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Diffusion of Forest Biorefineries in Scandinavia, North America and South America

N:o 39 / 2009

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ISBN 978-951-39-3504-7
ISSN 1455-1578
Jyväskylä 2009

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DIFFUSION OF FOREST BIOREFINERIES IN SCANDINAVIA, NORTH AMERICA AND SOUTH AMERICA

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JYVÄSKYLÄN YLIOPISTO, TALOUSTIETEIDEN TIEDEKUNTA

2009

UNIVERSITY OF JYVÄSKYLÄ

PREFACE

This project started to shape during the year 2007. At that time, there were already many biorefinery research projects going on or starting, but all of them were approaching the issue from technical point of view. From our perspective there was a need for more holistic approach; we decided to explore forest biorefineries as a business challenge which is connected to the whole society. We pursued to approach biorefineries as a new business opportunity at the level of single companies, but also at the level of the whole Finnish forest cluster. The leading thought was to incorporate international aspect to our project complementing the national perspective.

We were honored to work with and an excellent and professional management group: Pekka Rahkila, Andritz Ltd; Asko Ojaniemi, Benet Ltd; Timo Petäjä, Bio Fund Management Ltd; Petri Nyberg, Jyväskylä Innovation Ltd; and Jouko Yli-Kauppila, Metso Paper Ltd.

We are grateful to Tekes (Finnish Funding Agency for Technology and Innovation) for the financial support of the project. Also, we would like to thank Sami Kontola for his valuable effort in collecting the interview data in Brazil, and Sabrina Spatari and the late Professor Alex Farrell from Energy and Resources Group (UC Berkeley), who helped us in finding research contacts.

We hope that this study offers answers especially to the questions which were considered significant by our company partners. Also, we hope that the study serves the needs of many other interest groups by challenging the prevailing views of the development of biorefinery business and offering alternative scenarios for the future.

Berkeley 30.12.2008
Annukka Näyhä

Jyväskylä 30.12.2008
Sari Hämäläinen and Hanna-Leena Pesonen

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1 BACKGROUND

There is a large interest to promote biomass-based energy sources because of the global warming. Especially lignocellulosic, nonfood biomass feedstocks and technologies for converting these feedstocks into economical, low-carbon biofuels are widely studied at the moment. Decreasing of easily exploitable oil reserves at the same time as the usage of oil is rapidly increasing in many countries further increases interest towards biofuels. Even though in the last half of 2008 we have seen a rapid collapse in the price of oil, in the future strong pressure for price increase of oil is expected. In countries such as Finland, rich with biomass resources, biomass-based fuels can replace usage of expensive imported energy and improve current low national security of fuel supply.

One of the key goals of the European Union's energy and environment policy is to promote the utilization of renewable energy sources in order to reduce carbon dioxide emissions and to improve the security of fuel supply (EC 2005). The objective is to increase the share of renewable energy resources in the total energy consumption in the EU from 6 % to 12 % by 2010 (EC 2000). By the same year, the EU has committed to decrease greenhouse gas emissions by 8 % compared to the 1990 levels according to Kyoto Protocol. Consistent with this, G8 countries have negotiated about common climate goals and new climate agreement, pursuing the outcome of the deliberations by the end of 2009. G8 countries consider decreasing of greenhouse gas emissions by 50 % from 1990 levels by the year 2050. More recently, the European Union Commission published the 20-20 by 2020 package. This includes proposals for reducing the EU's greenhouse gas emissions by 20 % and increasing its proportion of final energy consumption from renewable sources to 20 %. The European Parliament adopted the EU climate change package in December 2008.

Both national security of energy supply and mitigating greenhouse gas emissions can be contributed by the same means; replacing fossil fuels by renewable energy sources. In Finland, the main renewable energy source is biomass, which can be utilized in heat and power production, as well as in transportation fuel production. From the Finnish perspective, forest industry offers attractive platforms for production of bioenergy. At the moment, forest industry is the largest bioenergy user and producer in Finland. Most of the bioenergy is generated from pulping liquors and solid wood biomass residues (Metsäteollisuus ry 2006). Forest industry's by-products, like bark, raw soap, saw dust and forest residues have a significant potential in bioenergy production also in the future (Helynen et al. 2003, Sipilä et al. 2005).

For decades, success of the Finnish forest sector has been based on increasing demand of forest-based products, availability of sustainable raw wood material, economic prices for energy, advanced forest industry technologies, efficient production machinery, and special status of the forest sector in the national economic policy. However, these elements, which have guaranteed the success of forest cluster, have largely disappeared nowadays.

(Seppälä 2000.) Because of the global competition, forest sector has started to relocate activities to new areas (Eastern Europe, South America, Asia), where production costs are lower, biomass resources are abundant, and demand for forest products are strongly increasing in the near future. Also other Scandinavian, likewise North American, forest companies are facing similar challenges.

In the Finnish forest cluster, the key in meeting these future challenges is to maintain current leadership in forest technology solutions. The lead cannot be maintained without continuous regeneration and innovations. (Niskanen 2005.) In the long term, vitality of the forest cluster has to be based on new investments, products, and business operations. Bioenergy and biomass-based products offer the greatest new possibilities for diversifying business operations and exporting technologies. (Hetemäki et al. 2006, Metsäneuvosto 2006.) Especially biorefineries, which can be integrated in the pulp and paper industry, seem to have a great potential in the future.

In principle, biofuels can be produced either by using thermochemical or biochemical conversion technologies. In Finland, production of biofuels by using a thermal syngas route, where solid biomass is gasified to Fischer-Tropsch liquids, is seen as the most promising option. These kinds of forest biorefineries have many synergy benefits, such as reasonably-priced residues are available on site, the existing wood procurement infrastructure and logistics of the forest industries can be used to full advantage, and the surplus energy generated in the gasification process can be utilized in paper mill. (McKeough & Saviharju 2005, Mäkinen et al. 2005, KTM 2006.)

There is plenty of ongoing lignocellulosic bioproduct research in the U.S., Canada, and Sweden (Hetemäki & Verkasalo 2006). In these countries, governments have also strongly invested in R&D. In the U.S., paper industry together with the Ministry of Energy and the Ministry of Agriculture, has started to develop manufacture of forest bio-products. (Agenda 2020 Technology Alliance, Mabee et al. 2005, Thorp 2005.) Department of Energy has announced 2007-2008 that it will invest $385 million for six large-scale biorefinery projects over the next four years and $114 million in four small-scale biorefinery projects over four years.

Successful implementation of biorefineries requires that challenges related to the biorefineries are neither seen as purely technical problems nor as issues, which are unconnected to the society. Diffusion of biorefineries, like diffusion of new technologies in general, is affected by several factors. Both research and development work (technology push) and activities, which encourage commercialization and implementation of new innovations (market pull), are needed. State policies and subsidizing mechanisms, collaboration between different actors, economic factors, organizational culture, and stakeholders' views influence the diffusion process. Also ecological aspects and sustainable exploitation of natural resources are significant issues, which influence success of new technologies. (Kruijsen 2002, Rennings 2000, Rogers 2003, Freeman 1996.) In order to promote biorefineries, information about economically efficient incentives and new business models is required. Effects of biorefineries

on national economy, raw wood markets and other forms of forest utilization should also be considered. (Hetemäki & Verkasalo 2006.)

Regeneration of the Finnish forest sector, as well as successful introduction of biorefineries and related new products and business models, requires information about global business environment besides national one. Knowledge of international business environment and research programs improves co-operation possibilities between countries, helps identification of own national strengths, and promotes integration of Finnish companies to abroad. From the Finnish perspective, collaboration with North America, which has advanced forest biorefinery R&D and similar structures and challenges in the forest industry, is especially important.

In this study, we pursue to contribute to these research and business challenges by exploring both the national and international factors, which have an effect on the success of forest biorefineries.

2 OBJECTIVES

This *research project aims to explore biorefinery concept and related new products and business opportunities in the forest cluster, as well as new business strategies and models of companies, which are part of the biorefinery value chain*. In this research, focus was on energy products of biorefineries, especially on liquid biofuels. The research explores economic, political, technological and ecological factors and collaboration between biorefinery value chain actors, which all can have an effect on the diffusion process of biorefineries and business operations. The changes in the business environment as well as new business competencies, leadership and strategic thinking needed in forest cluster companies are also studied. In addition, the role of the biorefineries on the forest cluster's competitiveness is explored. One of the key goals of the study is to identify competitive advantages based on which successful business operations can be built in the Finnish forest cluster.

In this study the factors, which contribute to the establishment and success of forest biorefineries, are compared between Scandinavia, North America and South America. The study concentrates on countries (Finland, Sweden, the U.S., Canada, Brazil), which have good preconditions for establishment of forest biorefineries, high quality research and development, similar structures in forest industry and abundant biomass resources.

Companies, which are part of the biorefinery value chain, can benefit from the results of the project in many ways when developing their business operations. The companies can use the results when they:

- Foresee changes in their business environment and pursue to allocate resources in successful way
- Identify strengths and weaknesses of their business operations

- Develop new business concepts and strengthen their business competences
- Build consortiums and networks with other partners in the biorefinery value chain
- Make decisions about new locations for their business operations
- Analyze competitive situation in the global markets

Overall, the aim of the research is not only to compare the factors, which contribute to the diffusion of forest biorefineries in the studied areas, but also to challenge the prevailing views of forest biorefineries as future business opportunities. Thus, the goal of the research is to bring new information, which is valuable for the companies related to the forest biorefinery value chain, as well as for political decision makers and academia.

As the outcome, alternative scenarios about the diffusion of forest biorefineries and related new business opportunities and concepts with their prerequisites, schedules and quantitative assessments will be presented.

3 METHODS

Data was collected in preliminary interviews and an internet survey. The interviews were conducted in Finland (5 interviews) and in the U.S. (5 interviews) in the beginning of the year 2008. The survey questionnaire was sent to 564 forest and bioenergy sector experts (researchers, company representatives, authorities) in North America, South America and Scandinavia in June 2008. Due to low response rate in the internet survey in South America, data was completed by interviewing 20 Brazilian experts in November 2008. The interviews in Brazil were conducted by using the same questionnaire as in the internet survey.

The prevailing views of biorefinery diffusion, which were gathered from the preliminary interviews, expertise of project steering group, and previous studies and literature, were used as background information when planning the questionnaire. The questionnaire consisted of five separate parts including following modules: *Background*, *Forest biorefinery diffusion*, *Feedstock & technologies*, *Scenarios*, and *Business models*.

The survey produced data, which is based on relatively large sample and could be analyzed by quantitative methods. 145 forest and bioenergy sector representatives responded the survey, so the response rate of 27 % was reached. Distribution of respondents by country and by sector is presented in Table 1. It should be noticed, that results presented in this report reflect the views of these selected bioenergy experts.

The data was analyzed by using SPSS statistical software. Following analyzes were conducted: frequencies, cross tabulation, Analysis of Variance (ANOVA), Kruskall-Wallis test, and Multivariate Analysis of Variance

(MANOVA). C*ross tabulation* displays the joint distribution of two or more variables. Crosstabs are usually presented as a contingency table in a matrix format. Whereas a frequency distribution provides the distribution of one variable, a contingency table describes the distribution of two or more variables simultaneously. *ANOVA* is a statistical technique used to determine whether samples from two or more groups come from populations with equal means. Like ANOVA, also *Kruskall-Wallis* test is used to test if population means are equal. However, Kruskall-Wallis is a non-parametric method and thus it does not assume a normal population, like the analogous ANOVA. Whereas ANOVA employs one dependent measure, *MANOVA* is a generalized form of ANOVA methods and covers cases where there is more than one (correlated) dependent variable and where the dependent variables cannot simply be combined. As well as identifying whether changes in the independent variables have a significant effect on the dependent variables, the technique also seeks to identify the interactions among the independent variables and the association among dependent variables, if any.

Analyzes were conducted both at single country level and by using the division between *North America*, *Scandinavia*, and *Brazil*. Grouping by the sector was done by using three different groups: *forest industry*, *researchers*, and *other*. MANOVA was conducted by using sum of variables for questions with multiple claims as well as by using single variables.

TABLE 1 Respondents by country and sector

	Finland	Sweden	U.S.	Canada	Brazil	**Total**
Car industry	1					**1**
Chemical industry	1	1				**2**
Energy industry	4		4	1		**9**
Forest industry	15	3	10	2	5	**35**
Investors	1	1				**2**
Oil industry	2		1			**3**
Public authorities	1		2			**3**
Research	22	10	15	5	12	**64**
Technology providers in the forest cluster	6	1	2			**9**
Other	9	2	1	2	3	**17**
Total	**62**	**18**	**35**	**10**	**20**	**145**

4 RESULTS

4.1 Drivers for Forest Biorefineries & Future Views

According to the respondents, *increasing price of oil is considered the greatest incentive for forest biorefineries and wood-based biofuels. Climate change, increasing demand for biofuels, and national security of fuel supply are also important drivers* for forest biorefineries. According to our results, climate change is a more important driver in Scandinavia and in Brazil than in the U.S. Correspondingly, national security of fuel supply is more important driver in the U.S. compared to the other countries. In addition, in Brazil encouraging international environmental and energy policies are considered an important driver for forest biorefineries. Considering the sectors of the respondents, the forest industry indicated climate change as less important incentive than the other sectors. Especially researchers highlight the importance of the national security of fuel supply.

According to the respondents, it is obvious that there is a *need for re-evaluation of wood utilization and the wood-refining chain from a fresh perspective in the forest cluster*. Forest biorefineries will be a way to avoid massive shutdown and loss of forest cluster facilities. The greatest consensus about the issue is found in North America, whereas most of the Brazilian respondents disagree with this. Considering the sectors, forest industry is the only group which does not fully agree with this view. However, in Scandinavia, especially in Finland, wood based biofuel production is more strongly regarded as a serious business opportunity for the forest cluster.

Respondents were asked to choose one of the four future views defined as *Business as usual*, *Restructuring the business*, *Sustainability*, and *Domestic competencies* (see Appendix 1, Module 4/5 for the detailed descriptions of the views), which would correspond to their impression of the future of the forest sector. *Sustainability* (41 %) and *Restructuring the business* (39 %) describe best the future development of the forest cluster, as 80 % of the respondents chose either of the two options.

In Brazil and in Scandinavia, *Sustainability* view gets more support compared to North America, as around 70 % of the Brazilian and 50 % of the Scandinavian respondents supported this view, whereas only around 20 % of the North Americans chose it. According to this future view, sustainability is the key issue in the financial decision making. The forest cluster is successful in a society, which respects ecological values and sustainable forest utilization. Production will be further developed towards energy and raw material efficiency. Biorefineries and related new energy products guarantee the forest cluster's success in a sustainable way.

According to *Restructuring the business* view, competitiveness of the national, traditional forest cluster disappears, and relying on old production

structures contains a high risk. Investments are aimed towards new markets and new business concepts. There is a strong interest and increasing amount of projects towards forest biorefinery concepts and new bioenergy products. In North America, where 51 % of the respondents chose this option, the view was more common compared to Brazil (15 %) and to Scandinavia (38 %).

4.2 Basic Scenarios for Biofuel Production in Forest Biorefineries

The *role of biorefineries in the forest cluster's competitiveness and biofuel production will remain insignificant for the next five years, but already in ten years the role will be significant*. In the U.S., the role of the forest biorefineries is evaluated as more significant in the near future compared to the other studied areas, especially to Brazil and Finland. However, in 20 years almost all the Brazilian respondents consider the role of forest biorefineries significant. In the other studied countries, 70-80 % of the respondents believe that the role of the forest biorefineries will be significant in 20 years.

In general, when compared to conventional or cellulosic agri-based biofuels, municipal waste-based biofuels, green electricity or hydrogen, wood-based biofuels have the greatest potential in compensating fossil fuels as liquid traffic fuel in the future according to the respondents. Brazil is the only exception; the Brazilian respondents think that conventional agri-based biofuels have the greatest potential in the future.

Wood-based biofuels produced in biorefineries will be mainly used in the domestic market, but in Finland also exporting of biofuels will have potential in the future.

In case there will be no radical changes in the business environment, liquid cellulosic biofuel production in the EU is estimated to be around four million tons in 2010, and around seven million tons in 2020 (Figure 1).

In the U.S., production of cellulosic biofuels is estimated to be 10 billion gallons (about 30 million tons) in 2022, if there will no radical changes in the business environment (Figure 2). Respectively, in Canada cellulosic biofuel production will be around five billion gallons (about 14 million tons) in 2022 (Figure 3).

In Brazil, production of cellulosic biofuels is estimated to be less than 20 million tons (7 billion gallons) in 2020.

The *production will take place mainly in the facilities integrated in a pulp mill or a pulp and paper mill integration*. In Brazil and in North America, minority of the production will also take place in facilities integrated in a sawmill or lumber industry. There is also some support for stand-alone facilities in North America. According to the respondents, *production capacity of the most biorefineries will be over 100.000 tons per year* in the studied areas, except in Canada, where most of the future facilities will have production capacity between 50.000 and 100.000 tons per year. Also the North American forest industry is more pessimistic

about this issue than the majority of the respondents, since they believe that most of the production will take place in biorefineries with a capacity of 50.000 to 100.000 tons per year.

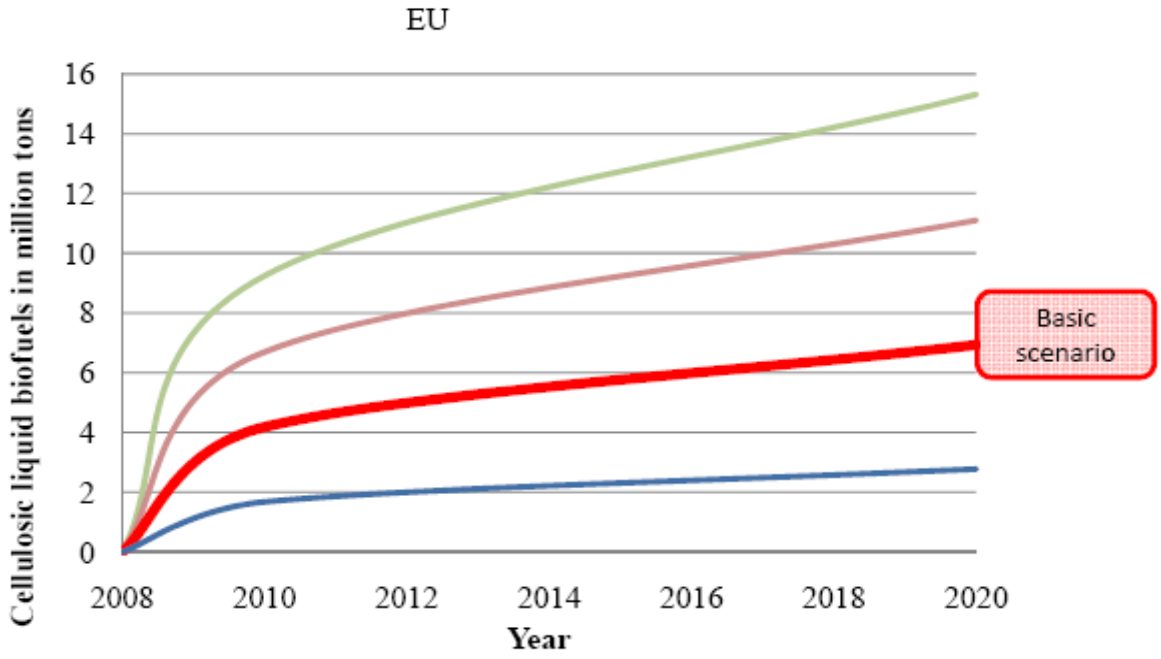

FIGURE 1 Basic scenario for liquid cellulosic biofuel production in the forest biorefineries in the EU. The other lines indicate the options presented to the respondents in the questionnaire.

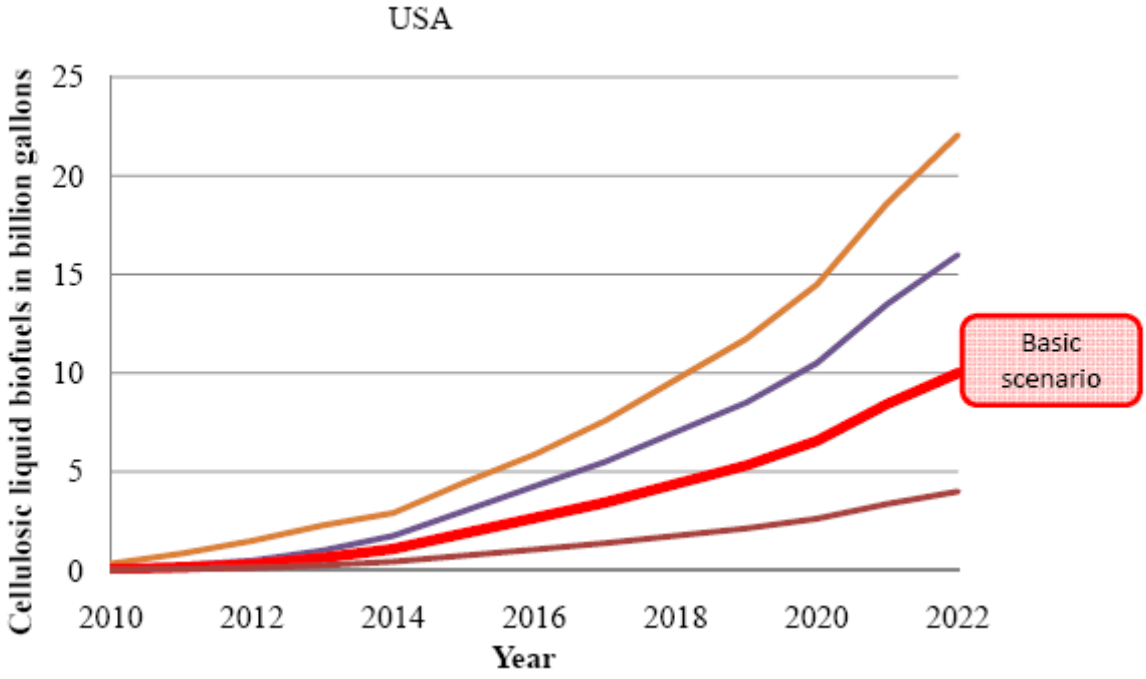

FIGURE 2 Basic scenario for liquid cellulosic biofuel production in the forest biorefineries in the U.S. The other lines indicate the options presented to respondents in the questionnaire.

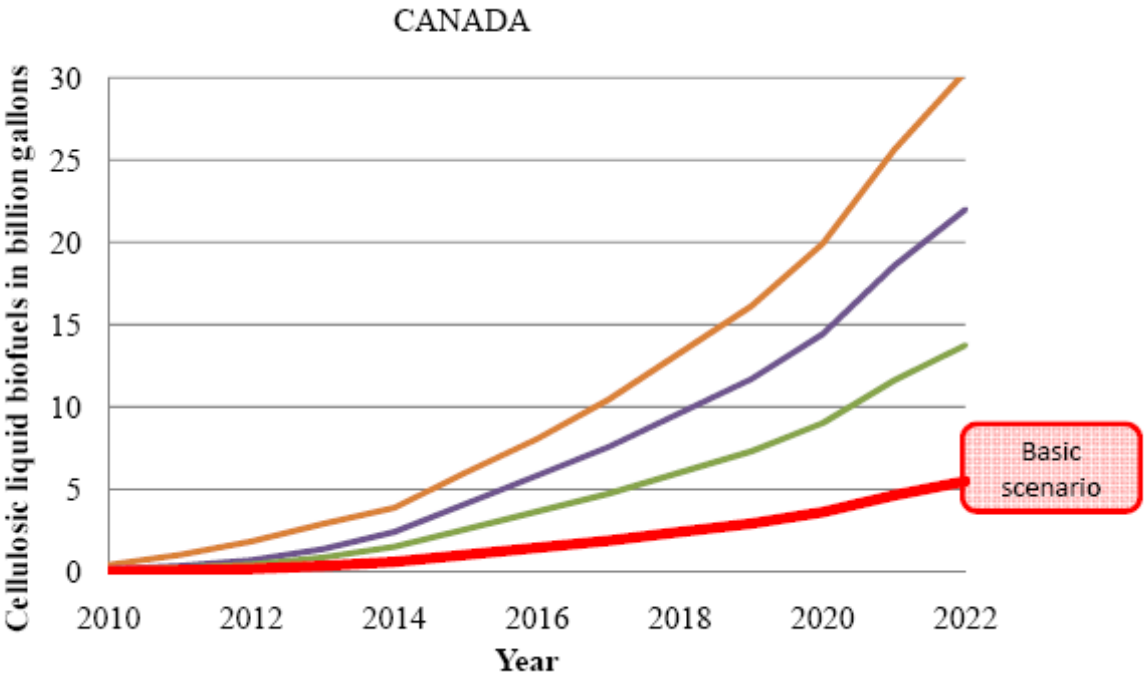

FIGURE 3 Basic scenario for liquid cellulosic biofuel production in the forest biorefineries in Canada. The other lines indicate the options presented to respondents in the questionnaire.

4.3 Products, Technologies & Raw Materials of Forest Biorefinery

In the future, there will be *two forest biorefinery products which probably have market potential: FT-diesel and ethanol for fuel*. 18 % of the respondents chose FT-diesel and 17 % of the respondents chose ethanol for fuel, when they were asked to select products with the greatest market potential of 15 different options. Considering biochemicals, polymers seem to have the greatest market potential in the future.

In North America and Brazil, the most important forest biorefinery product is ethanol for fuel. Respectively, FT-diesel is considered the most important product in Finland, and dimethyl ether has the greatest market potential in Sweden. Polymers divided respondents' opinions, since the Canadians consider polymers one of the most important product groups of forest biorefinery, whereas none of the Swedish respondents indicated polymers as a possible product.

Forest residues are the most significant wood-based biomass source in biofuel production in the future. Also, biomass from dedicated energy crops, black liquor from pulp industry, and urban organic waste are important wood-based biomass sources in the future. In this study, raw soap from pulp industry and tree oils got least support as significant wood-based biomass sources.

Biomass from dedicated energy crops has clearly stronger support in North America and Brazil than in Scandinavia. In Sweden, black liquor from

pulp industry was evaluated as the most significant biomass source. Urban organic waste has the strongest support in Finland. Besides already mentioned wood-based biomass sources, the Brazilian and the Canadian respondents consider lumber industry and sawmill residues as one of the most significant wood-based biomass sources in biofuel production. Also disease killed timber is supported in North America.

The greatest challenges related to the utilization of feedstock both in Scandinavia and in North America are logistics and transportation. The respondents also consider accessibility and competition for raw material significant challenges. In North America, public perceptions and environmental debate are regarded as greater challenges than in Scandinavia. Considering the sectors of the respondents, the researchers consider public perceptions a greater challenge than the respondents from other sectors.

In this study, timeframe for commercial scale implementation of the following technologies was studied: solid biomass gasification, black liquor gasification, fast pyrolysis, acid hydrolysis and fermentation, and enzymatic hydrolysis and fermentation. According to the respondents, *all these technologies will be implemented in less than five or 5-10 years. Solid biomass gasification and gas cleaning for synthesis applications will be commercialized first*. Implementation of enzymatic hydrolysis and fermentation will probably take more time than the implementation of other technologies.

Commercialization of solid biomass gasification will take place later in Brazil than in the U.S. and Finland. Implementation of enzymatic hydrolysis and fermentation will be faster in the U.S. than in other countries. Slightly over half of the Swedish respondents believe that black liquor gasification will be implemented in less than five years. Therefore, the implementation of black liquor gasification and gas cleaning for synthesis applications will be more rapid in Sweden than in other countries. Interestingly, the Finnish respondents are the most skeptical about the implementation of black liquor gasification.

When considering the sectors of the respondents, the researchers assess the implementation of fast pyrolysis to take place slower compared to the respondents from the other sectors. Also, forest industry in general seems to be more pessimistic about the implementation of black liquor gasification than the respondents from the other sectors. However, the Finnish forest industry believes in faster implementation of solid biomass gasification compared to the Swedish forest industry. Respectively, forest industry in Canada has faith in faster implementation of enzymatic hydrolysis compared to forest industries in the other countries.

According to this research, *the most important aspect when choosing production technology is that technology is able to accommodate a wide variety of feedstock. Production costs and capacity are also important issues* when considering production technology.

In North America, production capacity and technology able to accommodate a wide variety of feedstock are considered more important than in Scandinavia. On the other hand, the Scandinavians consider greenhouse gas emissions a more important factor than respondents in North America.

Researchers have chosen production costs as an important issue more commonly than forest industry. Researchers also consider the aspect that technology is able to accommodate a wide variety of feedstock more important than the respondents from the other sectors.

About third of the respondents foresee radical innovations in wood-based biofuel production in the near future. However, the Finnish respondents do not believe that there will be any radical innovations. Also the Brazilians are skeptical about this issue. According to the respondents, new innovations could be different kinds of separation technologies, especially extraction methods of hemicellulose and lignin. They could also be connected to biotechnology methods, such as new catalysts and enzymes.

4.4 Barriers & Prerequisites

In the survey, we analyzed factors which affect diffusion of forest biorefineries by presenting claims about economic, technological, political, ecological, raw material, and collaboration related issues in the questionnaire. Respondents could indicate their degree of agreement on a five-point scale.

4.4.1 Economic and Market Factors

The majority of the respondents evaluate that the *price competitiveness of wood-based biofuels is attractive in the current market situation*. Most of the respondents also think that wood-based biomass as a raw material is not too expensive for the production of biofuels. Thus it seems that the production costs of wood-based biofuels were not too high in the market situation by the time of the survey (June-July 2008).

According to this study, the *main economic barriers for forest biorefinery diffusion are insufficient public and private financing*. Over 50 % of the respondents think that public and private financing are not sufficient. Especially in Sweden, the lack of financing is highlighted. Also, over 60 % of the respondents consider support for demonstration and pilot plants inadequate. Inadequate investment capability of small and medium size companies is also an economic barrier for the forest biorefinery diffusion. Almost half of the respondents evaluate that SMEs are not capable to invest in the forest biorefineries. However, over 80 % of the respondents believe that large companies have investment capability. Investment capability of the large companies is questioned most in the U.S., where especially researchers stress the lack of investment capability. According to 80 % of the respondents, insecurity of biorefinery investments forms a significant barrier for forest biorefinery diffusion. Especially the American researchers agree with the issue. In addition, the Brazilian forest industry considers subsidies for production of biofuels more effective compared to the

subsidies for investments of new biorefinery facilities, whereas the Canadian forest industry strongly disagrees with this. In the other countries, forest industry has neutral opinion about the issue.

According to the forest industry, production of electricity for pulp and paper industry will be more profitable compared to the production of biofuels. On the contrary, the respondents from the other sectors believe that production of biofuels will be more profitable for pulp and paper industry. Thus, it is possible that this issue will become a barrier for the diffusion of forest biorefineries.

Overall, group "other" in Canada and researchers in the U.S. regard the economic and market factors more negatively than the other respondents. On the contrary, group "other" in Brazil, regards economic factors more positively compared to the other studied sectors.

4.4.2 Technological Factors

According to almost 60 % of the respondents, *technology will not become a barrier to biorefineries*. Instead, *lack of R&D expertise can create a barrier for diffusion of forest biorefineries*, since around 60 % of respondents think that the forest cluster has not enough R&D expertise to develop forest biorefineries. Especially in the U.S., lack of R&D is seen as a problem, whereas the Swedish respondents do not consider it a major barrier. It also seems that companies in the forest cluster cannot easily find consultancy for biorefineries. In addition, the variety of technical choices can be a barrier, because almost 80 % of the respondents believe that companies in the forest cluster are confused about the variety of technical combinations offered for the production of biofuels and chemicals. However, this does not seem to be a major problem for the Finnish respondents.

4.4.3 Political Factors

According to this study, there are *many political barriers for diffusion of the forest biorefineries*. Around 60 % of the respondents think that energy and environmental policies are not long-term and predictable. Unpredictable policies are considered a problem especially in the U.S. The majority of the respondents agree that there are political tensions between different parties about the industrial utilization of forests, especially in the U.S. and Canada. There are also inconsistencies between state (province) and national energy and environmental regulations in North America. In addition, the respondents in North America believe that strong political pressure towards agricultural-based biofuels hinders the forest biorefinery diffusion. Almost 90 % of all the respondents believe that politicians and other decision-makers have insufficient knowledge about the forest sector and forest management issues, which can also affect the diffusion of forest biorefineries.

Overall, the respondents in Scandinavia have the most positive attitude towards political factors, whereas the respondents in North America have the most negative reactions.

4.4.4 Ecological and Raw Material Related Factors

Most of the respondents think that *raw material demand of forest biorefineries cannot be satisfied solely with wood-based biomass*. Thus, there will be need for non-wood raw materials in forest biorefineries, e.g. agri-feedstocks. According to our results, the capability to collect and utilize existing wood biomass resources will be a limiting factor for the forest biorefinery diffusion, rather than the absolute amount of wood biomass. Almost 70 % of the respondents think that only wood biomass that cannot be used for higher value products should be utilized for biofuel production. In Scandinavia, there is a stronger consensus about the issue compared to North America. In addition, the forest industry, especially in Finland, strongly agrees with this.

Majority of the respondents believes that environmental impacts of collecting the wood biomass are not sufficiently known, which can hinder the forest biorefinery diffusion. Only forest industry disagrees with this.

According to this study, increasing public awareness about forest management issues and environmental aspects related to biorefineries promotes the diffusion of biorefineries. In addition, respondents are almost unanimous that wood-based biofuels produced in biorefineries will have a positive public response.

4.4.5 Collaboration

Almost half of the respondents think that the *forest industry companies are not willing to cooperate with other companies in the same industry* to develop forest biorefineries. However, according to the majority of the respondents, the *forest industry is willing to cooperate with companies outside the forest industry*. The respondents are almost unanimous that *forest industry is willing to cooperate with research institutes*. Interestingly, the respondents in North America indicate that the forest industry is not willing to cooperate with companies outside the forest industry, or research institutes either. Also, the petrochemical industry's willingness to cooperate with the forest industry in the production of wood-based traffic biofuels is questioned in the U.S. and in Brazil. Almost half of the respondents think that the forest industry is in contact with top experts of the sector worldwide. Especially the Brazilians agree with this.

Overall, North Americans have the most negative attitude, whereas Scandinavians have the most positive attitude towards issues concerning collaboration. Especially in Finland, attitudes are positive towards collaboration. When considering the sectors of the respondents, the researchers

have the most negative and forest industry the most positive attitude towards collaboration.

4.4.6 Prerequisites for Reaching the Political Goals for Liquid Biofuels

The respondents were given an opportunity to express their opinions about prerequisites for reaching the political goals concerning the production of liquid biofuels in their country (Directive 2003/30/EC, Government of Canada, Renewable Fuel Association) in the form of an open question. The most important issues for each country are discussed in this chapter.

In the U.S., respondents indicate that *public financing and development of technologies* are the most important prerequisites for actualizing the political goals concerning the production of liquid biofuels. The Americans also see that it is important to improve knowledge of politicians, public, and stakeholders in general about the environmental and social effects of various energy pathways. Some respondents consider high petroleum cost, consistent public policy, and collaboration between forest sector and oil and energy industries significant prerequisites for actualizing the political goals.

In Canada, the most important prerequisite for actualizing the political goals concerning the production of liquid biofuels is *investments in demonstration plants*. In addition, the Canadian respondents feel that forest management should be improved to increase feedstock availability. They also think that industry and government should focus their efforts and prioritize. Need for collaboration between forest sector and petrochemical sector is also mentioned.

In Finland, the most important prerequisite for actualizing the political goals concerning the production of liquid biofuels is *sufficient public and private financing*. Development and demonstration of technologies, and long-term predictable environmental policy and legislation are also considered important. The Finnish respondents also mention education of the politicians and the public, high oil and fuel prices, and political will to support the production of liquid biofuel as important drivers. Some respondents believe that there should be criteria for sustainability of biomass and its utilization. In addition the Finnish forest industry should prioritize and select competitive technologies, and there should be strong collaboration between forest industry and oil industry.

In Sweden, financing is the most important prerequisite for actualizing the political goals concerning the production of liquid biofuels. Another important issue is improvement of energy efficiency and production technologies in forest industry. Consensus about the political goals concerning production of liquid biofuels between society and industry, and mobilization of the many private forest owners through improved knowledge and profitability are also mentioned. In addition, the respondents think that high oil prices and acquiring better quality of feedstock would support the political goals.

Financing is the most important prerequisite for actualizing the political goals concerning the production of liquid biofuels also *in Brazil*. Other

frequently mentioned issues are development of technology and sustainability. There are also some respondents who believe that the price of oil is an important prerequisite.

In summary, the most important prerequisites for actualizing the political goals concerning the production of liquid biofuels are public and private financing, development and demonstration of technology, and collaboration between forest industry and oil industry. Other important prerequisites include education of politicians and public, high oil prices, and long-term predictable environmental policy and legislation. In addition, respondents in Canada, Finland and Sweden think that industry and government should focus their efforts and prioritize. Respondents in Brazil and Finland also consider sustainability an important issue.

4.5 Business models

According to 65 % of the respondents, existing infrastructure and permits in the forest cluster create significant competitive advantages for the forest cluster compared to other actors in the biorefinery business. Especially forest industry agrees with this. However, this study also indicates that large companies in the forest cluster concentrate on the optimization of the whole organization's business operations, and the possibilities of the single production units are not adequately recognized. According to this study, *wood-based biofuel and chemical production is considered a serious business opportunity in the forest cluster*. Especially in Finland, there is a strong belief in the production of biofuels. Only in the U.S., the respondents are slightly skeptical about production of wood-based biofuels. Overall, the business opportunities in the production of biochemicals divide respondents' opinions more than in the production of wood-based biofuels.

All studied countries trust in their own national strengths and their chance to be a leading actor in the forest biorefinery business worldwide. Only in Brazil, the respondents have some doubts about their potential to be a leading actor in this business. However, the Brazilian forest industry has strong faith in itself. In fact, they trust themselves more than forest industry in any other studied country. The Brazilian researchers and also the Canadian forest industry are skeptical about their country's potential role in the forest biorefinery business.

The respondents could also express their opinions about the national strengths and weaknesses of the forest cluster in their country related to the development of forest biorefineries. The most important issues concerning each country are discussed in this chapter. The most often mentioned strengths were biomass availability, raw material acquisition, transport and handling, technological know-how, and existing infrastructure. *All countries consider both availability of biomass and technological know-how their particular strengths.* The most often mentioned weaknesses were lack of R&D and innovations,

competition of raw material, lack of capital, and resistance to change. *The lack of R&D came up from the responds in all studied country.*

The most important strengths and weaknesses of each country are presented in Table 2.

TABLE 2 The most important strengths and weaknesses of the forest cluster related to the development of forest biorefineries.

	Brazil	**Canada**	**Finland**	**Sweden**	**U.S.**
Strengths	Forestry activities Know-how Collaboration between industries, research centers and technology providers	Availability of biomass Existing infrastructure Existing supply chain	Technological and chemical know-how Availability of biomass Raw material logistics	Knowledge of biomass handling Process expertise Existing infrastructure Technological leadership	The ability to harvest, transport and handle large amounts of wood biomass Availability of biomass Process engineering expertise
Weaknesses	Lack of R&D Competition of raw material Inflexibility of the pulp and paper sector Environmental sustainability	Lack of capital	Lack of public and private funding Low investment capability Resistance to change New business area and technologies outside the actual competence	Unwillingness to change from business as usual (inability to grasp the new possibilities)	Unwillingness to take risks Resistance to change (conservative industry) Lack of vision

According to the respondents, *the most important competences needed in the forest cluster/biorefineries are product and technological innovation, understanding of new markets, and business know-how*. Other important competencies are process expertise, management of wood supply chain, and consideration of long time perspective. Forest industry considers management of wood supply chain and process expertise more important competences in the forest cluster/biorefineries than other studied sectors. Issues like management of change, creation and management of networks, and ability to interact with and actively shape the environment are considered the least important. Respondents in Brazil consider ability to interact and actively shape the environment more important competence than the respondents from the other countries. The American respondents chose financial expertise more frequently than the other respondents.

Forest industry in Canada regards risk management skills as a more important competence in forest biorefineries than forest industry in other countries. Respectively, the North American researchers consider this

competence more important than researchers in the other countries. In addition, Scandinavian forest industry and the Brazilian researchers consider creation and management of networks more important competence than the other studied groups.

Production and collection of raw materials are the most challenging parts of the forest biorefinery supply chain to manage. Around 30 % of the respondents think that the most challenging part of the supply chain is production, and around 20 % that the most challenging part is collection of raw material. Considering the sectors, forest industry and researchers evaluate collection of raw material to be more challenging part of the forest biorefinery supply chain than the respondents from the other sectors. On the contrary, respondents from the other studied sectors consider production more challenging part of forest biorefinery supply chain than forest industry and researchers.

The respondents were asked to evaluate the significance of following partners in a forest biorefinery consortium: forest industry, technology providers in the forest cluster, energy industry, car industry, oil industry, chemical industry, and biotech industry. According to the results, *the most significant actors in the biorefinery business are forest industry and technology providers in the forest cluster*. The Swedish respondents also highlight the importance of the car industry, and the Brazilian respondents the biotech industry. The respondents consider forest industry as the most potential dominant actor in a forest biorefinery consortium, since 35 % of the respondents indicated forest industry, when they were asked which industry could be the dominant actor in the consortium. Other possible dominant actors in the forest biorefinery consortium are oil industry and energy industry.

According to our results, it seems that *issues relating to management and sharing of responsibilities in forest biorefinery consortia are difficult to foresee*. However, it is obvious that the forest biorefinery consortia will lead to a growing dependence on cooperation within the biorefinery value chain. There are also business opportunities for new actors in the forest biorefinery value chain. Almost 60 % of the respondents believe that forest biorefinery consortia offer small companies a possibility to enter new, larger markets. In forest biorefinery consortia tasks are divided in new way within the biorefinery value chain. The forest biorefinery consortia will also need new processes for strategy making and strong leadership. Especially the respondents from Brazil stress the importance of new processes for strategy making, whereas the Finnish respondents do not consider this as significant. The majority of the respondents also think that the dominant companies in the forest cluster are responsible for introducing and putting into practice new business ideas. Especially the Brazilians strongly agree with this.

Need for and ways of sharing of responsibilities, revenues, as well as synergy benefits between biorefinery value chain actors are difficult to foresee, because there were many respondents who had a neutral opinion about claims considering these issues.

According to almost 70 % of the respondents, the *forest biorefineries are sensitive to changes in the business environment*. Especially forest industry and

researchers agree with this. Most of the respondents also see that flexibility in production according to the market situation increases profitability of the forest biorefineries. The Brazilians strongly agree with both of the previous points. According to the respondents, acceptable level of ROI (return of investment) for the forest biorefineries is 10-15 %. In Scandinavia, acceptable level is lower than in other studied countries. Researchers seem to accept lower level (10 %) than respondents from other sectors (15 %).

5 CONCLUSIONS

5.1 Forest Biorefineries - Serious Global Business Opportunity

According to this study, biorefineries and related new energy products are considered a way to guarantee the forest cluster's success in a sustainable way. The majority of the respondents consider wood-based biofuels to have greatest market potential when compensating fossil fuels as liquid traffic fuel, only the Brazilians place more hope on conventional agri-based biofuels. In Scandinavia, especially in Finland, there is a strong consensus that production of biofuels is a serious business opportunity. In each studied country, own national strengths and the potential to have a leading role in the biofuel markets are strongly believed in. Based on the results it could be stated, that forest biorefinery business seems to have market potential, and global competition can be expected.

Even though the Scandinavians have more positive expectations about the business opportunities offered by the forest biorefineries, on the other hand, the North Americans expect biorefineries to play a significant role on their forest cluster's competitiveness within a shorter timescale. Also, in North America biorefineries are more strongly regarded as a way to avoid massive shutdowns and loss of forest cluster facilities. In North America, forest industry began to face similar challenges (decreased demand for forest industry products, increased production costs, offshore developments, shutdowns of pulp and paper mills) decade ago that the Finnish forest industry is facing at the moment. This is certainly one of the reasons why the North American forest industry highlights biorefineries as a way to avoid shutdowns of facilities.

According to this study, increasing price of oil is considered the most powerful global driver for forest biorefineries and new bioenergy products. The price competitiveness of wood-based biofuels was evaluated to be attractive by the respondents. Correspondingly, wood-based biomass as a raw material was not considered too expensive for the production of biofuels, and it seems that the production costs of wood-based biofuels are not too high. However, it has to be kept in mind that this reflects the market situation by the time of the survey. In June-July 2008, when the survey was conducted, the price of oil

peaked at almost $150/barrel, but has since then dropped down to less than $40/barrel by the end of December 2008. The global economic crisis currently at hand, which is also responsible for the dramatic price reduction of oil, might have some effect on the development of biorefineries by delaying temporarily efforts towards renewable energy sources in general. In the long run, however, the price of oil is expected to rise steadily, which will support the competitiveness of biofuels and biorefineries.

Besides the high price of oil creating a market opportunity for biofuels, other incentives towards biorefinery business differ slightly in the studied areas. In Scandinavia and Brazil, environmental aspects (climate change and sustainability) are emphasized, whereas in the U.S., national security of fuel supply and the competitiveness of forest cluster are highlighted.

One of the most interesting aspects rising from the results of this study is forest industry's reactions towards biorefineries, willingness to change, and above all, the rate of this change. It is obvious, that forest industry's attitudes towards the business potential of biorefineries and their willingness to take risks in investing into this new business will have a decisive impact on the diffusion process of the forest biorefineries. According to the forest industry, production of electricity for pulp and paper industry will be more profitable compared to the production of biofuels. In addition, large companies in the forest cluster seem to concentrate on the optimization of the whole organization's business operations, while the possibilities of single production units are not adequately recognized. These statements indicate a rather passive role of the forest cluster, while a more proactive attitude would be necessary for entering a new business.

Attitudes of the forest industry reflect some resistance for change, but it seems that unavoidable need for new business operations is widely recognized and admitted. Forest industry believes that traditional products like paper and cardboard have an important role also in the future, but besides the traditional business, also new business with new products such as wood-based biofuels are needed. Existing infrastructure and permits in the forest cluster create significant competitive advantages for the forest cluster compared to other actors, and the forest industry is evaluated to be the most significant actor in the biorefinery business. Also forest technology providers in the forest cluster will have a significant role.

Profitability of forest biorefineries and sensitivity of new business operations to changes in the business environment need to be carefully evaluated by the forest industry. Forest biorefineries are sensitive to changes in the business environment, and thus flexibility in production according to the market situation increases profitability of forest biorefineries. The accepted level of ROI (return of investment) for the forest biorefineries is according to the respondents 10-15 %, which is higher than traditionally in the forest industry. This probably indicates the higher level of risk associated with the new business and the uncertainty concerning its profitability. In Scandinavia, acceptable level of ROI is lower than in the other studied countries, which is consistent with the finding that the Scandinavians consider the production of biofuels a serious

business opportunity, and they therefore perceive the risks involved lower. When asked about the strengths and weaknesses about the forest sector in each country, the Americans indicated unwillingness to take risks as their most significant weakness, which is consistent with this finding.

Forest industry has positive attitude towards collaboration in developing biorefineries, and especially Scandinavian forest industry considers creation and management of networks an important competence. Attitudes towards collaboration are in general the most positive in Finland. Interestingly though, the forest industry companies are not willing to co-operate with other companies in the same industry to develop forest biorefineries. Also, forest industry's willingness to co-operate with research institutes, oil industry, and other companies outside the forest cluster is questioned in the U.S.

The most important competences needed in the forest cluster and biorefineries are product and technological innovation, understanding of new markets, and business know-how. Forest industry considers management of wood supply chain and process expertise more important competences than the other studied sectors. Issues such as management of change, creation and management of networks, and ability to interact with and actively shape the business environment are considered the least important. This is interesting, since these would be the crucial skills needed when entering a new business. All of these issues are so-called soft issues related to management and leadership, not technologies, and their importance is not often recognized. According to this study, the respondents do identify these issues at some level, but fail to see their true significance for the future of the forest cluster.

It seems that many challenges in external business environment for the diffusion of the forest biorefineries have been recognized, but issues related to management and leadership, as well as sharing of responsibilities, revenues and synergy benefits in biorefinery consortia are largely undefined. However, it is obvious that the forest biorefinery value chain will provide business opportunities for new actors, especially for small companies. Consortia will lead to a growing dependence on cooperation and new division of tasks within the biorefinery value chain. Thus, consortia will also need new processes for strategy making and strong leadership. Especially the Brazilians stress the importance of new processes for strategy making, but interestingly the Finnish respondents do not consider this as significant. The dominant companies in the forest cluster are responsible for introducing and putting into practice new business ideas, so whoever wishes to become the leader in biorefinery business, should carefully re-evaluate the practices in strategic planning.

5.2 Production Options and Business Models for Forest Biorefinery

According to this study, in North America and Brazil, the most important forest biorefinery product will be ethanol for fuel. Respectively, FT-diesel is considered the most important product in Finland, and dimethyl ether has the greatest market potential in Sweden. Considering biochemicals, polymers seem to have the greatest market potential.

Outlook for technical and raw material choices, as well as barriers and prerequisites for biorefinery diffusion are very similar in all the studied areas. The majority of production will take place in large-scale (capacity over 100.000 tons per year) biorefineries, which are integrated in pulp and paper industry. The respondents believe that all the studied technologies will be commercialized in less than ten years. Solid biomass gasification and gas cleaning for synthesis applications will be implemented first. It seems that the implementation of solid biomass gasification will take place later in Brazil than in the U.S. and Finland. The North American forest industry believes that also smaller scale facilities (capacity 50.000-100.000 tons per year) will be built. Outside Scandinavia, integration with sawmills or lumber industry, as well as stand alone facilities, are also considered possible.

Forest residues are considered the most significant wood-based biomass sources in biofuel production. Biomass from dedicated energy crops has clearly stronger support in North America and Brazil than in Scandinavia. In Sweden, black liquor from pulp industry is evaluated as the most significant biomass source. Urban organic waste has the strongest support in Finland. The Brazilian and the Canadian respondents consider lumber industry and sawmill residues one of the most significant wood-based biomass sources in biofuel production. Also disease killed timber is supported in North America.

When exploring natural conditions, available raw materials, and the history of production of biofuels, it is easy to understand that production of ethanol is highlighted in Brazil and North America. Biofuel production in Brazil is strongly based on sugarcane ethanol, which has been used there as a fuel since the 1970's. Respectively, in the U.S., corn-based ethanol is the main biofuel. In Finland, research of gasification technologies and production of FT-liquids started already in the early 1980's, which makes FT-diesel an obvious first choice for a biorefinery product. Sweden has long tradition in black liquor gasification research and production of related biofuels. One of the reasons for the greater interest in black liquor in Sweden compared to Finland is that there are also many stand-alone pulp mills in Sweden, meaning that there is no need for the surplus energy in paper facilities. In Finland, utilization of urban organic waste in energy production is actively discussed, and there would be room for new solutions, because incineration of waste is not as common as e.g. in Sweden. Therefore, it is understandable that utilization of waste is also seen as a possibility for the Finnish biorefineries.

The greatest challenges related to the utilization of feedstock for forest biorefineries both in Scandinavia and North America are logistics and transportation, though logistics is also mentioned as one of the most significant strengths in these areas. In North America, public perceptions and environmental debate are considered greater challenges for the diffusion of biorefineries than in Scandinavia. One of the reasons is that in North America, especially in the U.S., there is a strong ongoing political debate about forest management and utilization, and a balanced solution still needs to be found.

The most important aspect when choosing production technology for a forest biorefinery is that technology is able to accommodate a wide variety of feedstock. Thus it is understandable that solid biomass gasification, which is flexible with raw materials, got most support among the respondents of the survey. Production costs and capacity are also important issues when considering technology. In North America, production capacity and technology able to accommodate a wide variety of feedstock are considered more important than in Scandinavia. On the other hand, the Scandinavians consider greenhouse gas emissions a more important decision factor for forest biorefineries than the North Americans.

Third of the experts participating in the survey foresee radical innovations in wood-based biofuel production in the near future. Innovations are expected especially in new extraction methods of hemicellulose or lignin, and in development of new enzymes. Interestingly, the Finnish respondents do not believe that there will be any radical innovations in this sector. However, in the Finnish forest cluster, the key in meeting future challenges is to maintain current leadership in forest technology solutions. This lead cannot be maintained without continuous regeneration and innovations. Thereby, it is obvious that the Finnish forest cluster cannot afford the lack of innovativeness, if success in biorefinery business is wished to attain.

5.3 Best Case Scenarios for Biofuel Production in Forest Biorefineries

In chapter 4.2, we presented basic scenarios for liquid, cellulosic biofuel production in forest biorefineries assuming that there will be no radical changes in the business environment. Based on our results, we also outlined best case scenarios for each studied area, which are presented in Figures 4-6, and prerequisites for obtaining this development in the following Table 3. There is no figure available about the best case scenario for Brazil, but according to the results, production of liquid cellulosic biofuel in Brazilian forest biorefineries is estimated to be more than 25 million tons in 2020. Prerequisites promoting faster development of forest biorefineries and production of biofuels are very similar in all the studied areas.

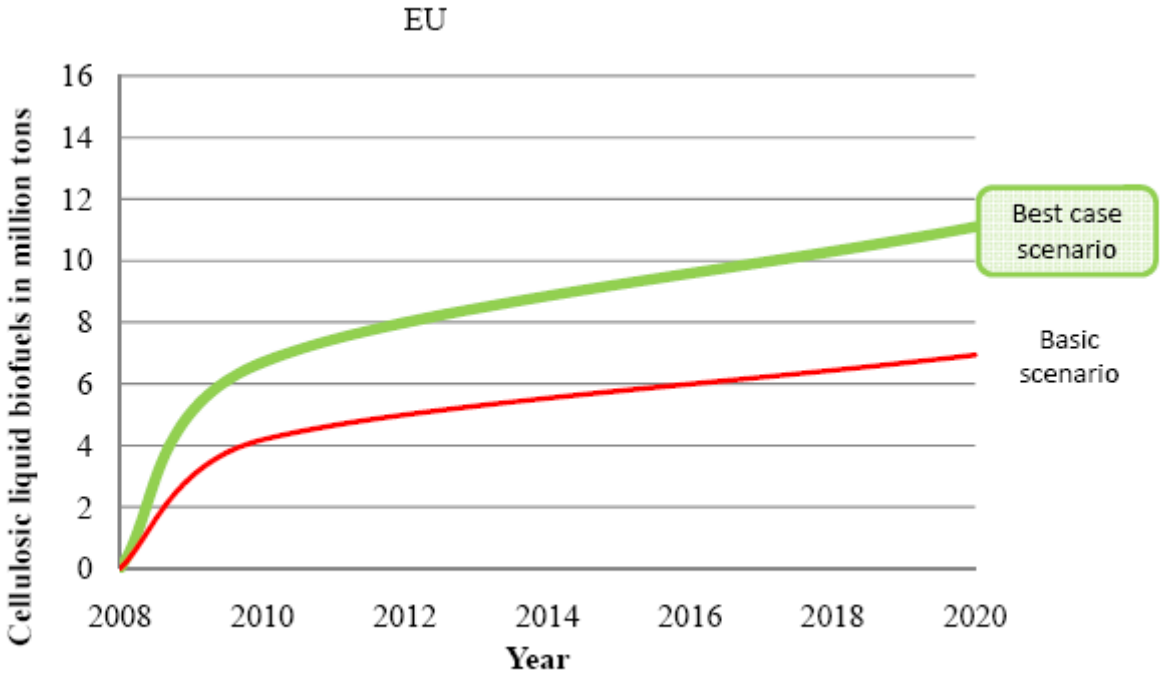

FIGURE 4 Best case scenario for liquid cellulosic biofuel production in the forest biorefineries in the EU

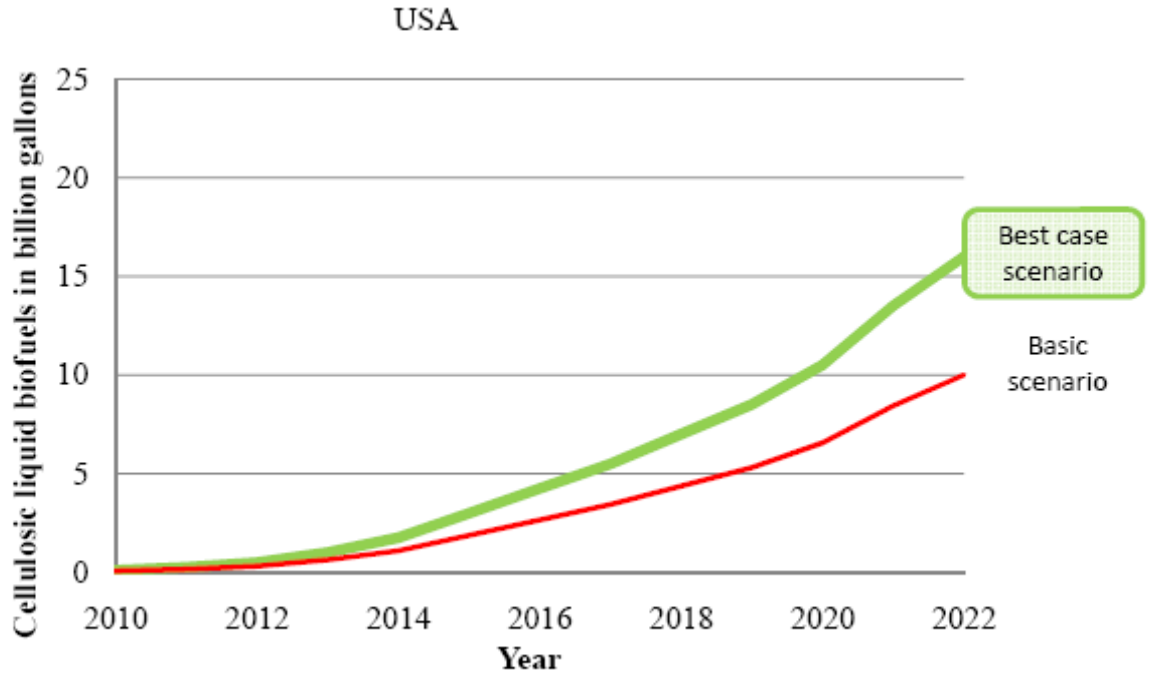

FIGURE 5 Best case scenario for liquid cellulosic biofuel production in the forest biorefineries in the U.S.

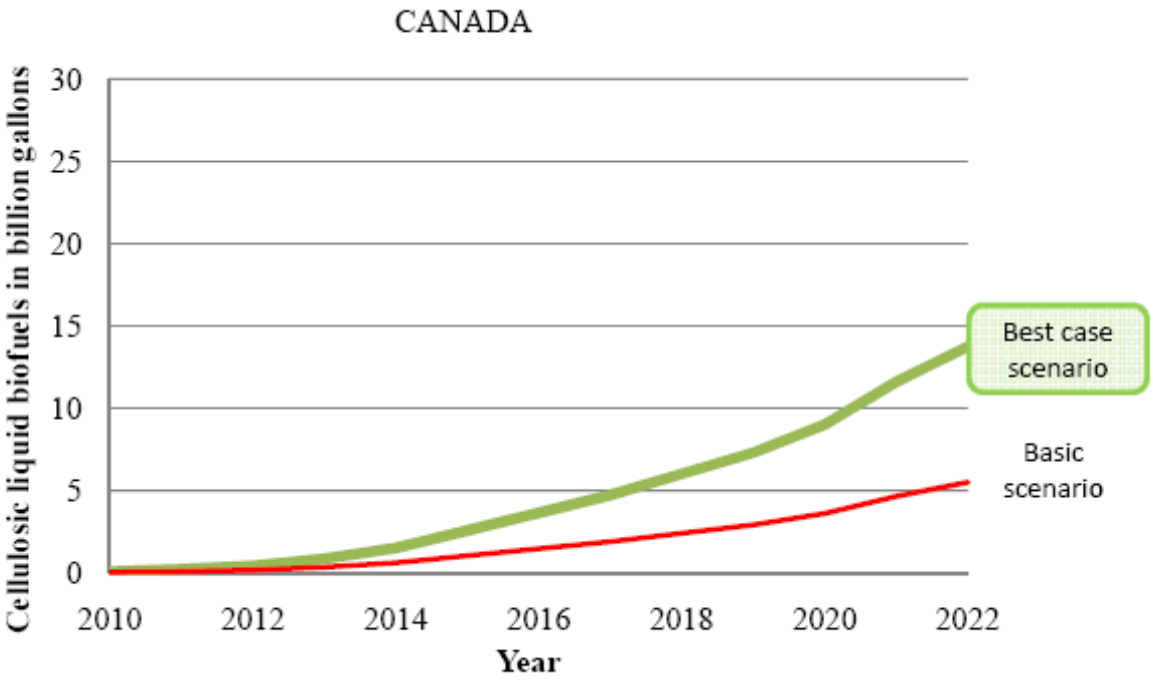

FIGURE 6 Best case scenario for liquid cellulosic biofuel production in the forest biorefineries in Canada

How will these prerequisites be implemented in practice, and what kind of challenges are related to these issues, are the questions which need to be answered in the future. What kind of strategic choices are needed that the success in biorefinery business can be attained? Which sectors will be successful? Which countries will be the winners and which the losers of the biorefinery business? Giving a straightforward answer to the above mentioned questions is very difficult.

There is a strong belief in the potential global leadership in biorefinery business in every studied country. The strengths of the forest cluster in the development of forest biorefineries are very similar in each studied country. Especially technological knowledge, biomass availability, existing infrastructure, and biomass logistics are highlighted. In addition to the common issues, existing networks and collaboration are strengths in Finland, Sweden and Brazil. In Finland, there is also a strong forest cluster and a lot of technological knowledge, so they have the potential to be leader in forest biorefinery business in the future. Also the Swedish respondents believe in their leadership in technology. On the other hand, the Americans are the only ones who consider the present situation in the forest sector as strength for them: they take the situation more as a challenge than a threat. The strengths of Brazil are favorable climate conditions for fast growth of biomass and lower costs of production and raw materials than in other studied countries.

TABLE 3 Prerequisites for obtaining the best case scenarios in the studied areas

Key elements in external business environment
High price of oil forcing to seek new energy production options intensively
Sufficient demand of liquid biofuels
Consensus about the sustainable energy production goals between society and industry
Long-term and consistent (integration between federal and state policies) energy and environmental policies
Strong political pressure towards non-agricultural biofuels
Increased private and public financing, reduction of financial risk (subsidies, tax incentives, loan guarantees) in forest biorefinery projects
Focused joint efforts by industries and governments towards forest biorefineries
Support for small and medium size companies in biorefinery value chain
Support for production of biofuels over electricity production in pulp and paper industry
Increased R&D (demonstrations, pilot plants), e.g. applications for micro-geography and local opportunities, economic wood fractionation and conversion technologies, short rotation crops with high yield
Increased knowledge of politicians and public about the forest sector, forest management and various energy pathways in general
Criteria for sustainability of biomass raw material and for its use
Increased knowledge of environmental impacts of collecting of wood biomass
Increased capability to collect, transport and utilize existing wood biomass resources
Improvements in forest management and mobilization of private forest owners in order to increase feedstock availability
Integrated use of other biomass sources along with wood-based biomass in biorefineries
Increased collaboration between forest industry companies and other companies in the same industry and between other stakeholders (energy industry, oil industry, research institutes)

Key elements in internal business environment
Reassessment of the situation and re-evaluation of the wood-refining chain in forest industry
Active participation and fresh attitudes of forest industry about new business possibilities
Efficient utilization of existing infrastructure and permits in the forest cluster in biorefinery business
Building and maintaining infrastructure in the forest cluster
Improvements in energy efficiency and production technologies in forest industry
Recognition of the possibilities of single production units by large companies in the forest cluster
Increased R&D expertise and availability of consultancy in the forest cluster
Increased product and technological innovation, process expertise, understanding of new markets, business know-how and management of wood supply in the forest cluster
Management of change
Increased joint effort of forest industry, oil industry, energy industry and technology providers in the forest cluster in the biorefinery business
Successful collaboration and division of tasks within the biorefinery consortium
Strong leadership in biorefinery consortium
New processes for strategy making in biorefinery consortium
Flexibility in production in biorefineries according to the market situation

Accordingly, weaknesses are also very similar in each country: lack of R&D and innovations, competition of raw material, lack of capital, and unwillingness to change were the most mentioned weaknesses in the studied countries. The most significant economic barriers for forest biorefinery diffusion are insufficient public and private financing and insecurity of biorefinery investments. Technology as such does not seem to become a barrier for the diffusion of forest biorefineries, but lack of R&D expertise and consultancy can create problems. Lack of raw material can also form a barrier, since the results indicate that demand of biorefineries cannot be fulfilled solely with wood-based biomass. The Americans consider the unwillingness to take risks their most significant weakness, which could make them careful with their investments in forest biorefineries. This creates other countries possibilities to gain competitive advantage. Environmental impacts of collecting the wood biomass are not sufficiently known and this can also form a barrier for biorefinery diffusion. Threatened sustainability of the environment is mentioned as an important weakness especially in Brazil. This could affect their ability to grow biomass in the future, if protection for the forests is increased. Also, sugarcane ethanol has such a strong position on the Brazilian market, thus it can be difficult to get enough support for wood-based biofuels there.

There are many political barriers for the diffusion of forest biorefineries, and many of them are emphasized in North America. According to the respondents, energy and environmental policies are not long-term and predictable, and there are political tensions between different parties about the utilization of forests. Decision-makers have insufficient knowledge about the forest sector and forest management issues. There are also inconsistencies between federal and national energy and environmental regulations. Political pressure towards agricultural-based biofuels also hinders biorefinery diffusion.

5.4 Strategies for the Finnish Forest Cluster

It is obvious that in long term the vitality of the Finnish forest cluster has to be based on new investments, products and business operations. Biorefineries offer the greatest new possibilities for diversifying business activities and exporting technologies. However, from the Finnish perspective, what are the important issues that need to be considered when developing biorefinery business?

Finland has a great potential to be world leader in the forest biorefinery technologies. Finland is also the only country in the survey, where the respondents believe in exporting of biofuels. However, the Finnish forest sector needs to act, and above all, sooner than later because as this study has shown, there are eager competitors who also wish to be the world leaders in forest biorefinery business. It is also important to look at the situation as a challenge, not as a threat.

The Finnish companies cannot compete with excessive financial support from government or private capital investors to R&D and start-up companies. Instead, biorefinery business needs to be based on national strengths. Finland has abundant lignocellulosic biomass resources and well-developed raw material logistics. However, there is need for further development and rationalization of wood supply chain and evaluation of exploitation of non-utilized lignocellulosic feedstocks, since the capability to collect and utilize raw materials will be the most challenging part to manage in biorefineries. It seems important that the Finnish forest sector considers also other raw material sources than forest residues, such as urban organic waste. Also, research of dedicated energy crops should get more emphasis.

The Finnish forest sector has long traditions in leadership in the forest technology solutions. Further specializing to solid biomass gasification technology offers many new business opportunities. However, there is a need to put more emphasis also to new technologies outside traditional competencies. Finnish strong know-how in chemical industry solutions could offer number of new possibilities.

The Finnish forest industry has highly respected expertise in industrial processing of wood material. One potential business model for Finnish biorefineries could be to concentrate on this expertise, i.e. to produce intermediate products such as synthesis gas or Fischer-Tropsch wax. These could then be sold to other industries to be refined to final products.

There is a strong need for innovativeness and out-of-the-box thinking for the forest sector, since the possibilities of the wood refining chain and forest biorefineries are not fully explored. Attitudes towards networking are in general quite positive, but this is not sufficient; there is a need for active creation of networks both nationally and internationally, as well as efficient commercializing and marketing of know-how abroad. The biorefinery value chain can offer new possibilities for SMEs e.g. in the area of raw material acquisition, new technology innovations, consultancy, and biochemical production. However, the SMEs would need support from strong networks for the commercialization of their know-how.

In addition, there is need for careful consideration of the internal organizational change and management of this new situation, as well as new strategies which are needed. If the Finnish forest sector aims to become the leader in biorefinery business, that would make them responsible for introducing and putting into practice new business ideas, as well as formulating strategies and guiding the entire network serving the biorefinery. These challenges and new tasks should be taken seriously, and new practices for strategy formulation, network management, and leadership should be actively developed.

Also there is obvious demand for long term political goals. For Finland, many decisions are made at the EU level, and national legislation needs to be adjusted to these policies. The Finnish politicians should have strong will to promote sustainable lignocellulosic biofuels and the government should finance biorefinery projects. Same efforts should also be taken at the EU level. In

general, increasing awareness of politicians as well as public about forest management issues and lignocellulosic based biofuels promotes the diffusion of forest biorefineries.

Overall, biorefineries will play a significant role in the future success of the Finnish forest cluster and Finland has a great potential to be world leader in the biorefinery technologies. Success needs to be based on national strengths; abundant lignocellulosic biomass resources, well-developed raw material logistics, strong know-how in the forest technology, biomass gasification, and chemical industry solutions. There is a need for fast entry into business, innovativeness, active creation of networks, marketing of knowledge, as well as careful consideration of the organizational change, new strategies, and management of the new business. Existing strong co-operation in the Finnish forest cluster forms an excellent opportunity for common future efforts. However, the forest cluster needs to abandon the resistance for change - the sooner the better.

EXECUTIVE SUMMARY

This study aims to explore biorefinery concept and related new products and business opportunities in the forest cluster, as well as new business strategies and models of companies, which are part of the biorefinery value chain. In this research, focus was on energy products of biorefineries, especially on liquid biofuels. The study explores economic, political, technological and ecological factors, and collaboration between biorefinery value chain actors, which all can have an effect on diffusion process and business operations. The changes in the business environment as well as new business competencies, leadership and strategic thinking needed in forest cluster companies are also studied. In addition, the role of the biorefineries in the forest cluster's competitiveness is explored. The factors, which contribute to the establishment and success of forest biorefineries, are compared between Scandinavia, North America and South America.

Data was collected in preliminary interviews (February-March 2008) and internet survey (June-July 2008). Due to low response rate in the internet survey in South America, data was completed by interviewing 20 Brazilian experts in November 2008. Together, 145 forest and bioenergy sector experts from North America, South America and Scandinavia responded the survey. It should be noticed, that results presented in this report reflect the views of these selected bioenergy experts.

Biorefineries and related new energy products are considered a way to guarantee the forest cluster's success in a sustainable way. Increasing price of oil is the most powerful global driver for forest biorefineries. In each studied country, own national strengths and the potential to have a leading role in the biofuel markets are strongly believed in. Forest biorefinery business seems to have market potential and global competition can be expected.

Attitudes of the forest industry reflect some resistance for change, but it seems that unavoidable need for new business operations is widely admitted. Existing infrastructure and permits in the forest cluster create significant competitive advantages for the forest cluster compared to other actors, and the forest industry is evaluated to be the most significant actor in the biorefinery business.

Forest biorefineries are sensitive to changes in the business environment, and thus flexibility in production according to the market situation increases profitability of forest biorefineries. The accepted level of ROI for the forest biorefineries is 10-15 %.

Many challenges in external business environment for the diffusion of the forest biorefineries have been recognized, but issues related to internal business environment are largely undefined. However, it is obvious that the forest biorefinery value chain will provide business opportunities for new actors, especially for small companies. Consortia will lead to a growing dependence on collaboration and new division of tasks within the biorefinery value chain.

Consortia will also need new processes for strategy making and strong leadership.

Outlook for technical and raw material choices, as well as barriers and prerequisites for biorefinery diffusion, are very similar in all the studied areas. The most important forest biorefinery products are expected to be ethanol and FT-diesel. Forest residues are the most significant wood-based biomass sources in biofuel production. The majority of the production will take place in large-scale biorefineries, which are integrated in pulp and paper industry. Solid biomass gasification and gas cleaning for synthesis applications will be implemented first. However, all the studied technologies will be commercialized in less than ten years. Experts participating in the survey foresee radical innovations in wood-based biofuel production in the near future. Innovations are expected especially in new extraction methods of hemicellulose or lignin, and in development of new enzymes.

The strengths of the forest cluster in the development of forest biorefineries are very similar in each studied country. Especially technological knowledge, biomass availability, existing infrastructure, and biomass logistics are highlighted. Accordingly, weaknesses are also very similar in each country: lack of R&D and innovations, competition of raw material, lack of capital, and unwillingness to change were the most mentioned weaknesses in the studied countries. The most significant economic barriers for forest biorefinery diffusion are insufficient public and private financing and insecurity of biorefinery investments. Technology as such does not seem to become a barrier for the diffusion of forest biorefineries, but lack of R&D expertise and consultancy can create problems. Lack of raw material can also form a barrier, since the results indicate that demand of biorefineries cannot be fulfilled solely with wood-based biomass. There are many political barriers for the diffusion of forest biorefineries, and many of them are emphasized in North America. According to the respondents, energy and environmental policies are not long-term and predictable, and there are political tensions between different parties about the utilization of forests. Decision-makers have insufficient knowledge about the forest sector and forest management issues. There are also inconsistencies between federal and national energy and environmental regulations. Political pressure towards agricultural-based biofuels also hinders biorefinery diffusion.

In case there will be no radical changes in the business environment, liquid cellulosic biofuel production in the EU is estimated to be around seven million tons, and in Brazil less than 20 million tons in 2020. In the U.S., production of cellulosic biofuels is estimated to be about 30 million tons, and in Canada about 14 million tons in 2022.

Biorefineries will play a significant role in the future success of the Finnish forest cluster and Finland has a great potential to be world leader in the biorefinery technologies. Success needs to be based on national strengths; abundant lignocellulosic biomass resources, well-developed raw material logistics, strong know-how in the forest technology, biomass gasification, and chemical industry solutions. There is a need for fast entry into biorefinery business, innovativeness, active creation of networks, marketing of knowledge,

as well as careful consideration of the organizational change, new strategies, and management of the new business.

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APPENDIX 1. INTERNET SURVEY QUESTIONNAIRE

BIOREFINERIES-FUTURE BUSINESS OPPORTUNITY FOR FOREST CLUSTER

Requirements and barriers for diffusion of forest biorefineries in Scandinavia, North America and South America

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DEFINITIONS

Biofuel:

Liquid, gas or solid fuel made from wood-biomass or heat generated by using wood biomass.

Forest industry:

A forest industry includes pulp, paper, paperboard and wood products industries (The latter contains sawmilling, plywood, chipboard, fiberboard and construction products industries).

Forest cluster:

A forest cluster is the gathering of industries and production facilities around the forestry and the forest industry. A forest cluster includes mechanical, chemical and packaging industries related to the forestry and the forest industry. A forest cluster includes also related energy, logistics and consulting companies, as well as research centers and universities.

Forest biorefinery:

A forest biorefinery is a multi-product factory that integrates biomass conversion processes and equipment to produce fuels and chemicals from wood-based biomass.

Forest biorefinery value chain:

A forest biorefinery value chain is a string of diverse companies, working together to satisfy market demand for wood-based biofuels and biomaterials.

Diffusion:

Expansion of utilization of a new concept.

Module 1/5 Respondent's background

It will take couple of minutes to answer to this module.

1. Your country?

Argentina
Brazil
Canada
Chile
Finland
Sweden
Uruguay
U.S.

2. Your province/territory?

Alberta
British Columbia
Manitoba
New Brunswick
Newfoundland and Labrador
Northwest Territories
Nova Scotia
Nunavut
Ontario
Prince Edward Island
Québec
Saskatchewan
Yukon

3. Your state?

Alabama	Hawaii	Massachusetts	New Mexico	South Dakota
Alaska	Idaho	Michigan	New York	Texas
Arizona	Illinois	Minnesota	North Carolina	Tennessee
Arkansas	Indiana	Mississippi	North Dakota	Utah
California	Iowa	Missouri	Ohio	Vermont
Colorado	Kansas	Montana	Oklahoma	Virginia
Connecticut	Kentucky	Nebraska	Oregon	Washington
Delaware	Louisiana	Nevada	Pennsylvania	West Virginia
Florida	Maine	New Hampshire	Rhode Island	Wisconsin
Georgia	Maryland	New Jersey	South Carolina	Wyoming

4. Field of activities / line of industry?

Forest industry
Energy industry
Oil industry
Chemical industry
Technology providers in the forest cluster
Car industry
Investor

Research
Public authority
Other, please specify

Module 2/5 Forest biorefinery diffusion

It will take 5-10 minutes to answer to this module.

1. In your opinion, what are the greatest incentives for forest biorefineries and wood-based biofuels in your country? You can choose as many options as you want.

Climate change
National security of fuel supply
Increasing price of oil
Increasing demand for biofuels
Decreasing demand for traditional wood-based products (e.g. pulp and paper)
Relocation of the traditional forest industry to South America and Asia
Encouraging national environmental and energy policies
Encouraging international environmental and energy policies
Other, please specify

2. What is your opinion about the following statements concerning economic and market factors that affect the diffusion of forest biorefineries (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree).

1. Large companies in the forest cluster have the investment capability to develop forest biorefineries.
2. Small and medium size companies in the forest cluster are capable to invest in forest biorefineries.
3. Private financing available for forest biorefineries is sufficient.
4. Public financing available for forest biorefineries is sufficient.
5. Uncertainty concerning the profitability of biofuel and chemical production creates insecurity for biorefinery investments.
6. Price competitiveness of wood-based biofuels is attractive in the current market situation.
7. For the pulp and paper industry production of electricity will be more profitable compared to the production of biofuels.
8. Wood-based biomass as a raw material is too expensive for the production of biofuels.
9. The oil industry's increasing control of the biofuel market reduces the forest cluster's opportunities in the biofuel market.

3. What is your opinion about the following statements concerning technological factors that affect the diffusion of forest biorefineries (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree).

1. Technology will become a barrier to biorefineries.
2. The forest cluster has enough R&D expertise to develop forest biorefineries.
3. Companies in the forest cluster can easily find consultancy for biorefineries.
4. Companies in the forest cluster are confused about the variety of technical choices and combinations offered for the production of biofuels and chemicals.

4. What is your opinion about the following statements concerning political factors that affect the diffusion of forest biorefineries (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree).

1. Energy and environmental policies in your country/region are long-term and predictable.
2. There are inconsistencies between state (provinces) and national energy and environmental regulations.
3. There exist political tensions between different parties about industrial utilization of forests.
4. Strong political pressure towards agricultural-based biofuels hinders forest biorefinery diffusion.
5. Politicians and other decision-makers have enough knowledge about the forest sector and forest management issues.
6. There is enough support for forest biorefinery demonstration and pilot plants.
7. Subsidies for the production of biofuels will be more effective compared to the subsidies for investments of new biorefinery facilities.

5. What is your opinion about the following statements concerning ecological and raw material related factors that affect the diffusion of forest biorefineries (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree).

1. The capability to collect and utilize existing wood biomass resources will be a limiting factor rather than the absolute amount of wood biomass.
2. Raw material demand of forest biorefineries cannot be satisfied solely with wood-based biomass (e.g. agri-feedstocks will be needed).
3. Only wood biomass, that cannot be used for higher value products, should be utilized for biofuel production.
4. Increasing public awareness about forest management issues and environmental aspects related to biorefineries promotes diffusion of biorefineries.
5. Environmental impacts of collecting of wood biomass (forest residues) are sufficiently known.

6. What is your opinion about the following statements concerning collaboration that affect the diffusion of forest biorefineries (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree).

1. The forest industry companies are willing to co-operate with other companies in the same industry to develop forest biorefineries.
2. The forest industry is willing to co-operate with companies outside the forest industry to develop forest biorefineries.
3. The forest industry is willing to co-operate with research institutes to develop forest biorefineries.
4. The petrochemical industry is interested in co-operating with the forest industry in production of wood-based traffic biofuels.
5. The forest industry is in contact with top experts of the field worldwide.

Module 3/5 Feedstock & technologies

It will take around 5 minutes to answer to this module.

1. In your view, what kind of forest biorefineries will have the greatest potential in your country in the future? Please, choose one alternative.

Biorefineries which are integrated in pulp mill/pulp and paper mill
Biorefineries which are integrated in saw mill/lumber industry
Stand-alone forest biorefineries
Integrated and stand-alone biorefineries have equal potential
No opinion

2. In the future (2020), the majority of the wood-based liquid biofuel production capacity in your country will take place in

Biorefineries, where production capacity is less than 50 000 t/a
Biorefineries, where production capacity is between 50 000 and 100 000 t/a
Biorefineries, where production capacity is more than 100 000 t/a
No opinion

3. In your opinion, when will commercial scale implementation of the following technologies take place in wood-based biomass processing?

<5 5-10 11-20 20-30 more than 40 years will not happen No opinion

Solid biomass gasification and gas cleaning for synthesis applications
Black liquor gasification and gas cleaning for synthesis applications
Fast pyrolysis
Acid hydrolysis and fermentation
Enzymatic hydrolysis and fermentation

4. This question relates to the previous question 3. In your view, what are the greatest advantages related to the technologies which are closest to the commercial scale implementation? Please, choose the three most important ones.

Less capital-intensive facilities will be needed compared to the other technologies.
Production costs are likely to decline faster than for the other pathways.
Potential to produce more fuel per tonne of biomass compared to the other pathways.
Technology is able to accommodate a wide variety of feedstock.
Quality of the end product is better compared to the other technologies.
Greenhouse gas emissions during the life cycle of the product are smaller compared to the other technologies.
Other, please specify
No opinion

5. Can you foresee any radical innovations that could be used in wood-based biofuel production in the near future? If yes, what could these wild cards be?

No
Yes, please specify
No opinion

6. In your view, which of the following wood-based biomass sources are the most significant in biofuel production in the future? Please, choose the three most important ones.

Forest residues (logging residues, forest reduction/restoration thinnings)
Disease-killed timber
Bark from pulp industry
Raw soap from pulp industry
Black liquor from pulp industry
Tree oils
Lumber industry/saw mill residues
Industrial organic sludges
Urban organic waste (e.g. waste paper, tree trimming residues, fuel management, construction lumber)
Biomass from dedicated energy crops (e.g. hybrid willow, poplar, eucalyptus)
Other, please specify

No opinion

7. In your opinion, what are the greatest challenges related to the utilization of feedstock chosen in the previous question 6? Please, choose the three most important ones.

Accessibility and competition for raw material
Unstable markets and volatility of raw material costs
Harvesting equipment and costs
Logistics and transportation economics
Storage of biomass
Quality of feedstock (e.g. dirt, moisture, density)
Infrastructure and new equipment designs for feedstock utilization
Public perceptions and environmental debate
Regulatory hurdles
Other, please specify
No opinion

8. In your opinion, which of the following forest biorefinery products will have the greatest market potential in the future? Please, choose the three most important products.

FT-diesel
Methanol for fuel
Hydrogen
Synthetic natural gas
Dimethyl ether (DME)
Ethanol for fuel
Butanol for fuel
Bio-oil by pyrolysis
Biodiesel by hydrotreatment
Biodiesel by tranesterification
Polymers
Resins
Lubricants
Solvents (e.g. acetone, ethanol, butanol, methanol)
Organic acids (e.g. lactic acid)
Other, please specify
No opinion

Module 4/5 Scenarios

It will take around 5 minutes to answer to this module.

1. In your opinion, what role will the production of biofuels in biorefineries play on the forest cluster's competitiveness in your country? (very insignificant, somewhat insignificant, neutral, somewhat significant, very significant)

In 5 years
In 10 years
In 20 years
In 30 years
In 40 years

2. In your opinion, which of the following views of the future describes best the future development of the forest cluster in your country? (Source, modified from Häyrynen et al. 2007)

1 Business as usual. There are no radical changes in the development of the forest cluster in the future. Production efficiency is further optimized. Raw material availability in the market is a crucial factor in future success. Production costs and demand determine locations for production facilities. Biorefineries and related new bioenergy products will not play a significant role in the forest cluster.

2 Restructuring the business. Competitiveness of the national, traditional forest cluster disappears. Staying with old production structures contains high risk. Investments are aimed towards new markets and new business concepts. There is a strong interest and increasing amount of projects towards forest biorefinery concepts and new bioenergy products.

3 Sustainability. Sustainability is the key issue also in the financial decision making. The forest cluster is successful in a society, which respects ecological values and sustainable forest utilization. Production will be further developed towards energy and raw material efficiency. Biorefineries and related new energy products guarantee the forest cluster's success in a sustainable way.

4 Domestic competencies. Globalization increases the risks related to international business, thus making domestic investments more stable and appealing. The national security of fuel supply and independence of imported oil will be seen as important issues. The forest industry core competencies are sustained in domestically and competitiveness of domestic companies are maintained**.** Combination of skills in biorefineries creates a core competence, which cannot be easily copied, thus making them a valuable competitive national advantage for the forest cluster.

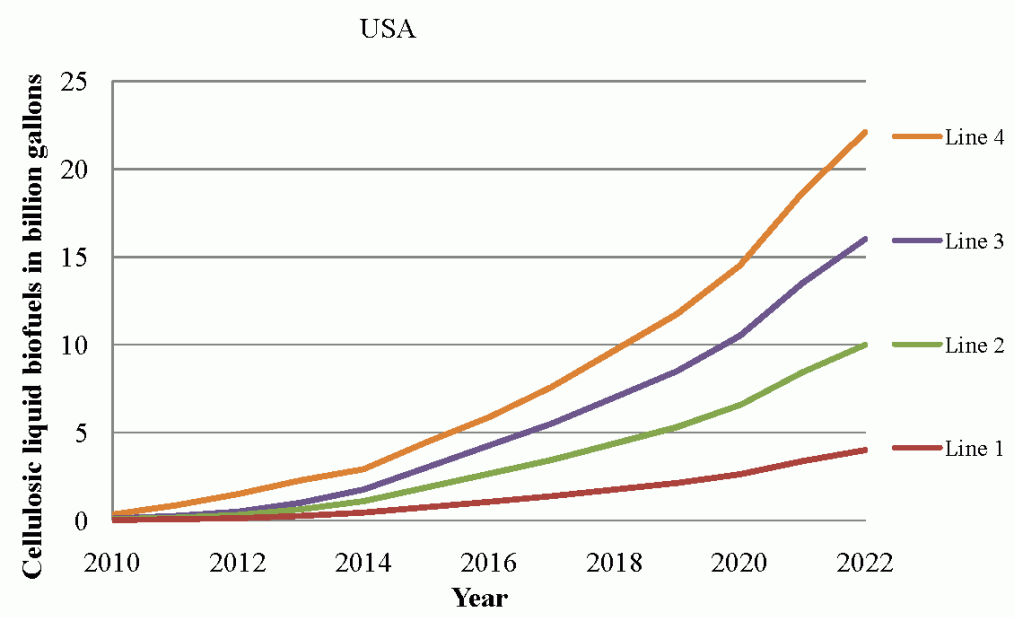
3. In order to get the right figure for the next question, please choose your own area.

U.S.
Canada
Finland
Sweden
Latin America

3a. In the case that there will be no radical changes in the business environment, which pathway describes best the CELLULOSIC liquid biofuel production in the U.S.? Please, choose one alternative.

Line 3 indicates the goal for the production of cellulosic biofuels according to the Renewable Fuel Standard.

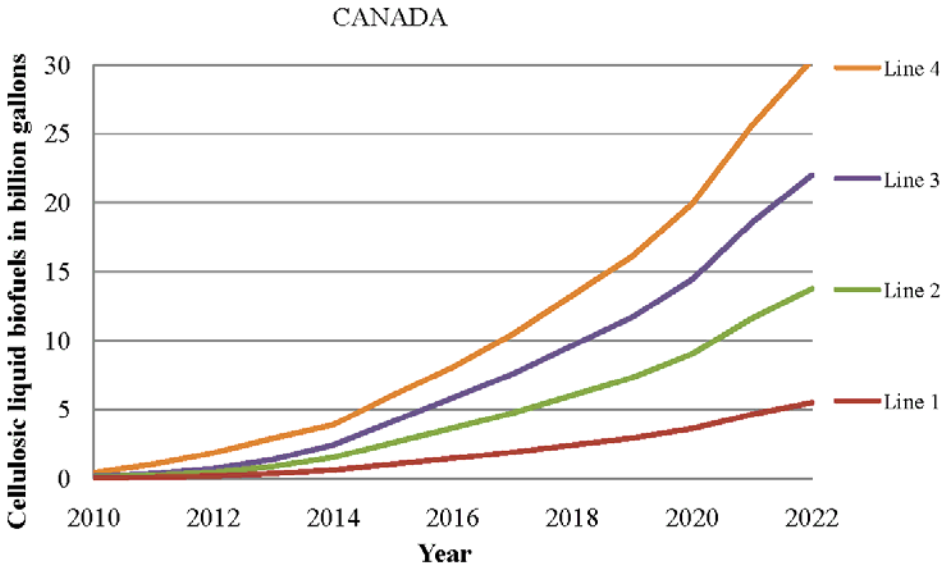
Line 1
Line 2
Line 3
Line 4



3b. In the case that there will be no radical changes in the business environment, which pathway describes best the CELLULOSIC liquid biofuel production in Canada? Please, choose one alternative.

The Renewable Fuels Standard requires 5 % renewable content in gasoline (app. 0,55 billion gallons) by 2010.

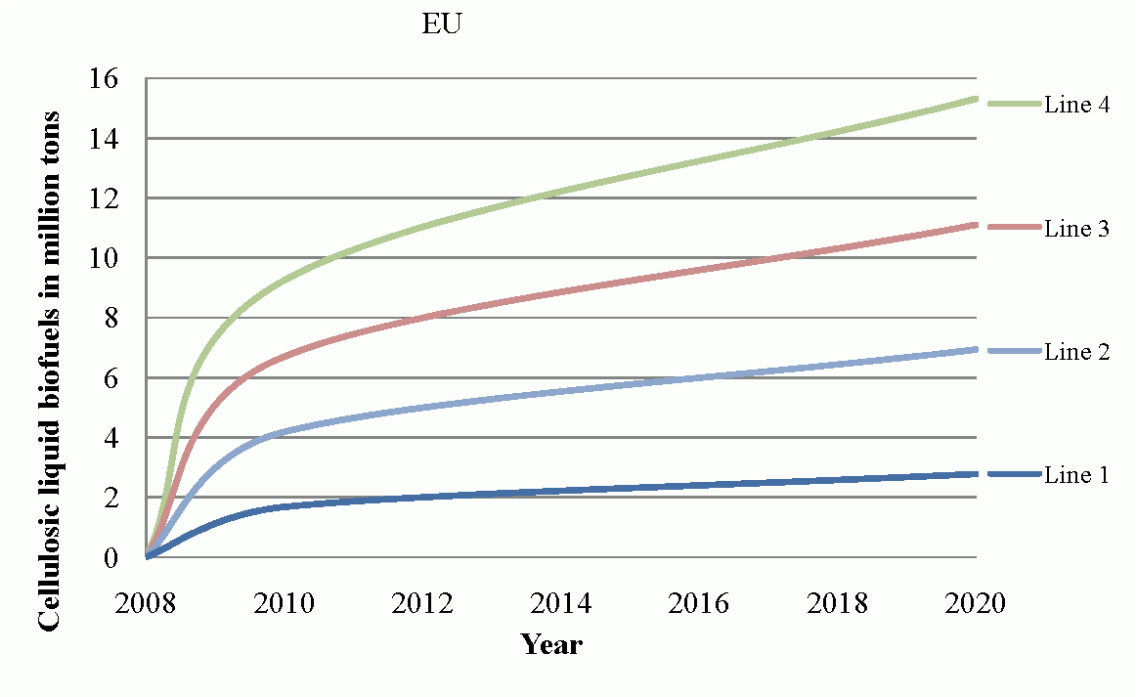
Line 1
Line 2
Line 3
Line 4



3c) In the case that there will be no radical changes in the business environment, which pathway describes best the CELLULOSIC liquid biofuel production in the EU? Please, choose one alternative.

The European Union has 5, 75 % minimum biofuel target in total transport use by 2010 and 10 % target by 2020. The assumption is that one third of the biofuel production will be cellulose-based. Line 3 indicates this assumption.

Line 1
Line 2
Line 3
Line 4



3d) How much CELLULOSIC biofuels will be produced in your country in the year 2020 in the case that there will be no radical changes in the business environment? Please, choose one alternative.

Less than 1 million tonnes
1-5 million tonnes
6-15 million tonnes
16-25 million tonnes
More than 25 million tonnes

4. In your opinion, what are the prerequisites for actualizing the political goals concerning production of liquid biofuels in your country? Please, define the most important factor(s) which would make this pathway possible.

Open
No opinion

5. In your view, which of the following renewable traffic fuels have the greatest potential when compensating fossil fuels in the future? Please, choose one alternative.

Conventional agri-based biofuels
Cellulosic agri-based biofuels
Wood-based biofuels
Municipal waste-based biofuels

Green electricity
Hydrogen
Other, please specify

Module 5/5 Business models

It will take 5-10 minutes to answer to this module.

1. What is your opinion about the following statements concerning reactions and foresight of the forest cluster to the changing business environment (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree).

1. There is a need for a comprehensive re-evaluation of wood utilization and the wood-refining chain from a fresh perspective.
2. Large companies in the forest cluster concentrate on the optimization of the whole organization's business operations and the possibilities of single production units are not adequately recognized.
3. Forest industry companies concentrate on growth in new market areas and do not consider new possibilities in their existing markets.

2. What is your opinion about the following statements concerning the biorefinery concept and new wood-based products (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree).

1. Existing infrastructure and permits in the forest cluster create significant competitive advantages for the forest cluster compared to other actors in the biorefinery business.
2. Wood-based biofuel production is considered as a serious business opportunity in the forest cluster.
3. Wood-based chemicals production is considered as a serious business opportunity in the forest cluster.
4. Capitalizing on biorefinery opportunities will be the only way to avoid massive shutdown and loss of pulp and paper facilities.
5. Forest biorefinery consortia offer small companies a possibility to enter new, larger markets.
6. Forest companies in our country have a chance to be leading actors in forest biorefinery business worldwide.
7. Flexibility in production according to the market situation (possibility to vary raw material mix and adjust processes) increases profitability of forest biorefineries.
8. Forest biorefineries are sensitive to changes in the business environment.
9. Wood-based biofuels produced in biorefineries will have a positive public response.
10. Wood-based biofuels produced in biorefineries will be mainly used in the domestic market.
11. In the future (2020), wood-based liquid biofuels will be produced on a commercial scale.

3. In your view, what kind of skills and business competencies will be needed in the future for the forest cluster/forest biorefineries? Please, estimate the significance of the following issues. (very insignificant, somewhat insignificant, neutral, somewhat significant, very significant)

Business know-how
Financial expertise
Risk management skills
Product and technological innovation
Business model innovation
Process expertise
Ability to interact with and actively shape the environment

Management of change
Recognition of new core competencies and applying new information
Understanding of new markets
Consideration of long time perspective
Creation and management of networks
Management of wood supply chain

4. In your view, what are the most important strengths of the forest cluster related to the development of forest biorefineries in your country?

Open
No opinion

5. In your view, what are the most important weaknesses of the forest cluster related to the development of forest biorefineries in your country?

Open
No opinion

6. In your opinion, what part of the forest biorefinery supply chain will be the most challenging to manage? Please, choose the most important one.

Forest management
Harvesting/collection of raw-material
Storage of raw materials
Pre-processing
Transportation to conversion
Production
Distribution
Marketing & branding
End use

7. In your opinion, how significant are the following partners in forest biorefinery consortia? (very insignificant, somewhat insignificant, neutral, somewhat significant, very significant)

Forest industry
Technology providers in the forest cluster
Energy industry
Car industry
Oil industry
Chemical industry
Biotech industry

8. In your view, which one of the following industries will be the dominant actor in the forest biorefinery consortium? Please, choose one alternative.

Forest industry
Technology providers in the forest cluster
Energy industry
Car industry
Oil industry
Chemical industry
Biotech industry
Other, please specify

9. What is your opinion about the following statements concerning forest biorefinery consortia (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree).

1. The forest biorefinery consortia will lead to a growing dependence on co-operation within the biorefinery value chain.
2. There are business opportunities for new actors in the forest biorefinery value chain.
3. The forest biorefinery consortia will lead to new division of tasks within the biorefinery value chain.
4. The forest biorefinery consortia will need new processes for strategy making.
5. The forest biorefinery consortia will need strong leadership.
6. The forest biorefinery consortia will lead to new division of power within the biorefinery value chain.
7. The dominant companies in the forest cluster are responsible for introducing and putting into practice new business ideas.
8. Sharing responsibilities between the biorefinery value chain actors will be problematic.
9. Sharing revenues between the biorefinery value chain actors will be problematic.
10. Sharing synergy benefits between the biorefinery value chain actors will be problematic.

10. In your view, what level of ROI (return of investment) would be acceptable for the forest biorefineries? Please, choose one alternative.

5 % ROI
10 % ROI
15 % ROI

11. This is the last question of the questionnaire. If you have any additional comment(s) concerning forest biorefineries, please add them here.

Open