xylophane has developed a new barrier material for food packaging made from the natural polymer xylan created from waste products from agriculture such as grain husks. The material is a renewable biodegradable material and an efficient barrier against grease, aroma and oxygen and is built up by combination of bio-based polyethane and their own barrier material. Xylophane has been granted € 1.7 million from EU which supports to build a pilot plant for demonstrating the industrial applications. Product development is done in close collaboration with customers from the packaging industry.[144]

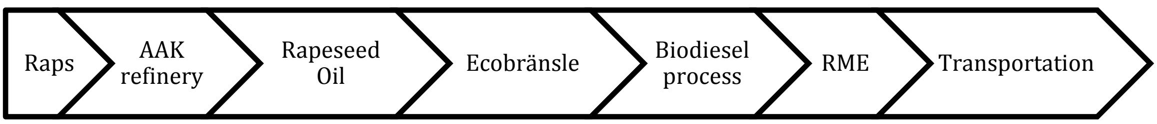
AAK

AAK refines vegetable oils from the plant kingdom as for instance raps, for specialized products and is a leading manufacturer of high value-added specialty vegetable fats. The products can be used as substitutes for butterfat and cocoa butter, trans-free solutions for fillings in chocolate and confectionary products, and in the cosmetics industry. AAK's parent company is AarhusKarlshamn and is headquartered in Malmö, Sweden.[145]

Ecobränsle

Ecobränsle most important product is pure RME sold to the transportation sector to be used in their trucks instead of using fossil diesel. The RME is made from rapeseed oil which is refined and pumped in from the AAK refinery to the Ecobränsle site before the biodiesel process starts. In Sweden approximately 90 per cent of all rapeseed oil come from AAK in Karlshamn and 60-70 per cent of this comes from the Skåne region in south of Sweden.[146]

Figure 6.1 – *Value chain of raps oil involving AAK and Ecobränsle.*



Source: Ecobränsle. (2013) *About us*.

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[144] Xylophane. (2013) *Press release renewable barrier material*. http://www.xylophane.com/wcm/documents/1.7_million_to_renewable_barrier_material.pdf
[145] AAK (2013). *Press Room*. http://www.aak.com/en/Press-room/
[146] Ecobränsle. (2013) *About us*. http://www.ecobransle.se/om-oss

Lidköping Biogas

Lidköping Biogas, opened in October 2012, is one of the first facilities in world that can produce liquid biogas. This is a joint project between the Swedish Biogas International Lidköping, Göteborg Energi and the Municipality of Lidköping. The facility is able to deliver renewable biofuels in form of liquid biogas to heavy vehicles and biogas to person cars, volumes equivalent to 60 GWh annually. The raw material used for the production is rest products from the local food industry and rest products from the local agricultural industry.[147]

Lantmännen

Lantmännen has an ethanol plant outside Norrköping and the plant is integrated with the neighbouring combined heat and power plant. As feedstock rest products from agriculture (wheat, rye, barley etc.) are used. Around 600 000 tonnes of grains are needed to produce 230 000 m^3 of ethanol every year.[148] The starch in the grain is broken down into sugars through add of water and enzymes. The sugars are fermented to ethanol by add of yeast.[149]

REAC Fuel

REAC Fuel has created a new and patented thermo-chemical technology platform, proven with high yields at the prototype scale, for processing lignocellulose biomass into sugars for use as feedstock for chemicals and liquid fuels. The lignin portion of the biomass contains sufficient energy for the thermal treatment and can be used as energy source for the process. They see hemp as an interesting feedstock for production of biofuels, since the hemp contains between 32-38 per cent cellulose and is robust, which makes it suitable for Nordic conditions.[150]

Biorefinery Öresund

In Anneberg, outside Landskrona the consortium Biorefinery Öresund wants to convert agricultural feedstocks to green chemicals. Examples of green chemicals they are evaluating are ethanol, butanol, and acryl acid, but they regard it to be necessary to also produce high value chemicals and not just bulk chemicals for being economically feasible. The consortium has a pilot plant for testing new concepts within biorefinery and received funding from EU, as a part of the Interreg-project. Lund Technical University, Denmark Technical University and Swedish University of Agricultural Sciences are some of the academic partners involved in the consortium project. Perstorp as well as Novozymes and Dansico are some of the members in the board for Biorefinery Öresund.[151]

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[147] Lidköping Biogas. (2013) *Facts about the plant.* http://www.lidkopingbiogas.se/fakta-om-lidkoping-biogas/

[148] Lantmännen. (2013) *Agroetanol.* http://www.agroetanol.se/

[149] Lantmännen. (2013) *Biorefineries.* http://www.agroetanol.se/en/Biorefineries/

[150] REAC Fuel. (2013) *About technology.* http://www.reacfuel.com/technology.html

[151] Biorefinery Öresund. (2013) About the project. http://www.biorefinery-oresund.org/

Perstorp

Perstorp operates in the market of specialty chemicals and is owned by the European private equity company PAI partners. As today, 75 per cent of their products are based on oil or natural gas. They have a stated vision to incorporate more sustainable and renewable products in their value chain in the future. As a part for meeting that vision Perstorp are members in *Sustainable Chemistry 2030*. Perstorp are also involved in the project Forest Chemistry, as a part of Sustainable Chemistry 2030, were value chains from forest are evaluated, see chapter 4.2 for more info.

Further, Perstorp has Scandinavia's biggest production site for production of RME in Stenungsund from Swedish and European raps. They have launched a new biodiesel for Nordic climate made of 100 per cent RME and have improved quality, for example. winter and storage performance parameters, through a new patented process.[152]

Perstorp has a new green product line based on renewable raw material and energy called Voxtar, which shrinks the carbon footprint by 75 per cent compared to the fossil equivalent. This new product is marketed to customers as a way to decrease environmental impact, differentiate the offer and demonstrate their sustainability commitment.[153]

Sveprol Bio Production

Sveprol is situated outside Norrköping and works with collection of used fats and oils (Used Cooking Oil, UCO) and they collect UCO from all over Sweden. They are being supplied with raw material from for instance restaurants, fast-food chains and grocery industry. The UCO is converted to biodiesel and technical oils. When producing the biodiesel, alcohol of biological origin is added making the biodiesel 100 per cent biological. Another positive aspect of manufacturing biodiesel from UCO is that the raw material does not consist of palm or raps oil, and therefore does not compete with food production.[154]

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[152] Perstorp. (2013) *Launch of new biodiesel.* https://www.perstorp.com/en/Media/News/2012/20120529_Perstorp_lanserar_ny_biodiesel/

[153] Perstorp. (2013) *About Voxtar.* https://www.perstorp.com/en/Products/Coatings_and_Resins/Liquid_alkyd_and_polyester_resins/About_Voxtar

[154] Sveprol Bio Production. (2013) http://www.mbpgroup.eu/content/sveprol-bio-production-ab-0

Universities

At *Lund University* a project called *GreenChem* lasted 2003-2010 and was funded by Mistra. Products evaluated in the project were for instance epoxides, acrylates, alkyl glycosides, alkanolamides and cyclic carbonates and example of participating companies were IKEA, Perstorp, AAK, AkzoNobel and AstraZeneca.[155] *Swedish University of Agricultural Sciences, SLU,* presented their strategy for 2013-2016 and there is a clear focus on how they can contribute to a sustainable bio-based economy. By use of biological raw materials to replace fossil raw materials in terms of biofuels processes, green chemicals and plant-based production of technical oils.[156]

6.3 Norway

Companies & Projects

Uniol

Uniol produces biodiesel which has green-house gas emission reduction potential of at least 55 per cent compared to fossil diesel. In the future, Uniol will be producing biodiesel based on multi feedstock technology. This implies a broader range of possibilities with regard to feedstock alternatives, for example different blends of vegetable oil, in addition to animal fat and used cooking oil. The biodiesel is transformed from vegetable oil to a so called methyl esther by adding 10 per cent methanol.[157]

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155 Lund University GreenChem. (2013) *Final report GreenChem.* http://www.greenchem.lu.se/fileadmin/greenchem/Filer/Interna_sidor/Reports/Greenchem_Final_report_foer_mejl.pdf

156 Swedish University of Agricultural Sciences SLU. (2013) *SLU Strategy 2013-2016.* http://www.slu.se/Documents/externwebben/overgripande-slu-dokument/om-slu dok/2012/slu-strategi-2013-2016-web-eng.pdf

157 Uniol. (2013) *Product Biodiesel.* http://uniol.no/product.html

6.4 Finland

St1

St1 thinks that one way to reach fossil free cars is to use ethanol as fuel. Their focus is primarily put on what is called ethical fine ethanol produced in the surrounding area. But they don't foresee that ethanol alone will solve the issue with fossil dependent cars, but as an important part in a mix of alternative fuels. St1 has a world patent on one method called Etanolix. This method can produce ethanol from waste from food industry, restaurants, and other waste stream and is named RE85 and produced in seven small plants in Finland. St1 plans to build similar plants in Sweden also utilising the same production technique. Ethanol has since long time been an alternative to gasoline, but the ethanol has been criticised due to production on land areas that could be used for food production, which is one underlying cause for why St1 has developed methods for producing sustainable ethanol from waste streams.[158]

Neste Oil

Neste Oil is the world's biggest producer of renewable diesel and renewable fuels from waste and residues. Neste is capable of producing renewable diesel on an industrial scale from more than 10 different feedstocks. Neste Oil has increased its use of waste- and residue-based renewable inputs by over 400 000 tons for refining into renewable fuels in 2012. A total of 742 000 tons of these raw materials were used compared to 330 000 tons in 2011. They increased their use of waste animal fat in particular last year and added waste fat from the fish processing industry to its feedstock base. Neste Oil used a total of 2.1 million tonnes of renewable inputs in 2012, of which palm oil accounted for 65 per cent, waste and residues for 35 per cent, and other vegetable oils under 0.5 per cent. Sources palm oil from Malaysia and Indonesia.[159]

Neste Oil produces and markets NExBTL renewable diesel based on Neste Oil's patented technology. NExBTL can be used in all modern diesel engines without any modification as such or blended with fossil diesel in various concentrations. Its use in a blend improves the technical qualities of the diesel and helps reduce emissions.[160]

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[158] St1. (2013) *Locally produced etanol.* http://www.st1.se/narproducerad-etanol

[159] Neste Oil. (2013) *News increased use of waste and residue based renewable input.* http://www.nesteoil.com/default.asp?path=1;41;540;1259;1260;20492;20697

[160] Neste Oil. (2013) *NExBTL renewable diesel.* http://www.nesteoil.com/default.asp?path=1;41;535;547;12335&voucher=0C845318-D00F-4409-BAA2-6021A44925CB

TransEco Development Program

The Finnish Ministry of Employment and Economy has supported the development of new biofuels for cars through the TransEco program, coordinated by VTT. Neste Oil and St1 are working together on a fuel project as part of the TransEco development program, which focuses on developing cost-efficient solutions tailored, that will enable the 20 per cent renewable target set for car fuel in 2020 as part of national climate goals. The majority of the funding for the project comes from the Ministry of Employment and the Economy, with the remainder accounted for VTT, Neste Oil and St1.[161]

Farm Energy Program 2010-2016

A national energy program for Finnish farms, drawn up by an expert group led by the Ministry of Agriculture and Forestry, was launched in January 2010. The program helps farms to reshape their energy use so as to reduce both costs and greenhouse gas emissions. This is a voluntary program and it encourages energy efficiency and the use of renewable energy sources. The aim with this program is to help Finland reach their national climate and energy targets.[162]

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[161] Nordic Council of Ministers. (2013) *Nordic Energy Solutions TransEco Development Program.* http://www.nordicenergysolutions.org/innovation/agencies-and-programmes/finnish/transeco-development-program

[162] Energy Efficency Agreements. (2013) *Farm Energy Program 2010-2016 for Finnish Farms.* http://www.energiatehokkuussopimukset.fi/en/agreement_sectors/farms/

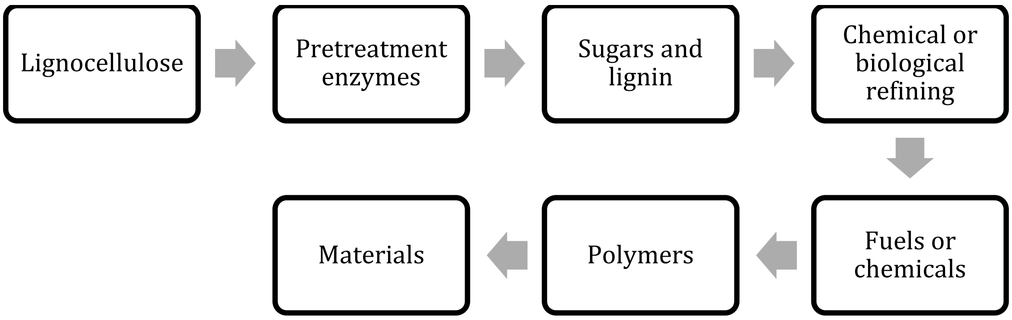
6.5 Denmark

Companies & Other Projects

Biorefining Alliance

In the Biorefining Alliance in Denmark it exist four main partners; DONG, HaldorTopsøe, Novozymes and Landbrug Fodevarer. They are the supporting 2nd generation biofuels and non-crop technologies. This alliance has been investigating several resources bases; agricultural, forestry, marine biomass and waste. They have different working groups for different areas: bioresources, biorefining, biofuels and bioproducts, and in each group both industrial and academic stakeholders are represented. One value chain they foresee can be seen in the figure below.[163]

Figure 6.2 – *One example of value chain the Biorefining Alliance foreseen.*



Source: Biorefining Alliance. (2013) *About the alliance*.

Novozymes

Novozymes has developed a robust microorganism that enables efficient production of bio-based malic acid. The technology makes it possible to produce plastic and other oil-derived products from renewable raw materials.[164] Bio-based malic acid can be converted into chemical derivatives used for a variety of plastic, polymer and resin products. Novozymes has started licensing its technology to produce and commercialize malic acid and derivatives made from renewable materials.[165]

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163 Biorefining Alliance. (2013) *About the alliance.* http://www.biorefiningalliance.com/english/home.html

164 Novozymes. (2013) *Develops fungus to produce biochemicals.* http://novozymes.com/en/news/news-archive/Pages/Novozymes-develops-fungus-to-produce-biochemicals.aspx

165 Novozymes. (2013) *Paving the way for biochemicals.* http://www.biotimes.com/en/articles/2012/March/Pages/Paving-the-way-for-biochemicals.aspx

The annual global market for malic acid is around 60 000 tonnes and has a growth rate of 4 per cent annually. The need for a viable cost-effective solution for biofuels provides a challenge. Biofuels require high quality raw materials. Danish scientists want to develop a new technology that may optimize bio diesel production and at the same time reduce concern for the environment. Novozymes hope that use of enzymes will make it possible to use materials of a lesser quality as for instance animal fat, recycled restaurant oil and waste products.[166]

HaldorTopsøe

HaldorTopsøe is active in research and development, process design, engineering and catalyst production. Technologies and research activities are focused according to feedback from industrial practice. Their catalysts and processes are developed in close collaboration between research, engineering, and production. HaldorTopsøe has a multi-facetted business with a product portfolio spanning from catalysts to proprietary equipment, process design, engineering and service. HaldorTopsøe is a partner in the project BioDME together with Volvo, Preem and a couple of other stakeholders, in the project they are utilising black liquor to produce green DME.[167]

Emmelev

Emmelev produces biodiesel with raps as a resource base. It was a given investment to do for them when they decided to build the plant for refining the raps oil to biodiesel, since they can add more value by refining it to biodiesel.[168]

Lemvig Biogas

Lemvig has since 1992 been the biggest biogas facility in Denmark. Liquid manure from around 75 farming sites, waste and rest products from industrial production are used for heat and electricity production. They generate more than 21 million kWh annually from the produced biogas and are sold locally in the electricity market. The excess heat from the cooling system to the gas turbine exceeds 18 million kWh annually and is distributed to the local heating distributing system. Examples of Lemvig resources that they uses is; fish waste, slaughter rest products, food waste, beverages/alcohols, all organic material with high content of lipids, proteins or sugar.[169]

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[166] Chemicals Technology. (2013) *Novozymes develops new biochemicals technology.* http://www.chemicals-technology.com/news/newsnovozymes-develops-new-biochemicals-technology

[167] HaldorTopsøe. (2013) C*orporate profile.* http://www.topsoe.com/about_us/Corporate%20profile.aspx

[168] Emmelev. (2013) *Products biodiesel* http://www.emmelev.dk/produkter/biodiesel/

[169] Lemwig Biogas. (2013) *Renewable energy and sound economy.* http://lemvigbiogas.com/GB.htm

DONG

DONG, a Danish state owned energy company, has focus on biorefining and works with solutions that efficiently utilise biomass for energy purposes. They want to develop a biorefinery concept that converts biomass and waste to valuable fuels that will be able to replace fossil oil for example in plastics and chemicals.[170]

DONG is building a 2nd generation bioethanol demonstration plant in northern Zealand, Denmark. The plant should be operational 2014-2015 and this is a project done in collaboration with Novozymes and Maajbjerg Bioenergy. DONG plans to use the plant to turn straw and agricultural waste into fuels, and it will have a capacity to process 30 000 tonnes of straw annually. The straw will be converted to 5.4 million litres of bioethanol, 8250 tons of solid biofuel, and 11 100 tonnes of animal feed. For this process enzymes, water and yeast are used. Enzymes play a large part in the process of breaking down the raw materials into fuel and Novozymes has developed a test product that can be used in the DONG plant.

DONG is one of the co-founders of a Danish biorefining research platform and one of the aims is to develop sustainable fuel solutions for the shipping industry. Production of bioethanol is today added to petrol, which is sold from around 100 Statoil petrol stations in Denmark. Bioethanol can also be used instead of oil in many different products such as plastic and a whole range of chemicals.[171]

Daka

Daka uses agriculture by-products and animal lipids, i.e. slaughter rest products and fallen stock for producing various products. *Daka Proteins* produces protein and fat products as for example pet feed and fish feed.[172] Furthermore, *Daka Biodiesel* producing biodiesel and bio-heating oil. Biodiesel is a FAME produced through a reaction between an alcohol and an oil/fat from agriculture or animal resource and they built Denmark's first plant for 2nd generation biodiesel.[173]

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170 DONG Energy. (2013) *Utilising biomass.* http://www.dongenergy.com/en/innovation/utilising/pages/default.aspx

171 DONG Energy. (2013) *Innovation biorefining.* http://www.dongenergy.com/en/innovation/utilising/pages/biorefining.aspx

172 Daka Proteins. (2013) *Proteins.* http://www.dakaproteins.com/page316.asp

173 Daka Biodiesel. (2013) *Biodiesel.* http://www.dakabiodiesel.dk/page539.asp

Maabjerg Energy Concept

Maabjerg Energy Concept is a consortium of Novozymes, DONG, Vestforsyning, Struer Forsyning and Nomi. NIRAS holds the role as primary adviser and the biorefinery will be operating in Jutland from 2016 and will become the first of its kind in Denmark.[174] The biorefinery will consist of a new bioethanol plant based on straw and a new waste (resource) treatment plant. At the same time the existing biogas and biomass-fired heat and power plant are expanded. The new activities also mean that the energy and nutrients in collected household and industrial waste is used optimally. Further, the biorefinery is expected to have an annual output of approximately 73 million litres of bioethanol, 99 million m^3 of biogas from which 76 million m^3 of biogas will be cleaned and upgraded to 47 million m^3 of renewable gas (natural gas) as well as heating electricity to households.[175]

B21st - Biomass for the 21th Century

New technology aims at the markets for advanced processing and supply of biomass to fuels and chemicals. The budget for the whole project is € 15 million and lasts 2011-2016 and involved partners are Copenhagen University- LIFE, DTU, Møller-Mærsk, DONG, HaldorTopsøe, Novozymes and Man.[176]

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[174] Niras. (2013) *Denmark's first biorefinery is being built in Western Jutland.* http://www.niras.com/Current-Events/News/2012/Denmarks-first-biorefinery-is-being-built-in-western-Jutland.aspx

[175] Maabjerg Bioenergy. (2013) *How it works*. http://international.maabjerg-bioenergy.dk/how-it-works/

[176] The Danish National Advanced Technology Foundation. (2013) *Biomass for the 21th Century.* http://hoejteknologifonden.dk/en/project_gallery/project_gallery/biomass_for_the_21st_century_b21st/

6.6 Summary Agriculture

To summarise, in the Nordic region as a consequence of natural prerequisite outlined in the introduction to this chapter more activities are carried out in Denmark and Sweden compared to Finland and Norway.

A similarity between the Nordic countries is that all countries have companies operating within agricultural value chains for biofuels. In this area several well-established actors are active, for instance Lantmännen, AAK, and Neste Oil. An example of a value chain is the one towards RME from raps feedstock, and that value chain includes for instance AAK and Ecobränsle.

One example of a chemical company that are involved in value chains from agriculture is Perstorp. Today they have around 25 per cent of the product portfolio based on renewable materials and a stated vision to have more renewable products in their value chains in the future. As one way to market their renewable products their products are put forward to customers as a way to decrease environmental impact, differentiate their offer and demonstrate their sustainability commitment.

Moreover, what is worth to highlight is the recent establishment of collaborative projects focusing on biorefining concepts from agriculture biomass (*Biorefinery Öresund* and *Biorefining Alliance*). This is something that has been seen in Denmark and Sweden and involves large actors as for example Perstorp, Novozymes, DONG, and HaldorTopsøe. The focuses are broad in these projects and thus evaluating several value chains including chemicals, fuels and materials. One value chain the Biorefinery Alliance foreseen is how lignocellulose could with enzymes be broken down into sugars and lignin and through chemical or biological refining go into value chains of fuels and chemicals value chains for instance used as polymers in different materials.

Further, what more could be outlined is the pattern of increased utilisation of waste stream value chains and companies utilising those resources for producing biofuels and biogas. Some examples of companies in this waste refining segment are Neste Oil, St1, DONG and Daka. Waste streams include for instance slaughter rest products, restaurant waste, and food- and grain production waste.

In the table below a summary of renewable material from agriculture in the Nordic country can be seen.

Table 6.2 –*Summary of material from agriculture.*

Area	Sweden	Norway	Denmark	Finland
Biofuels	Lantmännen, AAK, Sveprol, Ecobränsle	Uniol	Emmelev, Biorefining Alliance, DONG, Daka, Maabjerg, Biomass for the 21th Century	Neste Oil, St1, TransEco Development Program
Materials	Xylophane		Biorefining Alliance	
Biochemicals	Perstorp, Biorefinery Öresund, Lund University		Biorefining Alliance, Biomass for the 21th Century	
Biogas	Lidköping Biogas		Lemwig Biogas, DONG, Maabjerg Energy Concept	

7. Institutional Aspects

This chapter outlines the institutional framework and aspects that affect the development of renewable materials and corresponds to research question 3. The chapter starts with European Union programs and directives supporting a bio-based economy. This is followed by initiatives in the Nordic Region taken by the Nordic Council of Ministers. After that the four Nordic countries individual efforts towards a bio-based economy are presented.

7.1 European Union

An increasing global population and climate change are two underlying factors forcing to radically change the approach on production, consumption, processing and disposal of resources. With a bio-based economy is meant sustainable production to enable increased use of biomass in the different sectors of society. This aims to reduce the carbon footprint and the use of fossil raw materials. The EU *Bio-Economy Communication Strategy* highlights bio-economy as a key to create a sustainable Europe. It can create economic growth, reduce dependency on fossil resources and improve the economic and environmental sustainability. However, the European economy relies heavily on fossil resources, making it exposed to insecure supplies and market volatility. EU has therefore highlighted the importance of a bio-economy to have a competitive region and to become a low carbon society, where resource efficient industries, bio-based products and bioenergy contribute to a sustainable growth.[177]

It is stated in the *Renewable Energy Directive, RED,* that biofuels should account for 10 per cent of energy content by 2020 and EU wants to cut greenhouse gas emissions by 20 per cent. RED favours 2nd generation biofuels that are produced from lignocellulose, waste and residuals and these are double counted when calculating renewable target. The directive requires EU member states to produce a proportion of energy consumption from renewable sources such that the EU as a whole shall obtain at least 20 per cent of total energy consumption from renewable energy by 2020.[178] Within EU 300 million of certificates of emissions will be sold to create a financial ground for investments in renewable energy. This initiative is called *NER300* and aims to finance more than 30 new production plants for renewable energy and 10 plants for Carbon Capture and Storage, CCS. 300 million certificates of emissions have a market value of € 4.5 billion approximately.[179]

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[177] European Commission. (2012) *Innovating for a sustainable growth. Bio economy Communication Strategy.* *http://ec.europa.eu/research/bioeconomy/pdf/bioeconomycommunicationstrategy_b5_brochure_web.pdf*

[178] European Parliament. (2009) *Promotion of the Use of Energy from Renewable Sources*. http://europa.eu/legislation_summaries/energy/renewable_energy/en0009_en.htm

[179] European Commission. (2013) *Low carbon technologies, NER300 Program.* http://ec.europa.eu/clima/policies/lowcarbon/ner300/index_en.htm

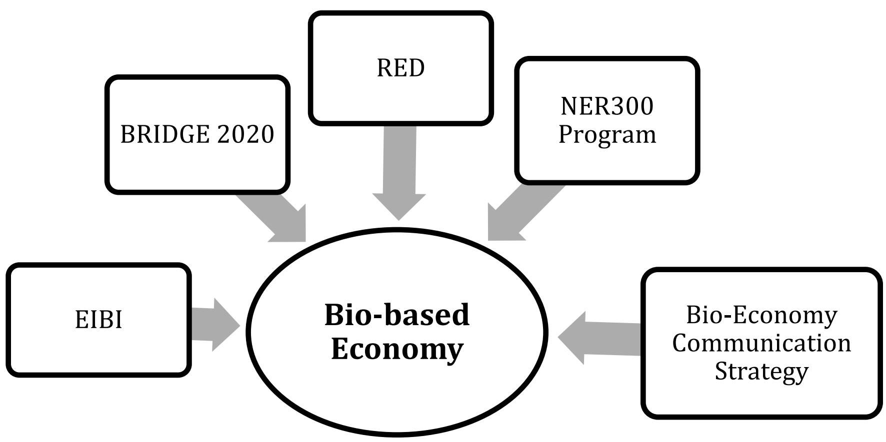
The objective with *BRIDGE 2020* is to favour innovation to deliver bio-based products that are better or at least comparable to fossil products in terms of price, performance, availability and environmental performance. BRIDGE will adress the entire value chain and will last between 2014-2020 and each of this value chains will have at least one flagship project. Companies will finance with € 2.8 billion and the European Commission with € 1 billion with focus on biorefineries. Within BRIDGE 2020 five different value chains are going to be evaluated;

1. From lignocellulose feedstock to advanced biofuels, bio-based chemicals and biomaterials
2. The next generation of forest-based value chains
3. The next generation agro-based value chains
4. Emergence of new value chains from organic waste
5. The integrated energy, pulp and chemicals biorefineries. [180]

The purpose of the *EIBI, European Industrial Bioenergy Initiative*, is to boost the contribution of sustainable bioenergy according to the RED directive. EIBI is focused on innovative bioenergy value chains not yet commercially viable and which can bring significant contribution to the bioenergy markets by large scale deployment. The main feedstocks evaluated are forest and agriculture residues, energy crops, black liquor, and the products in focus are diesel, naphtha, DME and methanol.[181]

All this initiatives on EU-level outlined above favours a development towards a bio-based economy and support the needed efforts. See figure below for a summary.

Figure 7.1– *Summary of some of the EU initiatives towards a bio-based economy.*



Source: Author's own illustration.

[180] BRIDGE2020. (2013) *About BRIDGE.* http://bridge2020.eu/about/
[181] European Industrial Bioenergy Initiative. (2013) *About EIBI.* http://www.biofuelstp.eu/eibi.html

7.2 Nordic Region

It is important to combine economic growth and more climate friendly development, hence issues concerning energy efficiency and renewable energy sources are important. In order to decrease the CO_2-emissions governance plays a central role.[182]

Nordic Council of Ministers is an inter-governmental co-operation between the Nordic countries and has taken a leading position on a European level in climate and energy issue in order to strengthen the Nordic countries competiveness. Protection of the environment is a top priority for the Council and one initiative in line with this is the *Nordic Ecolabel,* which guarantee certified environmentally friendly products. Through the Nordic Council of Ministers the Nordic region collaborate to meet the EU's climate goals, and demonstrate how sustainability and economic can be combined.[183]

NordForsk is an organization under the Nordic Council of Ministers that provides funding for Nordic research cooperation as well as advice and input on Nordic research policy. *Top-level Research Initiative* is the biggest research program in the Nordics so far within the areas of climate, energy and environment and was launched by the Nordic Prime ministers in 2008 and is supported by several national institutions and research councils.[184] One example of project that is carried out under this initiative is *The SusBioFuel* that aims leading to innovations in production technologies for conversion of lignocellulose biomass into 2nd generation bioethanol. These processes include pre-treatment, hydrolysis and fermentation. The project is a Nordic collaboration comprising participants from all Nordic countries and last 2011-2014.[185]

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[182] Nordregio. (2013) *How do global trends affect the Nordic countries.* http://www.nordregio.se/Events/Smart-sustainable-and-inclusive-regions/Introduction-to-articles/Ole-How-do-global-trends-affect-the-Nordic-countries1/

[183] Nordic Council of Ministers. (2013) *About the Council.* http://www.norden.org/en/nordic-council-of-ministers/the-nordic-council-of-ministers/why-the-nordic-council-of-ministers

[184] Nordforsk. (2013) *Green Growth in an era of climate change.* https://funding.nordforsk.org/nordforsk/call/call.jsp?cid=144

[185] Paper and Fibre Research Institute. (2013) *Biorefinery projects SusBioFuel.* http://www.pfi.no/Biorefinery/Biorefinery-Projects/SusBioFuel/

7.3 Sweden

Responsibilities for energy technology issues are shared by a number of key institutions in Sweden. The Ministry of Enterprise, Energy and Communication, the Ministry of Education and Research and the Ministry of the Environment are central players at the ministerial level, providing directions to institutions such as the Swedish Energy Agency, VINNOVA and Formas.[186] One example of target that has been set; Sweden's transportation sector should be completely independent from fossil fuels by 2030.[187]

In autumn 2012 the Swedish Government presented a research and innovation strategy to promote the development of a bio-based economy supported by a new research budget. The starting point is to analyse society and commercial needs to implement existing plans and ensure the growth of a bio-based economy that includes a national target of zero greenhouse gas emissions in 2050. Based on this the focus of research, development and innovation initiatives can be defined across value chain from production, refining and finally consumption. Some reasons why Sweden is likely to succeed have been identified; (1) the cultural background coming from a forest and farmer based civilisation living close to nature, (2) sound fiscal situation and can afford to invest in sustainable solutions, and (3) advantages in the ratio of land area to population size.

In the report *Swedish Research and Innovation Strategy for a bio-based Economy,* done by Formas, VINNOVA and the Swedish Energy Agency, the following four R&D focuses were identified that support Sweden towards a bio-based economy:

- *The replacement of fossil based raw material with bio-based materials.* Increased focus on production of materials from biomass and improved cultivation systems of forest through fertilisers optimising systems.
- *Smarter products and smarter use of raw materials.* Extended refining of biomass products. Waste and rest-products becomes new raw materials.
- *Change in consumption habits and attitudes.* Increased product lifetime and recycling. Transportation, distribution and storage parameters.
- *Prioritisation and choice of measures*. Consequences for the climate and conflict of objectives, policies steering the behaviour.[188]

[186] Nordic Council of Ministers. (2013) *Swedish research programmes.* http://www.nordicenergysolutions.org/innovation/agencies-and-programmes/swedish/swedish-research-programmes

[187] Nordic Council of Ministers. (2013) *Performance policy Sweden.* http://www.nordicenergysolutions.org/performance-policy/sweden

[188] Formas. (2012) *Swedish Research and Innovation Strategy for a bio-based Economy*.

The Swedish Energy Agency has three fuel programs on-going 2011 until 2015 with a budget of SEK 60 million. These funds will for instance finance two big pilot plants for black liquor gasification and one ethanol pilot plant. Further, the agency has decided to support ten biogas projects with in total SEK 67 million. The projects are first and foremost focused on pre-treatment of biomass, production of biogas and handling of rest products. In two of the projects, led by Sundsvall Energi respectively Scandinavian Biogas Fuels, biogas will be produced from forest residuals and the agency supports with SEK 18.9 million respectively SEK 10.4 million. The Government has since 2010 annually funded projects that supports market introduction of new technology and new solutions which strengthens the profitability of biogas production and contribution to an increased production volume.[189]

Formas is a Governmental research-funding agency related to the Ministry of Sustainable Development and invests almost SEK 1 billion every year on research at Swedish Universities. Formas brought forward a definition of a Swedish bio-based economy and presented a National research strategy for the period 2011-2016. In the strategy a bio-based economy is defined as an economy that works active for increasing the use of biomass within several different sectors in the society and to increase the refined value add from biomass. The purpose is to reduce environmental impact and the use of fossil resources and to optimize ecosystem. Formas funds research support a bio-based economy with SEK 30 million per year for 5 years, and which projects that gets support is to be announced 12th of June 2013.[190]

The Swedish Research Council is Sweden's largest funding agency and invests around SEK 5 billion annually in research at Swedish universities and institutes. They also functions as research-political advisers to the Government.[191]

Mistra is a foundation that supports environmentally friendly research that contributes to a sustainable society and invests annually around SEK 200 million within different research disciplines.[192]

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189 Mentor Online. (2013) *Biogas investments recivecs state funding.* http://www.mentoronline.se/iuware.aspx?pageid=3172&ssoid=164935

190 Formas. (2013) *Efforts towards a bio-based economy.* http://www.formas.se/PageFiles/7700/Anna%20Ledin%20och%20Karin%20Perhans%20-%20Formas.pdf

191 The Swedish Reseach Council. (2013) *Activities.* http://www.vr.se/inenglish/aboutus/activities.4.12fff4451215cbd83e4800021373.html

192 Mistra. (2013) *About Mistra.* http://www.mistra.org/om-mistra/om-mistra.html

The Stockholm Resilience Centre research on the governance of social-ecological systems and is a joint initiative between Stockholm University, the Stockholm Environment Institute and the Beijer International Institute of Ecological Economics at The Royal Swedish Academy of Sciences and is funded by Mistra.[193]

Stockholm Environment Institute, SEI, is an independent international research institute and is active in environment and development concerns at regional, national, and global policy levels. SEI was established in 1989 by the Swedish Government and has as goal to create sustainable development by linking science and policy, through providing analysis that supports decision makers.[194]

VINNOVA is a state agency for innovations and their task is to promote a sustainable growth by improving the conditions for innovations and to finance research that is motivated and requested. They invest annually approximately SEK 2 billion in different projects. VINNOVA has called for abstract defining important strategic research initiatives in the future and to create strong international competition capabilities within the field of sustainable solutions to the global challenges. Some initiatives worth mention, which have been granted funds from VINNOVA, are:

- *Blue Energy.* Will for instance evaluate marine cultivation for biofuel production. Led by Chalmers.
- *Sustainable Functional Textiles and Papers.* Wants to develop the textile and paper industry for how the structure in the industry can be changed and for prolonging their value chains. Led by Mid Sweden University.
- *New Processes for Bio-based Materials.* Wants to identify and describe efforts needed two create at least two new value chains with a turnover of at least SEK 500 million that could be commercialised within 3-5 years. Led by Innventia.
- *Green Agenda – Lignocellulose-based Products.* The goal is to identify the efforts needed to transform the pulp and paper industry to create biorefinery concepts. Led by SP.[195]

[193] Stockholm Resilience Center. (2013) *About SRC.* http://www.stockholmresilience.org/21/about-us.html
[194] Stockholm Environment Institute. (2013) *About SEI.* http://www.sei-international.org/about-sei
[195] VINNOVA. (2013) *Research agendas.* http://www.vinnova.se/foiagendor

The Swedish Bioenergy Association, Svebio, proclaims the potential for bioenergy utilization and they have in total around 300 member companies. The members are active in the whole value chain, from forest and agricultural, transport, trading and refining companies as well as final customers as kraft and power plants and industries.[196]

The Swedish Plastics & Chemicals Federation, P&K, is a branch organisation for plastic and chemical companies in Sweden and has 230 member companies who produce bulk chemicals, drugs, plastic raw material, glass, plastic products etc. P&K represents its member companies when they are in contact with the national authorities, Governmental departments and politicians. The member companies in P&K stands for approximately one fifth of Sweden's export and has in total 50 000 employees.[197]

The Federation of Swedish Farmers, LRF, is a branch organisation for the forest and agriculture industry. LRF believes that the base for a bio-based economy is political direction that gives long-term market conditions that remove uncertainty for investments. Incentives and political policies are needed to give a clear road direction for how the future will look like and what kind of energy sources that are going to be subsidised.[198]

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[196] The Swedish Bioenergy Association Svebio (2013) *About Svebio.* http://www.svebio.se/english/about-us

[197] The Swedish Plastics & Chemicals Federation. (2013) http://www.plastkemiforetagen.se/

[198] Formas. (2013) *LRF - The base for a bio-based economy.* http://www.formas.se/PageFiles/7700/Jan%20Eksv%c3%a4rd%20-%20LRF.pdf

7.4 Norway

Norway aims to become carbon neutral within 2030 through increased use of renewable energy, higher taxes on diesel and petrol, and tax exemptions for climate friendly vehicles. The Ministry of Petroleum and Energy is responsible for energy issues, while the Ministry of the Environment manage climate issues.[199]

Innovation Norway is the Governmental institution for innovation and development of companies and industries and the most important policy instrument and adviser in innovation policy. Innovation Norway has taken an initiative within bio-economy and provides funds to companies active in research for new applications and products from renewable bio-based materials.[200]

The Research Council of Norway is a strategic and funding agency for research activities and gives advice in research policy for the Norwegian Government and the overall research community. Further, the Council works to identify Norway's research needs and recommend national priorities to translate national research policy goals into action. In 2012 the Council's total budget was NOK 7 433 million.[201]

The Industrial Development Corporation of Norway, SIVA, is a Governmental organization and a national institution which ambitions to develop both regional and local industrial cluster through investment and knowledge networks as well as innovation centres. SIVA is co-owner in 80 innovation centres in Norway and has invested € 37 million in these innovation centres and has cooperation agreements between the Research Council of Norway and Innovation Norway.[202]

The Norwegian Bioenergy Association, NOBIA, has about 350 members along the value chain; forest owners, forest industry, producers of wood chips and wood pellets, equipment manufacturers, foreign companies selling bioenergy solutions, producers and distributors of thermal energy etc. NOBIO's main goal is a profitable production and distribution of bioenergy based on a significantly increased share of the energy market. NOBIO cooperate with Svebio, Danbio and Finbio and is a member of AEBIOM with office in Brussels.[203]

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[199] Nordic Council of Ministers. (2013) *Performance policy Norway*. http://www.nordicenergysolutions.org/performance-policy/norway

[200] Innovation Norway. (2013) *Financing bioeconomy.* http://www.innovasjonnorge.no/Finansiering/biookonomi/

[201] The Research Council of Norway. (2013) *Key figures.* http://www.forskningsradet.no/en/Key_figures/1138785841814

[202] The Industrial Development Corporation of Norway SIVA. (2013) *Summary of Siva efforts*. http://www.siva.no/sivabas/nyheter.nsf/nysivano/english%20summary

[203] Nordic council of Ministers. (2013) *The Norwegian Bioenergy Association.* http://www.nordicenergysolutions.org/solutions/bio-energy/industry-organisations/the-norwegian-bioenergy-association

7.5 Finland

Finland aims to increase the national share of renewable energy to 38 per cent in 2020, and to reduce overall energy consumption. Finland is one of the leading nations in the utilisation of bioenergy, often in combined heat and power plants Producers are guaranteed a minimum price for electricity from wind, biomass and biogas through feed in tariffs.[204]

The Finnish Funding Agency for Technology & Innovation, TEKES, is the main Government financing and expert organisation for research and technological development. Tekes participate in several research programs and projects and grants annually about € 600 million.[205] TEKES financed a program 2007-2012 called *BioRefine* that prioritised focus on sustainable, non-food competing, biomass feedstocks that offer clear advantages in reducing greenhouse gas emissions. In the program companies in the Finnish forest, energy and chemical industries pooled their knowledge to find ways to meet future energy and climate targets, by developing new products in their portfolio. VTT worked has a coordinator for the BioRefine project.[206]

The Finnish Innovation fund, Sitra, is a public fund reporting directly to the Finnish parliament and is guided by a vision of Finland as a leader in sustainability.[207] They consider bio-economy a promising sector with considerable future potential. However, the opportunities offered require changes in the society as a whole and Sitra argues that it must be understood that the future bio-economy is both global and local. Part of the production will be carried out locally, close to the raw materials and customers. This will minimise the need for transportation and promote efficient recycling of products. Special products and services will continue to be traded in the global market. The challenge for decision-makers will be to find the optimum combination of global and local activities. Sitra aims to increase understanding on the trends and the structures that make local businesses based on a sustainable bio-based material possible.[208]

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[204] Nordic Council of Ministers. (2013) *Performance policy Finland.* http://www.nordicenergysolutions.org/performance-policy/finland/finland

[205] TEKES. (2013) *Innovation funding.* http://www.tekes.fi/en/community/Innovation_funding/346/Innovation_funding/1238

[206] TEKES. (2013) *Sustainable production of new biomass based products.* http://www.tekes.fi/programmes/BioRefine/Current+topics/Sustainable+production+of+new+biomass-based+products?type=news

[207] The Finnish Innovation fund, Sitra. (2013) *About Sitra.* http://www.sitra.fi/en/about-sitra

[208] The Finnish Innovation fund, Sitra. (2013) *Bioeconomy.* http://www.sitra.fi/en/bioeconomy

The Academy of Finland finance scientific research and is an agency within the Ministry of Education, Science and Culture. The academy supports and facilitates researcher careers, internationalization and the application of research results. Funding research for approximately € 317 million in 2013 contributing to some 5 000 people's work at universities and research institutes.[209]

Research Institute of the Finnish Economy, ETLA is the leading private economic research organisation in Finland and they have analysed factors that foster innovation and facilitate adoption of new technology. Their research programs are engaged in, for instance labour market and education economics research, innovation research, economic policy research and economic growth.[210]

Finnish Business & Policy Forum, EVA, is a policy and discussion forum financed by the Finnish business community, and works as a networking arena for decision-makers both in business and society. EVA works in close co-operation with ETLA. EVA's task is to identify and evaluate trends that are important for Finnish companies and the society and aims to provide current information on trends to bring ideas to public debate.[211]

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[209] Academy of Finland. (2013) *About us.* http://www.aka.fi/en-GB/A/Academy-of-Finland/
[210] ETLA. (2013) *About ETLA.* http://www.etla.fi/en/etla/
[211] EVA. (2013). *Finnish Business and Policy Forum.* http://www.eva.fi/en/eva/

7.6 Denmark

In Denmark political objectives requires the supply of electricity and heat to be covered by renewable energy by 2035. Danish researchers have found that it would be better to support production of methanol and DME through gasification, instead of 2nd generation bioethanol since it becomes too expensive. The Danish Government listened to the researchers and immediately drew back all the support to 2nd generation bioethanol production.[212]

The Confederation of Danish Industry, DI, is a lobbying organisation for Danish businesses. DI regards that the energy market in the EU should be strengthened with a quota trading system as an important instrument and since investment in the energy area has long time perspective, EU needs already now prepare a 2030 framework according to DI.[213]

The Danish Council for Strategic Research was established in 2004 as an innovation council within the Danish funding system for research. The council seeks to ensure that strategic research in Denmark is organised to meet the challenges facing Danish society.[214]

The Danish Agency for Science, Technology & Innovation performs tasks relating to research and innovation policy. They offer support to research councils which allocate funds for strategic research and advise the political system. One important task for the agency is translating the political prioritisation of research and organising the interaction between government ministries, the research councils, universities and the industry.[215]

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[212] NyTeknik. (2012) *News Bioenergy, Denmarks bioethanol efforts.* http://www.nyteknik.se/nyheter/energi_miljo/bioenergi/article3402427.ece

[213] The Confederation of Danish Industry. (2013) *Europes energy and climate policy.* http://di.dk/English/News/Pages/NeedtorenewEuropesclimateandenergypolicy.aspx

[214] The Danish Council for Strategic Research. (2013) *About the Council.* http://fivu.dk/en/research-and-innovation/councils-and-commissions/the-danish-council-for-strategic-research/about-the-council

[215] The Danish Agency for Science, Technology and Innovation. (2013) *About the Council.* http://fivu.dk/en/the-minister-and-the-ministry/organisation/the-danish-agency-for-science-technology-and-innovation

7.7 Summary Institutional Aspects

To summarise, on EU-level several efforts have been taken which favours the development towards a bio-based economy and the *Bio-Economy Communication Strategy* highlights bio-economy as crucial to create a sustainable Europe. Moreover, the *RED directive* will drive demand for biofuels and especially 2nd generation biofuels that are produced from lignocellulose, waste and residuals since these fuels are double counted. Moreover, the *BRIDGE 2020* project aims to evaluate several new value chains with the objective to favour bio-based products and financing biorefinery projects. For instance, both forest and integrated pulp biorefineries are going to be evaluated which is of great interest for the Nordic region.

With this in background, the Nordic Council of Ministers has decided to be leading the conversion and take initiatives that favour a development towards a bio-based economy. The Nordic countries are far ahead and in the front of sustainable development in Europe, and pursue projects both on Nordic level and on a national level. Further, it is highlighted the importance to combine economic growth and a more climate friendly development. Governance is expected to play a central role in enabling these goals in the future. Much of the initiatives lie on the institutional level in the transformation towards a bio-based economy. However, companies will be the enablers and the market needs to steer this development in the long run, but institutional support will be needed in the beginning.

Examples of patterns that could be identified between the Nordic countries are that all the countries have taken an active stake in the conversion and set up ambitious targets that out-perform EU's general targets. For instance, Sweden's target with fossil free transportation sector by 2030, and Denmark's goal to cover heat and electricity with renewable energy sources by 2035. Moreover, a similarity between Sweden and Finland is that both countries have established national strategies for reaching a bio-based economy in the future, and the highlighted importance of having a sustainable society in the future.

Worth to highlight is the identified R&D focuses in the report *Swedish Research and Innovation Strategy for a bio-based Economy,* done by Formas, VINNOVA and the Swedish Energy Agency. In order to enable a bio-based economy fossil based materials must be replaced with bio-based materials. Further, the products needs to be 'smarter' and the use of raw materials must be done more efficient, which for instance could be accomplished through biorefinery concepts. What is also highlighted, not to be neglected, is the importance of change in consumption habits and prioritisation of choices.

The Nordic countries are organised in similar ways and institutions that correspond to the different areas of responsibilities in the Nordic countries can be seen in the table below.

Table 7.1– *Summary of institutional aspects.*

Area	Sweden	Norway	Finland	Denmark
Research Funding Agencies	Formas, VINNOVA, Swedish Energy Agency, Swedish Research Council	Innovation Norway, Research Council of Norway	TEKES, Sitra, Academy of Finland	Danish Agency for Science, Technology & Innovation
Research Councils & Institutes	Mistra, Stockholm Environmental Institute, Stockholm Resilience Centre	Innovation Norway, Research Council of Norway, SIVA	EVA, ETLA	Danish Council for Strategic Research, Danish Agency for Science, Technology & Innovation
Bio-Energy Organizations	Svebio	NOBIO	Finbio	Danbio

8. Analysis

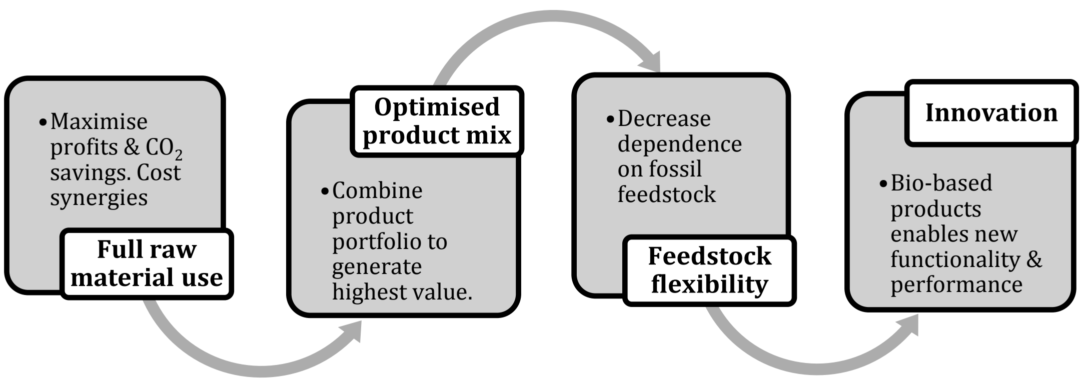
This chapter corresponds to research questions 3, namely; in what ways can the value chains be illustrated for the different renewable materials. Moreover, as a part of the thesis purpose, trends within the Nordic region for the different feedstocks are identified. The analysis is separated on which feedstock, but less consideration is put on the national origin since all Nordic countries are included in the same business centre at BASF, namely Europe North.

8.1 Value & Market Drivers

In the theoretical framework it was highlighted that firms have growing interest to create business strategies for addressing environmental problems. However, so far no simple relationships between firm's financial performance and environmental performance have been outlined. Firms may often be in a position to create value by addressing environmental problems, but often struggle to capture a large enough share of that value.

The chemical industry as such is a major contributor to Europe's economy and major sites and clusters have been developed over several decades. A multitude of products are derived and cascaded (serial usage) from basic oil components. Logistics and infrastructure have been and are core competences, and locations are normally superior. Thus, existing chemical clusters are excellent places to develop bio-based chemistry and novel production concepts at. Biomass has a higher underlying refined value, and thus can bio-based chemicals and material show out to be a very attractive alternative. Through full use of raw material the biomass resources can be more efficient used. Further, in a biorefinery approach you must be able to steer the process in order to create an optimised product mix. When including biomass feedstock the dependency on fossil fuels decrease and the flexibility increases. Through utilising biomass new products will be possible to create with new functionalities and performance enabling innovation possibilities. See figure below for an illustration of value drivers for renewable materials as been discussed in the text above.

Figure 8.1 – *Value drivers for renewable materials.*

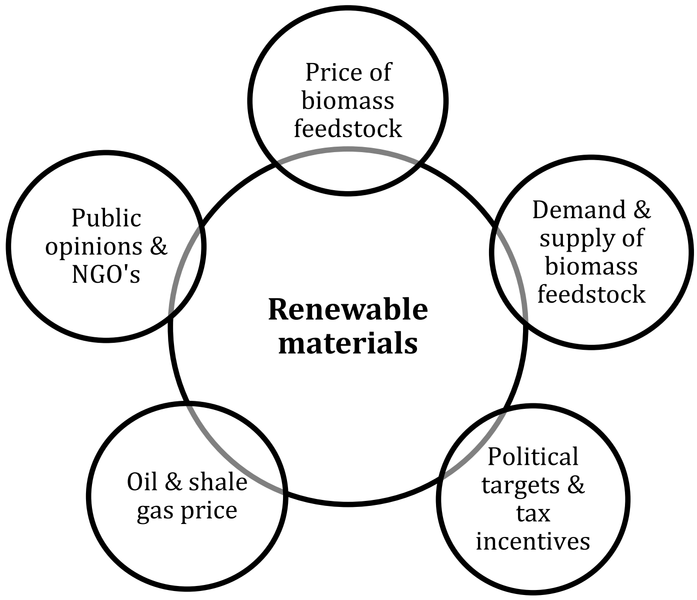


Source: Author's own illustration.

Moreover, several market trends can be identified, which drives the demand for renewable materials in the future. The consumer demand for environmentally friendly products increases and sustainability becomes more important, thus pushing for products including renewable materials. Further, the global population grows and the emerging economies demands increasing amounts of oil and other fossil based products that create a more competitive market for oil. Also to consider, which affect the market for renewables, will be the shale gas extraction in the U.S which could radically change the biomass competiveness in the near future.

The global issue of climate change and political targets and directives to reduce greenhouse gases impacts the market development. One example is the EU's Renewable Energy Directive, which proclaims an increased use of renewable energy. In the long run the demand and supply of biomass will be an important market driver which will affect the price development of biomass feedstock. The above mentioned market drivers can be seen in the figure below.

Figure 8.2 - *Market drivers for renewable materials.*



Source: Author's own illustration.

8.2 Forest Value Chains

Forest biomass offers some comparative advantages in comparison with other biomass feedstocks. First, forest is non-food competing which will be of great importance when the demand for food increases as the world's population grows. Moreover, large volumes are available, especially in the Nordic countries and there exist forestry infrastructure. There is a broad activity on the market and the interest for forest feedstocks are increasing. However, the performance ratio in comparison to the environmental and economic performance needs to be present, and it is not enough to just argue for the 'green' inherent value.

As outlined in chapter 4, private individuals own a majority of the forest feedstock in the Nordic region. This can become problematic in the future and have them to sell their assets on the market, and thus affecting the supply of biomass feedstock. Further, if more actors in the future involves in value chains of forest feedstock the competition between traditional forest industry, energy and chemistry will be fierce affects the price of forest feedstock.

One interesting similarity that can be highlighted is that Finland and Sweden both have a common strategy and a vision for the forest industry in the future. The Finnish Bioeconomy Cluster FIBIC's strategic target is to double the value of forest cluster products and services from the 2006 levels by 2030. The Swedish Forest Agency aims double the value by 2035 (*Vision 2035)* from SEK 50 billion to SEK 100 billion and half of that growth should come from new products. This gives clear indications what the forest industries, in the two biggest forest countries in the Nordic, are aiming towards, and how innovations will be necessary to accomplish this.

In the Nordics many large companies are seeing the original market within the pulp and paper industry diminishing and the downturn within mainly newspaper business. Hence an underlying pressure exists to find new markets and applications if not get stuck in useless facilities and equipment that has required large investments. The pulp and paper industry have great side streams that could be utilised into value chains of chemicals in the future and they have the existing production platforms that offers opportunities for industrial synergies. Through cluster collaboration it exist innovation and production possibilities to create competitive business landscapes for the future. To have profitable forest industry forest based chemicals will probably be needed if the business wants to survive. However, some obstacles exists that needs to be overcomed, for instance to have efficient extraction of surface chemicals, efficient separation techniques and new ways to produce small aromatic building blocks.

Sweden, Norway and Finland all have strong, broad and well-established research institutes and universities supporting the industry, in particular VTT in Finland, Innventia in Sweden and PFI in Norway. This is an important part in the development and their role to fill should not be neglected in the development of new value chains of forest-based feedstocks.

Interesting to notice in the Nordics is the shift in pulp mills towards the textile market with large actors as Domsjö Fabriker, Södra and StoraEnso have converted plants to produce dissolving pulp aimed for viscos and textile value chains. This is one example of how traditional pulp industries facing declining demand that opens up possibilities for developing new products for other value chains than their traditional. It is not unlikely that several pulp mills will follow after if it shows out to be profitable new market. Traditional cotton harvest can be very volatile from year to year and two major arguments that speak for a development of forest based textile; public opinion and water and chemical usage in traditional production. Further, increasing population drives the demand for clothes, and the cotton supply is expected to not be enough in the future. Also, the land area used for cotton production competes with arable land that could potentially be used for food production.

Further, opportunities exist within co-production of fossil and renewable materials as a method for green blending, for instance in value chains of biofuels. This could be regarded as one step on the way and by doing it in smaller fraction, product charteristics and technical processes could be evalutaed with considerable lower risk compared to a full renewable content. One succesful example of this is the tall oil from SunPine that goes into Preem's value chain of transportation diesel.

Moreover, lignin is a big part of the tree and large amounts of rest products containing lignin is produced in pulp mills. Through the LignoBoost technology, developed by Innventia and Chalmers, it is technical possible for pulp mills to refine the lignin to use it in new value chains. This is an area that recently has attracted interest from several actors in the Nordic region. If utilising the lignin the cost for carbon fibre could be lowered, hence making it economically feasible to go into value chains towards automobile industry. If lighter and bio-based materials could be used in cars great advantages could be obtained in terms of creating more sustainable and lighter car with less fuel consumption and thus lowering CO_2 emissions. Example of actors evaluating lignin for carbon fibre applications is for instance SCA, StoraEnso, VTT, Innventia and Chalmers. Furthermore, Micro Fibrillated Cellulose (MFC) is another interesting area that potentially offers new markets and applications. Several actors as for instance UPM, VTT and StoraEnso evaluate MFC.

The green bio-oil is another forest value chain that recently has given higher interest and large investments in pyrolysis plants have been made. One underlying driving force is that mainly forest residuals are utilized, and thus not competing with traditional forest value chains. In this stage the bio-oil is aimed to be used as industry oil for heat and energy purposes, but the future offers great market potentials if the bio-oil could be upgraded towards fuels for the maritime sector. That is because the bio-oil is sulphur free and an EU directive in place 2015 delimiting sulphur content to 0.1 per cent in maritime fuels which forces the industry to search for alternative fuels. Example of actors utilizing bio-oil is BillerudKorsnäs, Fortum and Green Fuel Nordic.

Sweden, Norway and Finland have broad-facility activities within the biofuel area with several actors on the market. Regarding the biogas market this is an area that is strong upcoming, with large investments in thermal gasification of forest residuals, for instance Göteborg Energi GoBiGas and Vaskiluodon Voima. The gasification technology aims both towards biofuels for the transportation sector, as well as biogas as a replacer of natural gas. In the figure below some of the identified trends in the Nordic region can be seen.

Figure 8.3 –*Examples of trends in Nordic region forest value chains.*

Conversions of pulp mills	•Decreasing demand for newsprint - need for new applications •Conversion of pulp lines towards dissolving pulp •Viscose for the textile market •Large actors; Domsjö Fabriker, Södra & StoraEnso
New materials	•Carbonfibres •Utilising rest product from pulp mills containing lignin •Lowering costs of carbonfibre •MFC - Micro Fibrilianted Cellulose, nanocellulose
Biofuel	•Pyrolysis of forest residuals - 'green bio-oil' •Replace fossil oil for energy purpose - lowering CO_2 emissions •Research towards upgrading to maritime fuel - sulphur free •Green blending - tall oil used blended in fossil diesel
Biogas	•Thermal gasification of forest residuals •Biofuels to cars and biogas as a replacer of natural gas •Large investments recently; GoBiGas & Vaskiluodon Voima

Source: Author's own illustration

8.3 Marine Biomass Value Chains

Marine biomass has potential as resource for several different areas, for example energy, chemicals, and ingredients for the food and feed industry. Algae's can be cultivated on unproductive land, and hence not compete with food value chains. Further, as one of the main advantages they capture carbon dioxide and uptake nitrogen and phosphor from the water. About 50 per cent of algae's weight is oil, which potentially could offer great opportunities in the future. However, 50 per cent is water and it is a challenging task to have effective separation processes.

The main focus in the Nordic region is towards biofuels and biogas by utilizing cultivated microalgae. But the challenge is to have the processes cost efficient enough. What more should be discussed is the weakness of researchers filling the gap to industry and have commercialized value chains, here the role of demonstration plants will have a central role the coming years. And also utilizing biorefinery approaches in order to differentiate the value streams and to have it economically feasible. Few companies have activities in commercial scale but some exceptions exist as AstaReal (antioxidants and colouring additive) and Simris Alg (omega-3) for example. Due to that fact of absence of commercialized projects it is hard to see the value chain relationships between different actors.

Furthermore, what has been noticed is that many projects are pursued in the Nordic region. But many projects are evaluating similar aspects or have similar project scopes. Thus better coordination and collaboration is needed a cross the Nordic region and intensified collective sharing of success stories for having a beneficial development in the future. In the figure below some of the identified trends in the Nordic region can be seen.

Figure 8.4 –*Examples of trends in Nordic region marine biomass value chains.*

Biofuel & biogas	•Mostly research projects in all Nordic countries •Many universities & research institutes active •Large companies involved; Neste Oil, Statoil & Wintershall
Food & feed	•Omega-3 fatty acids for both food and feed •Commercialized value chain Simris Alg - health nutrition •NTNU & CO_2BIO innovation network conducting research
Overlapping research	•Similar focus in research projects in the Nordic region •Cultivation conditions & evaluation of different algae species •Harvesting & upgrading techniques

Source: Author's own illustration.

8.4 Agriculture Value Chains

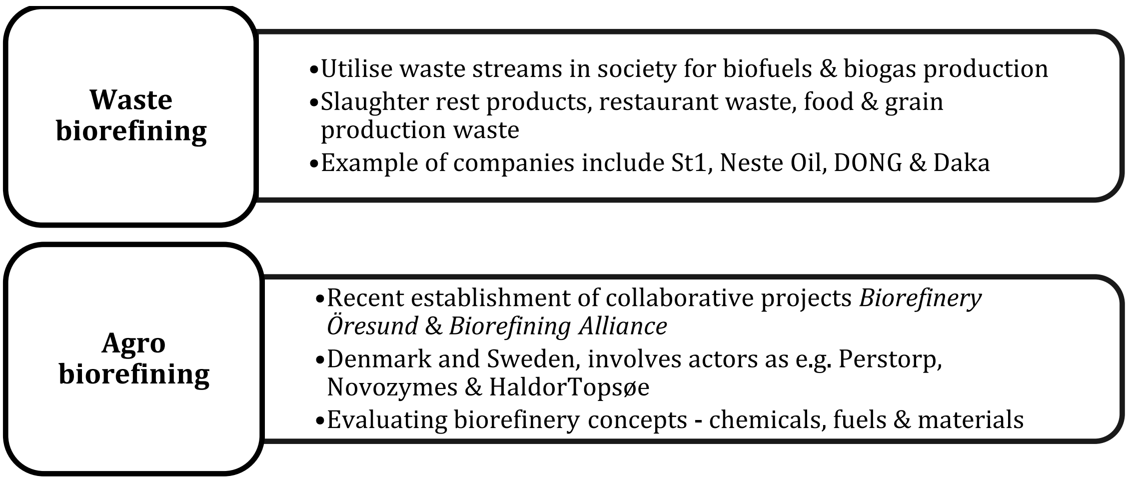
In the Nordic region, as a consequence of natural prerequisites, most activities are carried out in Denmark and Sweden. A similarity between all the Nordic countries is that all have companies operating within agricultural value chains for biofuels. In this area several well-established actors are active as for instance Lantmännen, AAK, and Neste Oil.

Moreover, a trend in the Nordic region is the increased use of waste from different parts of society, for instance restaurant oil and slaughter rest products. There is a great value in waste if it could be refined in the right way to the right products in value chains, towards for instance biofuels and biogas. Several actors have seen this opportunity and are exploiting it on a commercial scale, for example St1 and Neste Oil. Examples of waste streams include slaughter rest products, restaurant waste, and food- and grain production waste.

Furthermore, worth to highlight is the recent establishment and upstart of collaborative projects focusing on biorefining concepts from agriculture biomass (*Biorefinery Öresund* and *Biorefining Alliance*), which involves actors as for example Novozymes, DONG, and HaldorTopsøe. This is an interesting development that can shows out to have a large impact in future value creation within the agricultural sector and innovative market development.

One interesting example of a chemical company that are involved in value chains of renewable materials from agriculture is Perstorp. Today they has around 25 per cent of the product portfolio based on renewable materials and a stated vision to have more renewable products in their value chains in the future. As one way to market their renewable products their products are put forward to customers as a way to decrease environmental impact, differentiate their offer and demonstrate their sustainability commitment. In the figure below some of the identified trends in the Nordic region can be seen.

Figure 8.5 –*Examples of trends in Nordic region agriculture value chains.*



Source: Author's own illustration.

8.5 Institutional Aspects

As been outlined in the theoretical framework firms may often be in a position to create value by addressing environmental problems, but often struggle to capture a large enough share of that value. One reason can be explained by the concept of social dilemmas, i.e. situations when the rational short term interest of the individual is in conflict with the long term interest of the collective. As institutions exist at multiple levels companies may use leveraging and influencing strategies to be able to increase the share they capture of the value created by addressing environmental problems.

In Europe ambitious goal are set towards a bio-based economy and to accomplish this renewable material from biomass plays a central role. The value chain is built up of complex networks and many stakeholders are involved which affects the progress and market development in the future. Policies and political agendas are needed that enables and create stability for investments that create sustainable growth, and hence overcoming the 'social dilemma'. This could for instance be done through directed state owned venture capital funds or green procurement directives based on climate benefits. There must be a market pull to have a successful transformation towards a bio-based economy and green public procurement could potentially be one incentive to fill that role, which is under development at the moment. Furthermore, what more could increase the demand for renewable materials is through sustainability analysis of the whole value chain create certification of biomass products.

Moreover, one way to over-bridge the gap between academic research and industrial could be a clearer focus on research conducted for companies. This could practically be solved through researchers and professors having a 50 per cent position at a university and 50 per cent at a company. Further, important to get some early success stories were the whole value chain could be involved in order to show up a working value chain. Since implementation appears to be complicated, political incentives will probably play a large role in how the development will go.

What is interesting to mention is the representation of Nordic projects within renewable materials that have received finance from EU. Some examples of projects are:

- *Forest BtL* - Biodiesel and naphtha from forest biomass which has obtained financing from NER300
- *UPM* - Hydro treatment process of forest biomass towards value chains of biofuels, financed through NER300
- *BillerudKorsnäs* - Green bio-oil from forest residuals through pyrolysis, financing obtained from NER300
- *Göteborg Energi GoBiGas* – Thermal gasification of forest residuals, financing from NER300
- *Kalundborg Municipality* – Algae cultivation project for cleaning up industrial waste water
- *Biorefinery Öresund* – Agriculture biorefining towards fuels, chemicals and materials, financing from EU Interreg IVA Program

Nordic countries are innovative and are at a leading edge of thinking innovative ideas and have therefore attracted attention from the EU to support with financing. The Nordic countries take an active part in the development towards a bio-based economy and are active in search funds from EU. Therefore it should be highlighted that it is the Nordic countries which are active in fund search and that is why many investments are made in the Nordics. It is not the EU directing the Nordic, more the other way around.

It is political consensus in the Nordic region and a common will to lead the development. And the national governments and politicians are willing to support this development with financial supports. The base for a bio-based economy is political direction that gives long-term market conditions that remove uncertainty for investments. Incentives and political policies are needed to give a clear direction for how the future will look like and what kind of energy sources that will be subsidised.

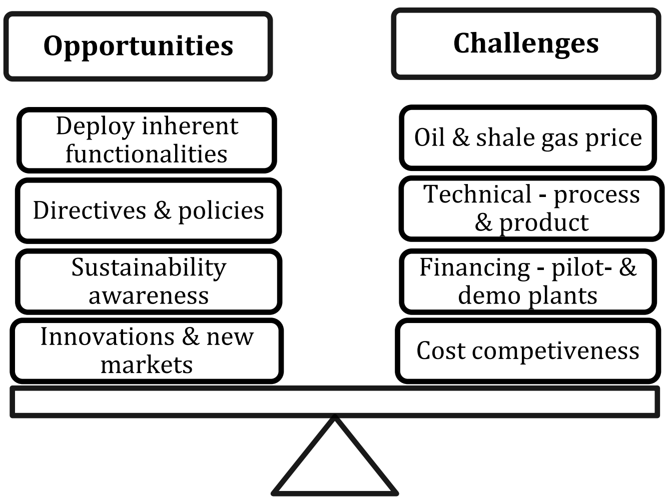
8.6 Outlook - Opportunities & Challenges

At the moment several actors and alliances are present to capture growth and profits offered by renewable materials. However, future combinations of players with different capabilities are still open and several trends earlier identified could require different future setup. In order to create the right alliances innovative business models will be needed, and entrepreneurship will play a central role for enabling the market development.

One challenge in the future will be competition from fossil resources and the exploitation of shale gas. Further, to overcome the technical obstacles related to process and product technology in order to have cost efficient processes. Plants for showing working concepts and complete value chains in large scale will be needed and one challenge related to this is the issue of financing. To replace fossil resources with biomass requires changes at both customers and suppliers side in the value chains. Sometimes the change process stops at the suppliers if they need to do investments and starts doubting if signals from the market are unclear and diverging. Several network clusters and collaborative projects aiming to combine the whole value chain and thus minimising the uncertainty in the development process and creating a better investment climate with less risk.

Even though several challenges have been identified above, many opportunities exist also. For instance, renewable materials have inherent functionalities that offer new innovative product opportunities and new market possibilities. Moreover, several directives and policies taken on EU-level as well as Nordic national level paving the way for an increased use of renewable materials. The awareness in the society, including both companies and individuals, for sustainability issues will drive the demand for sustainable products. See figure below for some of the opportunities and challenges.

Figure 8.6 – *Opportunities and challenges towards a bio-based economy.*



Source: Author's own illustration.

9. Conclusions & Strategic Recommendations

This chapter conclude the thesis and give strategic recommendations on the implications for BASF of identified trends. In order to take the right decisions in the future, market intelligence are needed which should be put forward in a transparent way in order to identify potential business opportunities.

The Nordic region needs to build on its existing strengths of green innovation and responsibility for the environment. Much of the focus for the future should be put on fostering a sustainable biomass supply and building new, innovative value chains. Further, process and product innovation should be prioritised and thus optimising efficient processing through R&D and up-scaling of biorefinery concepts. In terms of market development, optimised policy frameworks will be important for the future. There is a political will to reach a bio-economy and this development is supported by the national governments.

The development of renewable materials is still in an early phase and great opportunities exist in forming the value chains and direct the development in the future according to BASF's preferences. With respect to the different feedstock possibilities for producing renewable materials, several arguments speak in favour for forest feedstock. First, large volumes are present and as a consequence of natural prerequisites comparable advantages in terms of biomass volumes and population size exists. Moreover, the downturn in pulp and paper offers infrastructure which can be rebuilt into biorefineries and to produce other end-products than the traditional ones. Also, not to be neglected, the forest feedstock is non-food competing, which becomes more important with an increasing population.

Synergies when combining value chains exist. For instance in terms of integrating algae cultivation with power plant for cleaning of industrial waste water through uptake of carbon dioxide and nitrogen. The algae biomass could then be refined into oil and for instance biodiesel. Another example of synergies that could be obtained is through integrating lignin refining technology in an existing pulp mill for refining the black liquor to pure lignin. Moreover, pulp mills have large waste streams that today are used as internal fuel for energy purpose, but through right processes could be refined into green chemicals. If refining this waste streams synergies could be obtained. The production could be run as usually and at the same time refine the waste streams into higher value products.

Gasification of forest material is an area that has attracted more and more investments and interest recently, and within this area BASF has opportunities to sell gas cleaning chemicals which can show out to have a great market potential in the future with increasing volumes.

Within marine biomass algae offers potential towards omega-3 fatty acids which is in a commercialisation stage by the Swedish company Simris Alg and these activities are tracked by Pronova. If the process for utilising algae for omega-3 shows out to be commercial viable it opens up new production sources for omega-3 fatty acids.

The area of renewable materials should not be regarded as a threat to BASF traditional fossil chemical business. Instead, the market offers growth potential, since new innovative process will require new products matching the companies' processes. For BASF it is important to consider the future customer demand for renewable materials. Many businesses, as for example IKEA and SCA, converting their value chains and starts demand 100 per cent renewable materials in their value chains and hence pushing for more sustainable materials. Customer willingness to pay will be one challenge to manage. If the renewable products could be better in terms of performance parameters or if considering the total cost of ownership, they would become very competitive in the future.

The first part of the value chain is of particular interest in regard to the optimisation of new feedstock processing, for example with already existing chemical compound products. The middle part of the value chain is interesting regarding the development of new renewable chemical products or the implementation of existing products in new applications. BASF as a focused chemical converter can use its capabilities to expand bio-based intermediates within existing portfolio. Potential in the future exists through raw material integration via partnerships and create alliances where possibility to capture growth exists.

If renewable materials will have a market breakthrough human behaviour must change and successfully replace fossil products with bio-based. A sustainable thinking must have a natural place in all human minds, and BASF can enable this through its central role in many businesses. Primarily, a circular life cycle think needs to be applied, but the challenge will be how to implement it. One way could be to take responsibility for the products the entire life time, not just from 'cradle to grave', but further 'cradle to cradle'.

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Interviews

Academic Researchers

Name	Title	Institution	Date	Form
Hans Theliander	Professor Chemical Engineering	Chalmers University of Technology	19th of March	In person
Camilla Pettersson	Project Manager Blue Bio	Gothenburg University	12th of April	Telephone

Companies

Name	Title	Company	Date	Form
Camilla Rööst	Head of R&D	Södra Innovation	2nd of April	Telephone
Åsa Östlund	Program Director	SP, MISTRA Future Fashion	4th of April	Telephone
Åsa Burman	Project Manager GoBiGas	Göteborg Energi	15th of April	Telephone
Christian Kugge	Project Manager R&D Centre	SCA	15th of April	Telephone
Jörg Brücher	Project Manager Biorefinery	Holmen Energy	4th of April	Telephone
David Blomberg	Research Engineer	Processum	16th of April	Telephone
Anders Persson	Project Manager Strategic Development	BillerudKorsnäs	17th of April	Telephone

Appendix I - Interview Guide

The following interview guide has been used when conducting the open interviews.

Introduction & Background

- Tell shortly about yourself and your role.

Value Chains for Renewable Materials

- What are your thoughts regarding renewable materials value chains?
  - Biochemicals
  - Bioenergy and biofuels
  - Biomaterial and biofibers
- Where in the value chain are you at the moment, and where do you want to be?
- Which trends can you see?
- Where in the value chain are you positioned and how are you connected?

Institutional Aspects – Development of a Bio-based Economy

- How will the institutional aspects affect the development of renewable material and a bio-based economy?
  - Laws/rules, tax incentives and directives
  - Research programs

Outlook for the Future

- Which initiatives and projects are you pursing and planned in the future in the area of renewable raw materials?
- Where to you see the most promising market in the future?
- In your mind, how do you foresee the future value chains and the relationships between the value chains actors?