2013

Aviation biofuels in Saskatchewan, Canada

The Development of a Value Chain to facilitate Sustainable Implementation

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BSc Thesis

Science, Business and Innovation

VU University Amsterdam

Saskatoon, Canada

July 15, 2013

Aviation biofuels in Saskatchewan, Canada

The Development of a Value Chain to facilitate Sustainable Implementation

What are the possibilities and implications in creating a pro-active Value Chain for biojet fuels within Canada?

What are the social, economical, political, technological and logistic characteristics and objectives; what positions do relevant stakeholders have?

What is the role of the European Union; how can collaboration between Canada and the EU help the implementation of biojet fuels?

Aviation Biofuels in Saskatchewan, Canada

The Development of a Value Chain to facilitate Sustainable Implementation

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Saskatoon, July 15 2013

i. FOREWORD AND ACKNOWLEDGEMENTS

For successful completion of the Bachelor Science, Business and Innovation (SBI) at the VU University Amsterdam, I have done a graduation project in the form of an internship in Saskatoon, Canada. This project is a combination of scientific research and writing a bachelor thesis, covering the core areas of Science, Business and Innovation.

During my internship, I have done research on aviation biofuels in Canada at Ag-West Bio Inc. As a non-for profit member-based organization, funded by the Saskatchewan provincial government, Ag-West represents the agricultural sector. Ag-West operates as a catalyst in connecting people and organizations in this field, facilitating business development and commercialization on the macro as well as the micro-level. This thesis presents the results of the scientific research on how to facilitate the implementation of so-called biojet fuels in Canada by creating a Value Chain. At this moment, Canadian biofuel policies are behind of European mechanisms on biofuels, whereas the knowledge, raw materials and necessary stakeholders are in place. This research is focused on filling these gaps and creating a pro-active Value Chain on biojet fuels for Canada. The research has taken five months, of which four are covered in this thesis. The fifth month serves mainly to start implementing the results.

I would like to thank the following people, without whose help and support this thesis would not have been possible. I would like to show my gratitude to Mike Cey, Director of Corporate initiatives and my supervisor at Ag-West Bio; Judie Dyck, Honorary Consul of The Netherlands; dr. Philipp Pattberg, Professor at the VU University Amsterdam and my first VU-supervisor; and drs. Peter van Hoorn, Professor at the VU University Amsterdam and my second VU-supervisor for their valuable insights and directions in this research. I also would like to thank all organizations that have cooperated in my research for sharing their information and knowledge in this field. Special thanks to SkyNRG, Air Canada, WestJet, KLM and Ag-West's partners Agrisoma Biosciences Inc. and Mustard 21. Finally, I would like to thank my parents Loekie van den Breemer and Frank Osseweijer and my boyfriend Alte Venema for their constant support during the time I worked on this research.

Floor Osseweijer

Saskatoon, July 15 2013

ii. Executive Summary

The aviation industry is a fast growing sector, as it is the only network that provides the possibility of rapid worldwide transport. Air transport is becoming more popular in world trade, tourism and travelling, the connection of companies for meetings and conferences, and many other businesses. It is a convenient way of bridging large distances in relatively short time. Though, aviation has a negative side-effect, namely the production of green house gases (GHG) that affect climate change. At this moment, aviation accounts for 2-3% of all anthropogenic CO_2-emissions (*Beginner's Guide to Aviation Biofuels*, 2009; McCollum, Gould, & Greene, 2010). Within Saskatchewan (Canada), Ag-West Bio has indicated a potential business opportunity to develop an aviation biofuel (biojet fuel) out of industrial oilseed crops *Camelina sativa* (camelina) and *Brassica carinata* (carinata) grown in the Canadian Prairies (Ag-West Bio Inc., 2012a). This research is aimed at developing a value chain to facilitate the implementation of this biojet fuel in Canada.

To derive at the development of such a value chain, first the socio-economical and political situation have been explored to indicate the need and the broader context. In growing oilseed feedstock, CO_2 from the atmosphere is absorbed. In burning the crop-derived fuel, this carbon dioxide is released again. The next generation of feedstock will absorb this CO_2 for growing. This shorter carbon cycle allows for a relatively carbon-neutral life cycle. Biojet fuel produced out of the oilseed camelina, grown in Saskatchewan, shows an 84% reduction in emissions over the entire lifecycle (*Beginner's Guide to Aviation Biofuels*, 2009).

Saskatchewan and Manitoba currently fully rely on import of Jet A-1 fuel (Bailey, 2012). Here lies an opportunity for regionally produced biojet fuel. Once biojet fuel becomes economically competitive with conventional petroleum-based Jet-A1 fuel, this can provide a significant solution for the current fuel shortage and dependency. Current infrastructure is suitable for distribution of biojet fuel, wherein trucking appears to be the most appropriate transport mechanism seen its flexibility in volume and just-in-time delivery and the relatively low capital costs. According to the financial analysis of a 230 MLPY refinery plant, biojet fuels out of camelina and carinata can be competitive with Jet A-1 fuel in the near future, considering crop improvements and further development of refinery technologies (S. Porter & Saville, 2012). In the short term, Canada is an important region to map, but in the longer run biojet fuel export outside of Canada may be an opportunity as well.

The focus of the biofuel policies of the European Union is on three core principles: *security* (availability of supply), *competitiveness* (referring to price affordability) and *sustainability* (an environmental dimension) (Egenhofer, Grigorief, Socor, & Riley, 2006). The Roundtable for Sustainable Biofuels (RSB) has established twelve criteria that are considered to be at the basis of sustainable biomass production. If biofuels meet these criteria, they operate within the core principles and are approved as renewable fuel source (Roundtable for Sustainable Biofuels, 2010). Subsequently, the EU has set mandatory targets for her Member States within the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD). Among others; by 2020 20% of all energy consumption has to be sustainable, food competition is not accepted and the consequences of (in)direct land use change have to be limited (European Parliament and Council, 2009a, 2009b). In order to achieve beneficial effects for the world as a whole, more intense activities outside Europe's boundaries are required. Europe can function as a role model in developing policies to achieve this.

The next focus was on the technological characteristics of the feedstock and the refinery process. Biofuel-feedstock focuses on second-generation non-edible crops. For Saskatchewan these are Camelina sativa and Brassica carinata. Both crops are relatively disease resistant and know an extraordinary drought and heat tolerance (Blackshaw et al., 2011). Together with the possible use as a rotational crop on fallow land, this feedstock is highly suitable to be grown in the Canadian Prairies (Shonnard, Williams, & Kalnes, 2010). For our research outcomes carinata will be used in the form of Agrisoma Resonance® Energy Feedstock (Agrisoma Biosciences Inc., 2013).

The refinery process, as developed by Honeywell UOP, consists of several steps (Kinsaul & Wadsworth, 2013). The first step is crushing the oilseeds and extracting remaining oil by washing with hexane. The triglycerides and free fatty acids in the derived oil have to be converted in high-energy molecules (Hemighaus et al., 2006). This happens in three steps: deoxygenation, selective hydrocracking / isomerization and product separation (Kinder & Rahmes, 2009). The refined product is a mixture of different products, so has to be fractionated. By distillation, the co-products naphtha, LPG and HDRD diesel are obtained (Lupton, 2012).

With this information about the biojet fuel industry, a start has been made to develop the Value Chain, by first exploring the involvement of the stakeholders. One of the most important stakeholders in the biojet fuel field is the aviation sector itself, consisting mainly out of umbrella organizations and airlines. Umbrella organizations (ATAG, ICAO, IATA) have objectives to grow carbon neutral from 2020 on and reduce their CO_2-emissions with 50% by 2050. Biojet fuels are one of the options to achieve this (International Air Transport Association, 2012). International Supply Chain Manager SkyNRG from The Netherlands has promising objectives, applicable to Canada (Faaij & Dijk, 2012). Personal contact with Canadian airlines has indicated their willingness to cooperate in this renewable project if it is financially attractive. Since WestJet is not flying into Europe and therefore not bothered by their environmental policies, incentives have to be provided (Tauvette, 2013). Next to having a public role, airlines are identified as main off-takers. Other identified stakeholders are the government, research institutes, farmers, franchisee companies, financial service providers and joint venture partners.

Within the biojet fuel market, six main forces were identified, taking entry barriers into account (M. E. Porter, 1979). S*uppliers* of oilseed/feedstock and biojet fuel have bargaining power in increasing prices, depending on how many suppliers are in place. *End users* or off-takers are the airlines and airports. Their bargaining power is the use of cheaper alternatives (Jet A-1) instead, to drive down price levels. The *government and public* influence the market by creating policies and imposing mandates on environmental actions. Financial support or tax exemptions is another power to steer the market towards a certain direction. *Competition* within the biojet fuel market is still rare, but main bargaining powers are distinctions in pricing, technology, level of innovation, quality and service. The Jet A-1 suppliers are seen as the main current competitors, as they offer a cheaper and more well-known alternative. The degree of *new entrants* to the market is low, given the high capital investments and level of technology. However, they should be monitored carefully in case they offer advantages. The main current *substitute* is Jet A-1 fuel, which is threatening seen the cost and scale advantages. Future substitutes can be hydrogen or electrical planes, since biojet fuels are still considered to be an intermediate solution. *Complementary* products could be the introduction of biojet specific engines. The existing bargaining powers will be of relatively low influence. This is since the aim is to develop a value chain where all stakeholders work pro-actively together to reach a common goal. Competition among actors will be minimized, and collaboration maximized to increase the chances of success in competing the Jet A-1 fuel market.

A SWOT-analysis has indicated significant strengths, such as environmental benefits, short-term deployment and a high potential market. Opportunities are high, seen the decrease in fossil fuel dependency, decrease in import and contribution to existing biofuel goals and policies. Weaknesses to take into account are short-term financial state, requirement of high acreage and dependency of weather conditions. Important threats to monitor are concerns around food security, (in)direct land use change and the financial crisis.

The supply chain consists of five main links. Feedstock Production, Supply Logistics, Conversion, Distribution and End Use. The value chain describes the value that is added to the product by every link in the chain through a combination of primary and support activities. This way, a breakthrough in the market can be realized, creating a market pull at the side of the end users. To overcome the valley of death, several gaps in the value and supply chain need to be filled. Most important are contracting farmers on production levels and prices, the establishment of a processing and refinery plant, developing governmental policy and support, contracting airlines on off-take agreements, contracting distributors and creating a market for the protein meal once approval for livestock feed use is in place. A strategic approach to address this has been developed, consisting of several steps. The value chain and existing gaps have already been identified. The next step is creating a market pull, i.e. demand at the side of airline companies. Policy and support mechanisms at the side of government and investors have to be defined. Then, long-term agreements on off-take and price for farmers as well as airlines need to be signed. Next, a refinery will be established at commercial scale, followed by the contracting of distribution companies.

All in all, the creation of a pro-active Value Chain requires a lot of effort, and external support is needed to achieve this. However, as a result of this research concrete stakeholders representing all focus area's have been defined and approached. At this point discussions take place on possible future steps, and within a month from now a trade mission will be organized in Saskatoon to introduce all stakeholders personally and accelerate development and implementation of concrete action plans on biojet fuel implementation for the separate steps of the Strategic Approach. There is a role for the European Union in the form of the Dutch company SkyNRG, who will serve as a supply chain manager and one of the leaders of this project.

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INTRODUCTION

The aviation industry is a fast growing sector, as it is the only network that provides the possibility of rapid worldwide transport. Air transport is becoming more popular in world trade, tourism and travelling, the connection of companies for meetings and conferences, and many other businesses. It is a convenient way of bridging large distances in relatively short time. Though, aviation has a negative side-effect, namely the production of green house gases (GHG) that affect climate change. At this moment, aviation accounts for 2-3% of all anthropogenic CO_2-emissions (*Beginner's Guide to Aviation Biofuels*, 2009; McCollum et al., 2010).

Currently, there are three main options to reduce GHG emissions in air transport, encouraged to be used in combination with each other (Faaij & Dijk, 2012). The first is operational improvements. This has got mainly to do with operating as efficient as possible, more direct routing, scheduling of flights and coordination between airlines to prevent empty seats. The second option is making technical improvements on the aircraft and its engine. The aircraft design should be even more aerodynamic, wing tips have to be included and the material should be as light as possible. Turbines can be improved, and so can the fuel efficiency of the engines. Third, the fuel should be changed from petroleum-derived Jet A-1 fuel to renewable jet fuel, so-called biojet fuel (Faaij & Dijk, 2012). In the past few years, operational and technical improvements have already resulted in major reductions in the use of fuel. Biojet fuels are a relatively new solution, but are expected to create a large cutback in GHG emissions in the near future. This thesis will focus on the development of biojet fuels in Saskatchewan, Canada.

The centre of attention will be to create a value chain to facilitate the implementation of biojet fuels. Chances of success depend on several factors, among others the competitive advantage of the biojet fuel, the adaptability of the current value chain and the cooperation with involved stakeholders. In order to sufficiently address these problems at all levels, the research has been divided in the four sections 'Socioeconomics and politics', 'Science', 'Business and Actors' and 'Collaboration EU and Canada'. The main research question is:

What are the possibilities and implications in creating a pro-active Value Chain for biojet fuels within Canada?

Two overall sub-questions are:

What are the social, economical, political, technological and logistic characteristics and objectives; what positions do relevant stakeholders have?

What is the role of the European Union; how can collaboration between Canada and the EU help the implementation of biojet fuels?

RESEARCH METHOD

This is a qualitative research. The research is conducted as a desk research. This means that there is reflection on existing literature material and no direct contact with the research object is in place (Saunders, Thornhill, & Lewis, 2009). Each of the first two sections serves to answer the first sub-question and is composed of background information and research outcomes of preliminary research, gathered from literature. These data are integrated into one cohesive information source, providing an overview of the current status of the industry. This part can therefore be seen as a literature survey, since it completely depends on existing literature (Verschuren & Doorewaard, 2007).

In the third section, new analyses are made based upon experience and insights in the industry (Osseweijer, 2013), but literature is used as well. This section provides the results of those market analyses. Since the key variables had already been defined, only relationships between them will have to be described and explained. This part therefore is an Explanatory Research (Harvard University, 2013). Stakeholder consultations, partly in the form of a questionnaire, are part of these analyses. The questionnaire was developed in advance, addressing subjects that were not found in public literature. The interviews had a conversational character, the prepared questions were not posed literally. The information has been processed in the form of a summary of the conversation and has been included in the research outcomes that way. Outcomes of these questionnaires have been used in determining further direction of the research. In fact, this has resulted in the organization of a Trade Mission to introduce involved stakeholders.

The last section addresses the second sub-question and comes up with a proposal, based on the earlier done literature research and analyses (Osseweijer, 2013), as in a Descriptive Research. This is the main concrete outcome of the research. The term desk research does not truly hold here, since the organization of a trade mission is part of the proposal. Thereafter, conclusions will be drawn.

Thesis Organization

The first section serves to indicate the societal need for biojet fuels, the current and future economical and market state and the political field. The contribution of biojet fuels in mitigating climate change will be explored first, to specify benefits for society and environment. Next, economical and market characteristics and potential of the biojet fuels will be investigated, based upon current Jet A-1 fuel data. Goals are to evaluate the logistics, potential markets and define the jet fuel pricing to determine the competitive advantage. One of the objectives of this research is to indicate the possibilities of establishing a coordinated Value Chain on biojet fuels in Canada. As such a framework is already in place in the European Union, their policies will be outlined first, using information in various policy reports and articles. Also, their future outlook will be discussed.

The second section, Science, will provide detailed information on the scientific background of biojet fuels. The oilseed crops that can be used as feedstock for the development of aviation biofuels will be outlined and reviewed on suitability based upon different literature studies. Subsequently, the technology used for processing these oilseeds to biojet fuel will be discussed, paying attention at crushing and refinery processes.

The next section provides analyses results and indicates which actors are active and important in the biojet fuel business. All stakeholders involved in the aviation fuel industry will be discussed and their influence on the transition to a sustainable industry will be determined. This includes a review of the influence of umbrella organizations in the aviation sector, as well as the objectives and influences of the large European and Canadian airlines. Subsequently, the stakeholders will be analyzed according to Porters five (six in this case) forces model and a SWOT-analysis. Based upon these data, a supply and value chain to facilitate the implementation of biojet fuels will be designed.

In the last section, the possibilities for future cooperation between the European Union and Canada will be explored. Canada can use the European policies as an example in developing its own framework, as outlined in the Business section. Taking all information acquired in the Business section into account, the gaps that currently exist in this value chain will be analyzed. Steps to take to develop a coordinated pro-active Value Chain on sustainable implementation of biojet fuels will be outlined in this section. These are the main outcomes of the research.

The final conclusion will provide an integrated overview of the outcomes of the different sections. Altogether this will lead towards answering the initial research question and coming up with a way to facilitate the implementation of biojet fuels in a sustainable manner.

I. Socioeconomics and Politics

Economic, political and societal characteristics of biojet fuels.

Plant-based feedstock absorb CO_2 from the atmosphere as they grow. In using this feedstock as a fuel, CO_2 is emitted back in the atmosphere again. A short carbon-cycle is created this way. On the contrary, in the use of petroleum-based fuels, CO_2 which has previously been locked underground is released again into the atmosphere. This way, CO_2 accumulates, which has many consequences (Kinder, 2009). *Apart from the environmental objectives, economic, political and societal incentives stimulate the search for alternatives to petroleum-based fuels in all sectors* (Hemighaus et al., 2006)*. It is expected that biomass resources are going to play a significant role in meeting the future energy requirements for aviation.*

In this section, the economic , political and societal influences of the so-called biojet fuels will be outlined. In chapter 1, the extent to which biojet fuels contribute to mitigating climate change will be discussed. The future market perspectives of the biojet fuels are discussed in chapter 2, addressing the economics of technology, society, potential markets and logistics. Chapter 3 addresses the political context by focusing on current regulations in the European Union, who is considered a leader in this field and a possible benchmark for Canada.

THE CONTRIBUTION OF BIOJET FUELS TO MITIGATING CLIMATE CHANGE.

There are several reasons for developing biofuels in general, already mentioned in the introduction of this section. First of all, the world will eventually consume fossil fuels, so an alternative has to be designed. The scarcity and unreliability of the current fossil fuels, increases their price. This is another reason for searching for alternatives. Third, burning fossil fuels causes unwanted impacts on the environment, resulting in climate change. One of the requirements for the alternative fuels therefore is a reduction in its environmental impacts. This chapter therefore discusses the relevance of biojet fuel use.

CLIMATE CHANGE

The changing climate is a result of the greenhouse effect. It can be observed in rising temperatures, a rising sea level, floods, droughts, storms and changing weather conditions. The greenhouse effect is strengthened by the emission of greenhouse gases (GHGs). Examples of these gases are carbon dioxide (CO_2) , methane, nitrous oxide and hydrofluorocarbons (HFCs). CO_2 accounts for around 75% of the anthropogenic global warming. These GHGs are emitted by a number of sources. The most important is mankind, in the production and consumption of products GHGs are produced in large numbers. People use fossil fuels, which consist of carbon stored in the earth many hundreds of millions of years ago. Therefore, this carbon is not part of the present carbon cycle. The flows of carbon dioxide emitted these days, cannot fully be absorbed by the forests and oceans, and therefore accumulate to a large extent in the atmosphere. This stock of GHGs in the atmosphere retains heat, which together with the solar radiation results in global warming. The extent of this global warming depends on the climate sensitivity, the responsiveness of the climate system on the rising stock. Climate change is the result of this global warming (Stern, 2008).

The origin and degree of climate change have been studied by different research groups. The current CO_2-concentration is 395.98 parts per million (ppm CO_2e) (Earth System Research Laboratory, 2013). This is rising around 2.5 ppm CO_2e per year or even faster in the future, taking the developing economies of Brazil, India and China into account. For various future concentrations, the temperature change relative to preindustrial temperatures has been calculated. At those future concentrations, the likelihood of different temperature increases are expressed in Table 1-1 (Stern, 2008).

In preindustrial times, the concentration was only 280 ppm CO_2e. In the near future, stabilization is required as the temperature increase has to be limited as much as possible. The costs of stabilization are getting higher at higher concentrations, also dependent on the policy used. To be effective at large scale, action is required in every sector involved in GHG emission.

TABLE 1-1: LIKELIHOOD (IN PERCENTAGE) OF EXCEEDING A TEMPERATURE INCREASE AT EQUILIBRIUM. SOURCE: STERN, 2008

Stabilization level (in ppm CO_2e)	2°C	3°C	4°C	5°C	6°C	7°C
450	78	18	3	1	0	0
500	96	44	11	3	1	0
550	99	69	24	7	2	1
650	100	94	58	24	9	4
750	100	99	82	47	22	9

MITIGATION

Biofuels are a good candidate to contribute in solving the problem caused by fossil fuel use. In this report the focus is on the aviation sector, using biojet fuels derived from industrial oilseeds as a mitigation tool. In growing the feedstock, CO_2 from the atmosphere is absorbed. In burning the crop-derived fuel, this carbon dioxide is released again. The next generation of feedstock will absorb this CO_2 for growing. A shorter carbon cycle is created this way, which allows for a relatively carbon-neutral life cycle. However, additional emissions are made during the lifecycle, for example the equipment used in seeding, growing, harvesting, transporting and processing the feedstock. In

Figure 1-1, the lifecycle of an airplane running on fossil fuels versus one on biojet fuels are shown schematically. Taking these emissions into account, biojet fuel produced out of the oilseed camelina still shows an 84% reduction in emissions over the entire lifecycle (*Beginner's Guide to Aviation Biofuels*, 2009). The Saskatchewan oilseed crops will be camelina and carinata, which will be outlined later in this report. Currently, no life cycle analyses on these crops exist. However, as the crops have the same characteristics as canola, except for being an industrial crop instead of edible, no restrictions are expected (Industry Consortium: Mike Cey and Ron Kehrig, 2013).

The opportunity of camelina and carinata exists to use them as rotational crops. This has additional environmental benefits and the land can be used for production instead of lying fallow (Shonnard et al., 2010). Another external benefit is the protein rich meal, which is a co-product of the biojet fuel. This meal can be used as livestock feed. No extra emissions or commodities have to be addressed to produce this feed.

Other ways in which climate change can be mitigated, are efficiency improvements in aircrafts and systems design, in order to save fuel. Materials could be even more lightweight, and the design aerodynamic (McCollum et al., 2010).

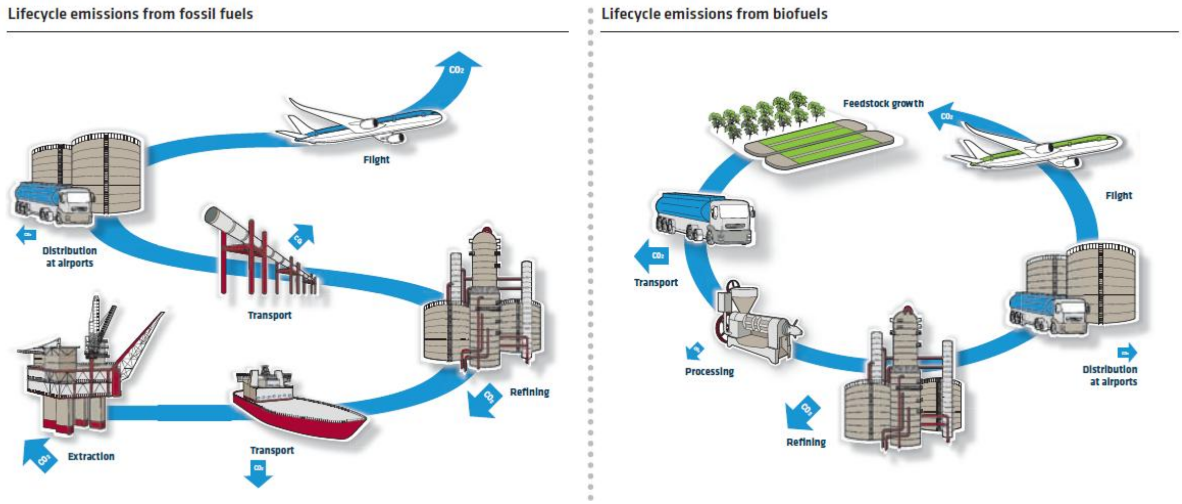

FIGURE 1-1: LIFECYCLE EMISSIONS FROM FOSSIL FUELS USED IN AIRPLANES, VERSUS LIFECYCLE EMISSIONS FROM BIOJET FUELS. AT EACH STAGE IN THE DISTRIBUTION CHAIN, CO_2 IS EMITTED. IN THE CASE OF BIOFUELS THE CO_2 WILL BE REABSORBED TO A LARGE EXTENT AS THE NEXT GENERATION OF FEEDSTOCK IS GROWN. SOURCE: BEGINNER'S GUIDE TO AVIATION BIOFUELS, 2009

2. Biojet fuels in perspective

Technical, economical, societal and sustainability requirements on biojet fuel.

In order to establish a value chain for the biojet fuels at the end of this report, it is important to know what the current value chain of Jet fuels looks like. Current Jet fuels are derived from petroleum. Canada does not fully supply the domestic market for jet fuel, but rather relies on imports from the USA and off-shore. In this section, the production, import and export rate of Canadian fuels will be determined. Within Canada, the fuel transport patterns and the shortages will be identified. Based on these data, the extent to which biojet fuels produced in Canada may replace the petroleum-derived fuels will be explored, both technically and logistically. Subsequently, possible trading patterns with the United States are mentioned. These objectives will help identifying the technical, economical, societal and sustainability requirements of biojet fuels. In Appendix A. an overview of the current situation of Jet fuel can be found. This implies data on the production, consumption, import and export, and data on fuel trade within Canada.

Biojet Fuels as Alternative to Petroleum-derived Jet Fuels

Logistics

After reading Appendix A. it is clear to see that most can be gained in establishing plants in the province of Saskatchewan (Bailey, 2012). At the moment, Saskatchewan, along with Manitoba, is fully dependent on their neighboring regions as they possess no fuel refineries that produce jet fuel. Of benefit in Saskatchewan is that the soil is highly suitable for growing camelina and carinata, and the space for acres is available. On top of that, those provinces are located in a central area for further distribution of the fuels.

A feasibility study has indicated a production plant of 230 million liter per year (MLPY), based on plant equipment and available markets (S. Porter & Saville, 2012). Using current technologies and current yield and oil content averages for camelina and carinata (respectively 40 and 45%), around 1 million acres of arable land would be required for such a production plant. Considering future improvements in seed and oil yields, the needed acreage will reduce to around 780,000 acres (S. Porter & Saville, 2012).

Table 2-1: Potential airport markets for SK-produced biojet fuel. Source: Bailey, 2012

Biojet Markets	Potential volume (million liters/year)	Supply Chain / Transport
Regina / Saskatoon airports	17 / 13	Truck from source to airport storage.
Winnipeg Airport	65	Truck (rail in longer term) from source to airport storage.
Calgary Airport	250	Truck or rail from source to airport storage.
Department of National Defense – Cold Lake	25	Truck or rail from source. Also interest in biofuel development
Other Manitoba, Western Ontario and USA markets	30 ++	Truck and potential rail transport from source to airports.
Total Potential Market	400 +	

The current Jet fuel supply to Saskatchewan occurs by pipeline to Regina, the fuel is then distributed by truck and railway to the rest of the province. Turning this around, the SK-produced biojet fuel could be supplied to other regions the same way. The potential short-run airport markets for SK-biojet fuel are outlined in Table 2-1. The potential volumes are determined by taking into account the 50%-blending ratio, so 50% of the current markets of the represented airports (Bailey, 2012). In the supply of the biojet fuels important actors like Esso and Apron should be considered, as they mostly control the infrastructure around fuel distribution at small airports. At the eight large Canadian airports like Calgary and Winnipeg, the airlines own and control the infrastructure (Ehman, 2013). This is less of an entry barrier. Negotiation between Shell/Apron, the airline company and biojet supplier is necessary. Governmental intervention can form an important part in facilitating implementation here. Airlines usually have more than one supplier for security of supply. An extra supplier therefore is welcome to the supply chain, as long as its potential supply volume is large enough at a given point.

The transport mechanism that is most likely to be used to transfer the SK-biojet fuels at this time, is trucking. Trucking is a flexible way of transport, as well in potential volume as in just-in-time delivery. Capital costs are relatively low compared to pipelines or railway. On top of that, all possible customer points have the opportunity to receive trucked products as the infrastructure is already established. Processing costs are slightly higher for trucking than for railway or pipeline transport. The railway infrastructure is not fully developed yet and it is expensive to build distribution and receiving infrastructure, so additional unloading costs and risks would have to be taken into account. The same holds for pipelines, the present infrastructure is not sufficient so the costs of a new pipeline would need to be factored. (Bailey, 2012)

Next to the biojet fuel potential within Canada, there is a large potential for distribution abroad in the long term. The easiest accessible regions are the Northern US-regions. In terms of fuel distributions, the United States are divided into five Petroleum Administrative Defense Districts (PADDs) (U.S. Energy Information Administration, 2013). At this moment, Atlantic Canada has developed trading patterns with PADD 1, the East coast of the USA. Geographically seen, future Canadian biojet fuel supply regions can be the mid-northern states of PADD 2 and 4 (the Midwest and the Rockies). Other US regions are more likely to import fuel shortages from Asia. For distributing biojet fuel to PADD 2 and 4, the price has to be competitive.

Potential trading patterns for Canadian biojet fuels with Europe will be explored August 2013. This is part of the same research, but will not be included in this report.

Jet fuel pricing

In order to have commercial success and be available at large scale, biojet fuel prices have to be competitive with the price of petroleum derived Jet A-1 fuel. In collaboration with Ag-West Bio, several financial analyses have been done (Ag-West Bio Inc., 2012b; Bailey, 2012; S. Porter & Saville, 2012). It has to be said that feedstock prices, co-product prices, capital costs and utility demands for processing plants are still very uncertain, what makes it impossible to do an absolute analysis.

Crude oil prices are closely correlated with biofuel prices. Several reasons could be pointed out for this. First of all, fossil fuel is the raw material for a large range of products. Most important here are diesel, gasoline and Jet A-1 fuels. When fossil fuel prices rise, Jet A-1 fuel prices will rise too. As a consequence, the demand for relatively cheaper alternatives, possibly biojet fuel, will increase. An increase in demand can cause an increase in price. A crop that is priced and acts relatively the same on the market as camelina and carinata, is soybean (International Bioresources Research Group, 2012). In Figure 2-1, the soybean and crude oil prices of the past ten years are displayed. It can be seen that the two are closely correlated, the correlation

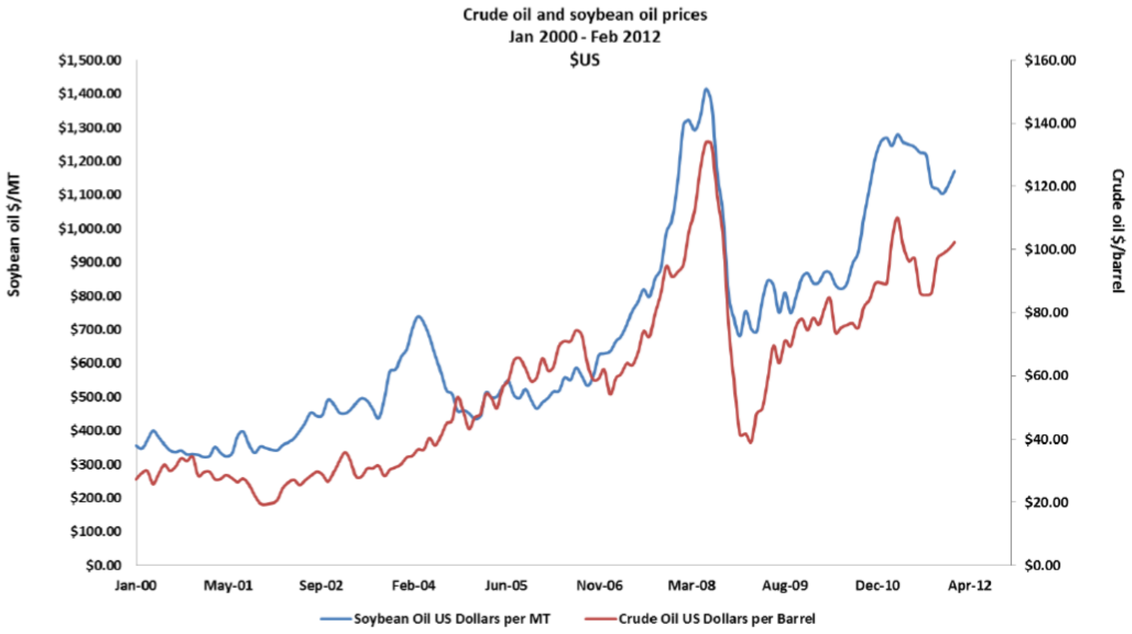

FIGURE 2-1: SOYBEAN AND CRUDE OIL PRICES IN US$ FROM 2000 - 2012. SOURCE: IFS, 2012

coefficient is estimated at 0.9 (International Bioresources Research Group, 2012; International Financial Statistics, 2013). A second explanation for this correlation lies in the price of diesel and gasoline that is affected by crude oil prices. Diesel is used in cultivation of the oilseed feedstock, and gasoline in the transportation of the feedstock and later the oil. Volatility in these production and transportation costs influence the price of the feedstock and biojet fuel. To become more aware of all costs involved in determining the price of oilseeds, an analysis has been made. This analysis includes the price of the oilseeds according to field production, transportation, and production costs. The costs of refining the oil is determined, taking into account all necessary materials. Also, the price (and therewith the income) of the produced biojet fuel and it's co-products is determined. This is displayed for camelina and carinata in Appendix B.

According to the results of the analysis in Appendix B, biojet fuels out of camelina and carinata can be competitive with Jet A-1 fuels. According to their green character, tax exemptions or subsidies can be expected too on the short term. On top of that, engines will be more efficient in the future, which lowers operational fuel costs. However, this also counts for fossil fuels so does not contribute to the competitive advantage.

Aviation in 2050

The market of biomass feedstock is going to increase significantly, seen the many end-uses such as biofuel, food, animal feed, chemicals and other natural products. It is assumed that by 2050, aviation runs 100% on biojet fuels, giving that current test flights are already successful (Agrisoma Biosciences Inc., 2012a). These fuels won't all be derived from camelina and carinata, but comparable feedstock also requires the use of land to grow. The aviation-sector world-wide is expected to rise with 5% yearly, though the demand of Jet fuel is expected to relatively decrease with 50% due to efficiency and aerodynamic improvements of the aircrafts (Rosillo-calle, Teelucksingh, & Seiffert, 2012). Despite of this decrease in demand, the availability of biomass in 2050 should be regulated thoroughly to avoid surprises and to preserve security of supply and fuel quality. Given that the aviation industry is aimed to be operating carbon-neutral by 2050 and fuel costs will decrease, their competitiveness will increase significantly.

EU-policies in relation to biojet fuels.

The European Union (EU) is seen as a leader in global environmental politics, due to their rapid emergence of green policies over the last few years. The EU is known for its ambitious targets regarding GHG reduction through the development of alternative energy sources (Afionis & Stringer, 2012). These targets are set in different progressive policy schemes, wherein the focus is for a great deal on the transport sector. Sustainability plans and studies solely for aviation have been developed, those may provide insight in the design of future biojet fuel policies with potential value for North-America. Europe has the objective to 'lead by example', taking leadership in international negotiations in order to shape and motivate global practice in this field.

Historical background

With the introduction of the Kyoto Protocol in 1997, the phenomenon of climate change began its rumors in the European politics. Governmental activities to reduce GHG emissions were undertaken in different fields and on different scales. Several factors have supported the EU to develop itself as a role model in climate change governance (Afionis & Stringer, 2012). First of all, climate change seemed to be inspiring to the public to reinforce legitimacy of the EU. It could provide a catalyst towards reaching goals such as 'spurring technological innovation, increasing energy security and creating jobs' (Jordan, Huitema, & Van Asselt, 2010). Enhancement of an innovative and competitive EU industrial sector is one of the key drivers for biofuels. Those are products with relatively advanced and innovative production processes, plus the creation of highly educated employment. On top of this, agriculture in the EU is supported by the production of biofuels, creating lowly educated employment (Londo et al., 2010).

Subsequently, the development of climate and sustainability policies addressed concerns on energy security. As transport is the sector with the highest fuel import dependency and it is given that peak-oil is not far away, there is a high ambition level for biofuels (Londo et al., 2010). In its energy strategy, the European Commission (EC) focused on three core principles: *security* (availability of supply), *competitiveness* (referring to price affordability) and *sustainability* (an environmental dimension) (Egenhofer et al., 2006).

The first and foremost driver for the development of sustainable policies is climate protection. Renewable energy is used to reduce GHG emissions and increase energy efficiency, as discussed in chapter 1. Climate Change Mitigation. Within climate protection, biodiversity is addressed. A loss of biodiversity is for some an argument against the use of biofuels, but there are measures aiming at the prevention of such effects (Londo et al., 2010).

In 2001, when the Kyoto Protocol was already set, Europe's progress in meeting the reduction targets was poor. To reinforce the implementation and meet its 8 percent reduction objective, the EC had to take action. They identified biofuels as a key future energy source for transport (Afionis & Stringer, 2012). The current transport system was almost completely running on oil, so biofuels would fit into this infrastructure. On top of that, the petroleum oil was originating from Russia and the Middle East, which are politically unstable regions. Biofuels would help in addressing energy security issues. A Directive on biofuels was developed in 2003 and again in 2009, as a coherent EU policy. Policy mechanisms on biofuel promotion included subsidization schemes, tax exemptions, funding for R&D projects and encouragement of biofuel feedstock production. According to the 2003 Directive, by 2005 2% of the produced or imported fuel should be renewable and by 2010 the target was 5.75%. These targets were non-binding for the member states, which turned out in not fully meeting them. Therefore, in 2009 new targets were set, mandatory this time. By 2020, a minimum of 10% of the produced and imported fuel has to be renewable, meeting the sustainability criteria of the Roundtable on Sustainable Biofuels. Biofuels still are the main source of renewable energy in transport. The sustainability criteria include that the feedstock cannot be derived from primary forests, lands with high biodiversity value, protected territories and carbon-rich areas. These are considered non-tariff trading barriers. The biofuels also have to emit at least 35% less GHG than the replaced fossil fuel(European Parliament and Council, 2009b).

Canadian biojet fuel policy

Geographically seen, North-America (NA) consists of Mexico, the United States (US) and Canada, but here is referred to the US and Canada only. There is said to be a North-American Union (NAU), but this is far from the operational intensity the EU knows. Though, the countries do undertake environmental projects together. An example is the Air Quality Agreement 1991. To prevent trans-boundary air pollution, emissions had to be reduced. Another example is the North-American Agreement on Environmental Cooperation (NAAEC) 1994, which aims for protection of the environment and measurements for continuous improvement. To make sure the policies were implemented, the Commission for Environmental Cooperation (CEC) was established. In practice, only few progressive policies in the field of biofuels are operational. Both countries are not participating in the Kyoto Protocol. In general, the development of a Canadian governmental policy on GHG emissions reductions will wait for the US to act first. The Canadian government will subsequently harmonize with the US policy. This position is highly criticized by environmentalists as well as nationalists because of the lack of leadership and progressiveness (Sawyer & Fischer, 2010).

Under the National Round Table on Environment and Economy (NRTEE), Canada has also set its targets. A non-mandatory 17% reduction of GHG emissions based on 2005 levels by 2020. In a 2012 report the progress was determined in the form of a reality check, and it appeared that significant steps have to be taken on short notice to reach the target (National Round Table on the Environment and the Economy, 2012). The NRTEE has ceased operation as of March 2013.

Current state

The European Union is progressive in its policies towards sustainable development. In terms of biofuels, the main directives are the Renewable Energy Directive 2009 (RED) and the Fuel Quality Directive (FQD). Following upon these directives, lots of initiatives and implementation plans at various levels have been developed and published. In this section, first the main objectives of RED and FQD will be outlined. Recently, both directives have been revised. The outcomes of this review will be described as well. Next, all actions currently undertaken within the EU in the field of biofuels, will be extensively discussed.

Renewable Energy Directive 2009/28/EC

The RED 2009 builds upon the directives 2001 and 2003. The main aim is to promote the use of energy from renewable sources by setting mandatory targets for Member States. The mandatory targets provide certainty for investors and to encourage continuous development. Within the directive, important points are promoting the security of energy supply, promoting technological development and innovation and providing employment opportunities and regional (rural) development. Within the EU, the individual targets for each Member State differ. Past efforts in using renewable energy, the renewable energy potential, energy mix, energy consumption and GDP are taken into account to provide a starting point with weighted mandatory targets. Though, the renewable energy target in transport, which is central to this research, is set at the same level for each Member State (European Parliament and Council, 2009b). This is necessary to ensure consistency in transport fuel specifications and availability. Trade in transport fuels across Europe is not expected to cause any problems.

In short, the outcomes of the Renewable Energy Directive are the following (European Parliament and Council, 2009b).

- By 2020, the total share of renewable energy sources (RES) in final energy consumption has to be 20% in the EU. The distribution over the Member States depends on different national factors, so-called burden sharing. Among this 20%, 10% addresses the use of renewable energy sources in transport, mandatory for each Member State. Also, the energy efficiency has to be increased with 20% by 2020.
- The biofuel-feedstock cannot be derived from primary forests, lands with high biodiversity value, protected territories and carbon-rich areas. Compliance of these sustainability criteria has to be reported. Biofuels derived from degraded or contaminated land receive a bonus of 29 g CO_2eq/MJ. Biofuels from waste, residues, non food cellulosic material and lignocellulosic material will count twice in working towards the RES transport target.
- The minimum GHG reduction of biofuels has to be 35%, from 2017 on this has to be 50%. New installations require a minimum GHG reduction of 60% from 2017 on.
- It is proposed to incorporate indirect land use changes by the end of 2010. Also, by this time National Renewable Energy Action Plans of the Member States are required.

The Renewable Energy Directive will be approached in harmony with the Fuel Quality Directive discussed next.

Fuel Quality Directive

The aim of the Fuel Quality Directive (FQD), is to achieve a better air quality that does not have significant negative impacts on human health and environment. For this, the emissions of harmful air pollutants such as sulphur and carbon dioxide have to be reduced. In the FQD, minimum specifications for petrol and diesel fuels are established (European Parliament and Council, 2009a). One of the key objectives within the FQD is minimizing the consequences of indirect land use change (iLUC). This concept will be explained in the Science section. Several possible policy elements have been set up for countries to mix with. An example of these policies is the introduction of an e-iLUC factor in the calculation of external GHG emissions caused by biofuel production. Also, the minimum required level of GHG savings could be increased, which would compensate partly the additional emissions caused by iLUC. This increase could be combined with a bonus for cultivation on unused or idle land (The Netherlands, 2009). Either of those policies could be merged with an extended use of bonuses. Next to degraded or contaminated land, also biofuels cultivated on unused or idle land should receive the bonus of 29g CO_2eq/MJ. Internationally, action can be undertaken in establishing sustainability criteria for other biomass sectors and incorporating European measures. Protection of primary forests, lands with high biodiversity value and carbon-rich areas has to be extended to the international level, this helps addressing iLUC (European Commisson, 2010; The Netherlands, 2009).

In short, the outcomes of the Fuel Quality Directive are the following (European Parliament and Council, 2009a).

- The environmental quality standards are tightened further for certain fuel parameters.
- A mechanism is introduced in order to report on the reduced GHG emissions along the fuel life cycle. The energy supply has a binding reduction target of 6%, which will rise to 10% in the future. Other technological advances in electricity transport and other energy sources than oil have a reduction target of 2%. Energy and environmental aspects of biofuel development are coordinated in sustainability criteria.
- By the start of 2011, the sulphur content of inland waterway fuel has to be reduced to 10ppm.
- More widespread use of ethanol in petrol by setting the 10% target towards E10 petrol. Vapor pressure in these blends are subject to approval, seen socio-economic and environmental impacts such as air quality.
- The allowed biodiesel content in diesel is increased to 7% (B7), more is possible with consumer info.

Both directives have a lot in common, the main difference is that the FQD focuses on (bio)fuels. In the review, the food versus fuel issue is addressed. The amount of food crop-based biofuels that is allowed to contribute to the reduction target is limited, so more has to be invested in second generation biofuels. On top of that, biofuels produced from second and third generation feedstock not creating an additional demand for land, will contribute more towards the 10% renewable energy target in transport. Subsequently, instead of working towards 2020 targets, perspectives have to be ahead of this time path to secure long-term GHG reduction and renewable energy supply.

Aviation Biofuel Policies and Initiatives

Above discussed directives set the targets that have to be achieved in order to mitigate climate change, but it has to be assured that these targets are actually reached. Several options and mechanisms to accomplish this are offered, but true implementation still has to occur.. The risks in this industry includes that Business as Usual (BAU) is maintained and no serious or coordinated changes are made in the production of food and fuel. Opportunities, in order to address these risks, can be achieved through good governance(Faaij & Dijk, 2012). This is why targets are set. To prevent Business as Usual approaches, the development of regulations and incentives to implement and achieve the targets is very important. Several of such mechanisms, on various levels and within the various industries, are discussed in Appendix C. Here, just a few of them will be mentioned.

The various developed sustainability frameworks can be found on the international, national and regional level. These initiatives can be governmental as well as non-governmental (NGO). Examples of all sorts are the OECD Roundtable on Sustainable Development, International Civil Aviation Organization (ICAO), Global Bioenergy Partnership, Renewable Transport Fuel Obligation (UK), Biofuel Sustainability Ordinance and ISCC

(Germany), Cramer Criteria and NEN (Netherlands), Sustainable Biomass Consortium, Strategic Energy Technology (SET) Plan, Council for Sustainable Biomass Production, European Advanced Biofuels Flight path Initiative, Initiative Towards sustAinable Kerosene for Aviation (ITAKA) et cetera ("European Biofuels Technology Platform," 2013). Please note that this list is far from being complete. As mentioned, several of these mechanisms will be partly outlined in the appendix of this section, focusing on their contribution to sustainable aviation. RSB is built around twelve principles that are considered to be the basis of sustainable biomass production. These are listed and explained in Table 3-1 (Roundtable for Sustainable Biofuels, 2010). These principles are being considered to underlie all discussed policies.

TABLE 3-1: PRINCIPLES AND CRITERIA OF THE ROUNDTABLE FOR SUSTAINABLE BIOFUELS. SOURCE: RSB, 2010

	Principle	
1.	**Legality**	Laws and regulations have to be followed
2.	**Planning, Monitoring and Continuous improvement**	of sustainable biofuel operation, using an open and transparent impact assessment and management process and an economic viability analysis.
3.	**Greenhouse Gas Emissions**	As biofuels have reduced lifecycle GHG emissions compared to fossil fuels, the contribute significantly to climate change mitigation.
4.	**Human and Labor rights**	cannot be violated by biofuel operations.
5.	**Rural and Social Development**	Biofuel production can contribute to the social and economic development.
6.	**Local food security**	food security has to be maintained or improved.
7.	**Conservation**	Negative impacts on biodiversity and ecosystems have to be avoided.
8.	**Soil**	Soil health has to be maintained and degradation reversed.
9.	**Water**	The quality of surface and ground water resources has to be maintained or enhanced and supply secured.
10.	**Air**	Air pollution from biofuels will be minimized along the supply chain
11.	**Use of technology, Inputs, and Management of waste**	Production efficiency will be maximized, while societal and environmental risks will be minimized.
12.	**Land rights**	Land rights and land use rights will be respected by biofuel production and use.

FUTURE POLICY OUTLOOK

The future of biofuels is dependant of numerous factors. First of all, the last steps in testing have to be undertaken before certification is complete. Technologies for especially the conversion of second and third generation biomass have to be developed further. From this point on, biofuels meet the RSB sustainability criteria and can be introduced into commercial flights on large scale. Next, feedstock has to be grown to ensure a steady supply that meets the demand of biofuels. The biofuel supply for aviation cannot influence the amount that can be supplied to other forms of transport. The biorefineries have to be in place to produce biofuels, and they are required to have the facilities to make jet fuel blends. To be sure the biojet fuel can compete with petroleum-derived Jet fuel, the costs have to be indicated to set the right price. Probably, at least in the upcoming years, the government has to assist financially to provide incentives for industry to produce and distribute enough cost-competitive fuel. It is clear that effort from all stakeholders is needed to make the transition towards a biojet fuel-based transport system. These include governments, energy companies, airlines and the agricultural sector (*Beginner's Guide to Aviation Biofuels*, 2009). In chapter 6. Stakeholders and appendix E. all involved stakeholders are outlined and mapped.

An interesting question is what it will take to meet the objectives that are set. As the world outside of the European Union is not yet actively reducing emissions, is it realistic for the EU to meet its directives within the set time span? Though the objectives are relatively ambitious, the answer is yes. The policy is developed for use within the boundaries of Europe, only addressing the emissions within the EU. The fact that the targets are ambitious remains, so the policy has to be implemented strictly with support of all stakeholders. Though, in order to achieve beneficial effects for the world as a whole, more intense activities outside Europe's boundaries are required. Europe can function as a role model in developing policies to achieve this.

Intermediate Summary Socioeconomics and Politics

In this section the socio-economical and political situation have been explored to indicate the need and the broader context of biojet fuels. In growing oilseed feedstock, CO_2 from the atmosphere is absorbed. In burning the crop-derived fuel, this carbon dioxide is released again. The next generation of feedstock will absorb this CO_2 for growing. This shorter carbon cycle allows for a relatively carbon-neutral life cycle. Biojet fuel produced out of the oilseed camelina, grown in Saskatchewan, shows an 84% reduction in emissions over the entire lifecycle (*Beginner's Guide to Aviation Biofuels*, 2009).

Saskatchewan and Manitoba currently fully rely on import of Jet A-1 fuel (Bailey, 2012). Here lies an opportunity for regionally produced biojet fuel. Once biojet fuel becomes economically competitive with conventional petroleum-based Jet-A1 fuel, this can provide a significant solution for the current fuel shortage and dependency. Current infrastructure is suitable for distribution of biojet fuel, wherein trucking appears to be the most appropriate transport mechanism seen its flexibility in volume and just-in-time delivery and the relatively low capital costs. According to the financial analysis of a 230 MLPY refinery plant, biojet fuels out of camelina and carinata can be competitive with Jet A-1 fuel in the near future, considering crop improvements and further development of refinery technologies (S. Porter & Saville, 2012). In the short term, Canada is an important region to map, but in the longer run biojet fuel export outside of Canada may be an opportunity as well.

Canadian bio(jet) fuel policies are not yet highly in place. There exists a non-mandatory 17% reduction target of GHG emissions based on 2005 levels by 2020, but the progress to date is little (National Round Table on the Environment and the Economy, 2012). Also, some funds are available to support research and implementation in this field. The focus of the biofuel policies of the European Union is on three core principles: *security* (availability of supply), *competitiveness* (referring to price affordability) and *sustainability* (an environmental dimension) (Egenhofer et al., 2006). The Roundtable for Sustainable Biofuels (RSB) has established twelve criteria that are considered to be at the basis of sustainable biomass production. If biofuels meet these criteria, they operate within the core principles and are approved as renewable fuel source (Roundtable for Sustainable Biofuels, 2010). Subsequently, the EU has set mandatory targets for her Member States within the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD). Among others; by 2020 20% of all energy consumption has to be sustainable, food competition is not accepted and the consequences of (in)direct land use change have to be limited (European Parliament and Council, 2009a, 2009b). In order to achieve beneficial effects for the world as a whole, more intense activities outside Europe's boundaries are required. Europe can function as a role model in developing policies to achieve this.

II. Science

The scientific background of biojet fuels.

It is expected that biomass resources are going to play a significant role in meeting the future energy requirements for aviation. Technologies are in place for developing renewable jet fuels out of various feedstock. The question is which technologies will provide the most advantages, as well economically as environmentally, and what feedstock is used in this. In this section, the most promising feedstock and processing technologies for Saskatchewan will be outlined.

In the following chapters, the scientific background of the so-called biojet fuels will be outlined. In chapter 5, the feedstock suitable for biojet fuel production is reviewed, taking into account the quality requirements of jet fuel. In the next chapter, the technology for processing this feedstock is worked out in detail, as well as its chemical composition.

CROPS SUITABLE FOR BIOJET FUEL PRODUCTION AND THEIR OUTLOOK.

Air transport accounts for 2-3% of all the CO_2-emissions, and the sector is growing (*Beginner's Guide to Aviation Biofuels*, 2009; McCollum et al., 2010). Jet fuels, the fuels used in aviation, are mostly kerosene-based. The most common used jet fuels which satisfy international standards are Jet A and Jet A-1. Jet A-1 fuels must meet the requirements of the British specification DEF STAN 91-91 (Jet A-1), ASTM specification D1655 (Jet A-1), and IATA Guidance Material (Kerosene Type), NATO Code F-35. Among others, freeze and boiling points are required to be within a fixed range, related to the chain length of the hydrocarbons. In jet fuels, typically C_{8-16} (iso)-paraffins are used. In Figure 4-1, the Jet A-1 fuel characteristics are expressed in the first column (UOP LLC, 2011).

FEEDSTOCK CHARACTERISTICS

Given their energy content, petroleum-based fuels such as Jet A-1 are preferred over other substitutes. However, recent instabilities and increases in petroleum prices, and concerns about environmental effects and energy security have supported the search for alternatives. Biomass seems a good candidate as a fuel resource, addressing these objectives. To be suitable for use in the existing engines, these so-called biojet fuels must have a similar chemical composition as the aforementioned Jet A-1 fuels. This is called drop-in fuels. This also facilitates potential blending opportunities. Subsequently safety requirements, cost competitiveness and sustainability are considered. The time it takes for the crops to mature, as well as the crop yield, seed oil concentration and oil yield are reflected on (Blackshaw et al., 2011). There are several additional issues that have to be taken into account facing the development of the biojet fuel industry. The several crops suitable for biojet fuels will be outlined next, but here it can be said that food security and related land-use are some of the major concerns. Therefore the conflict with food cultivation should be avoided by using second-generation biomass. Besides, people fear for competition in land for food and fuels, which may lead to a rise in food prices. An important aspect of biojet fuels is the reduction of greenhouse gas (GHG) emissions. In growing the crops, CO_2 from the atmosphere is absorbed. In burning the crop-derived fuel, this carbon dioxide is released again. A shorter carbon cycle is formed this way, which allows for a relatively carbon-neutral life cycle. Another concern is indirect land use change (iLUC) impacts. When forest is converted to agricultural land, this contributes to climate change as CO_2 will be absorbed in a lesser extent. Even still, biofuels are considered to produce approximately 80% less CO_2 throughout their entire life cycle. All these additional issues will have to be faced when developing sustainable biojet fuels. (*Beginner's Guide to Aviation Biofuels*, 2009; Hemighaus et al., 2006)

For producing fuels out of biomass, different feedstock can be used. For example algae, green waste material and oilseed crops. In this research, the focus is on oilseed crops, producing fuel from vegetable oil. In a scientific research by R.E. Blackshaw et al. (2011), the following crops have been taken in consideration: napus canola, Camelina sativa, oriental mustard, juncea canola, flax, soybean, rapa canola, yellow mustard and Brassica carinata (or Ethiopian mustard). Considering yield and oil concentration, the oilseed crops with the highest potential as biofuel feedstock were camelina, flax, rapa canola and oriental mustard. Ethiopian mustard (carinata) is promising as well, especially for use in biojet fuels. (Blackshaw et al., 2011) Unfortunately, crops such as flax and canola incorporate competition with food markets. This would not fit in (future) policies. Therefore the focus lies on the non-edible vegetable oils, and in this research camelina and carinata seem to be the most suitable crops for this. In the next two paragraphs their characteristics will be outlined thoroughly, in Figure 4-1 the biojet fuel properties are compared to those of Jet A-1 fuel (UOP LLC, 2011).

Green Jet Fuel Properties

Properties	Jet A-1 specification	Honeywell Green Jet Fuel Bio-synthetic paraffinic kerosene (bio-SPK) made from camelina	50/50 Blend of camelina bio-SPK & Jet A-1
Flash point, °C	Min 38	45	46
Freeze point, °C	Max -47	-57	-57
Net heat of combustion, MJ/kg	Min 42.8	43.9	43.6
Thermal stability (JFTOT)			
• Filter pressure differential, mm Hg	Max 25	0.0	0.0
• Tube deposit rating (visual)	Max 3	1	1
Aromatics, % volume	Max 22	<0.3	8.5
Sulfur, % mass	Max 0.3	<0.001	0.05

FIGURE 4-1: PROPERTIES OF JET A-1 FUEL, BIOJET FUEL OUT OF CAMELINA AND A BLEND OF BOTH. SOURCE: UOP LLC, 2011

CAMELINA SATIVA

Camelina sativa (camelina) belongs to the *Brassicaceae* family. The crop has been grown in Europe and Asia during the Bronze Age and Middle Ages. It was used for many purposes varying from lamp-oil to soap. (Pilgeram et al., 2007) In North America, the crop has been introduced only recently, and cultivation is still increasing. Doing research, improvements have been made on seed yield, seed size and oil content of the seeds, as well as on disease resistance. The current oil content is slightly higher than 40% of the total weight, but is expected to rise to at least 45% in the upcoming years (Ag-West Bio Inc., 2012b). The camelina-oil has a unique fatty acid profile. The oil will be used as biofuel feedstock, and valuable co-products can be produced from the rest of the seed. Most important is the protein-rich meal, optimized for use as animal feed. The meal has not yet been approved for use as livestock feed in Canada, which means there is no Canadian market yet. The Feed Innovation Institute (FII), based at the University of Saskatchewan in Saskatoon, is doing research upon the suitability of the meal for approval as livestock feed (Canadian Food Inspection Agency, 2011). Table 4-1 and Table 4-2 respectively display the nutrients composition and the amino acid profile of the camelina meal (S. Porter & Saville, 2012). For economically feasible production, meal approval is required. In the United States meal approval already exists for beef cattle, swine, broiler chickens and laying hens (Church, 2012).

Camelina has several advantages as a crop. First of all, the crop is relatively disease resistant. For example resistance has been found to flea beetles (Henderson, Hallett, & Soroka, 2004), the cabbage root fly, Diamondback moth, the mustard sawfly and the pollen beetle (Deng, Yun, Zhang, Xu, & Cal, 2004; Onyilagha et al., 2012), alternaria black spot and blackleg. Resistance to diseases such as white rust and clubroot have not yet been identified, though the new developed cultivars are likely to be resistant. (Ag-West Bio Inc., 2012b) Another important advantage of camelina is it's extraordinary drought and heat tolerance. It's a short-season crop. These characteristics fit well within the climate of the Canadian Prairies (Newlands & Townley-Smith, 2012). Camelina is highly recommended for use as a rotational crop on fallow land of wheat. This brings several benefits. First of all, soil moisture is conserved, which provides higher crop yields the following year. Second, by alternating crops, pest problems and disease potential are reduced. Third, a positive change in the nutrient profile of the soil takes place. (Shonnard et al., 2010) Also, by using the fallow-cropping approach, the concern about food security decreases.

TABLE 4-1: MEAN VALUE OF THE NUTRIENT AND MINERAL CONTENT OF CAMELINA MEAL. SOURCE: PORTER & SAVILLE, 2012

Dry Matter (%)	98
Protein (%)	33
Fat (%)	17.8
Calcium (ppm)	2597
Phosphorus (ppm)	12231
Potassium (ppm)	14879
Sodium (ppm)	17.6
Chloride (ppm)	18.7

TABLE 4-2: MEAN VALUE OF AMINO ACID PROFILE OF CAMELINA MEAL. SOURCE: PORTER & SAVILLE, 2012

Amino acid	(%)
Arginine	2.72
Cysteine	1.07
Lysine	1.56
Methionine	0.95
Threonine	1.23
Tryptophan	0.34

BRASSICA CARINATA

Brassica carinata L. (carinata) belongs to the *Cruciferae/Brassicaceae* family. The crop finds its origin in East Africa, and is often referred to as Ethiopian mustard (Blackshaw et al., 2011). As with camelina, carinata is known for its high heat and drought tolerance, so it can be grown on soil where other crops would not survive. In Saskatchewan, it is suitable to be grown in the semi-arid region of the south-west (Agrisoma Biosciences Inc., 2012b). Research and field-trials are done to increase the oil yield and content. The current oil content is slightly higher than 40% of the total weight, but is expected to rise to at least 45% in the upcoming years (Ag-West Bio Inc., 2012b). The oil has many health benefits, but due to the high concentration of glucosinolates and eruic acid, food-use is limited (Mnzava & Schippers, 2007). This makes carinata a good candidate as an industrial oilseed crop for use in biofuels. In Africa, the meal has already been used to feed livestock for a long time. In Canada carinata is only now commercially available, so the meal has not been approved to feed animals yet. The Feed Innovation Institute is doing research upon the suitability of the meal for approval as livestock feed (Canadian Food Inspection Agency, 2011). For economically feasible production, meal approval is required. The maturity period of carinata is mid- to longterm. Though, the crop is highly suitable for use as a rotational crop on fallow land, replacing other oilseed crops. This lowers the chance for diseases. The crop is relatively disease restistant. For example, carinata has increased resistance to Alternia brassicae (black spot), Sclerotinia sclerotiorum (Yang, Rahman, Liang, Shah, & Kav, 2010) and Leptosphaeria maculans (causes blackleg) (Subramanian, Bansal, & Kav, 2005). Also carinata shows resistance to white rust (Warwick, Gugel, McDonald, & Falk, 2004), aphids and flea beetles (Johnson et al., 2011). Clubroot, however, can cause damage (Hasan, Strelkov, Howard, & Rahman, 2012). (Ag-West Bio Inc., 2012b)

This crop is being developed by Agrisoma Biosciences Inc., and traded as Agrisoma Resonance® Energy Feedstock. Advanced crop improvement technology makes sure oil yield and quality is continuously enhanced (Agrisoma Biosciences Inc., 2013).

BIOFUEL QUALITY

The first step in substituting petroleum-derived Jet fuels by biojet fuels, is providing a blend of both. Flights with blends up to 50% are already approved commercially (Hemighaus et al., 2006). Nowadays, successful test flights on 100% biojet fuel are already done (Agrisoma Biosciences Inc., 2012a). In some cases, engines powered on a mix of biojet fuel and Jet-A1 fuel showed an improvement in fuel efficiency. Drop-in biojet fuels have to meet the same American Society for Testing and Materials (ASTM) jet fuel specifications as Jet A-1 fuels. This includes that no separate storage and distribution systems are needed for the biojet fuels, nor do engines have to be adjusted. These specifications and the biofuel quality requirements will be discussed in the section Science. Joint Inspection Group (JIG) and the International Air Transport Association (IATA) are establishing a set of standards on biojet fuels to provide worldwide consistency (International Air Transport Association, 2012). In the near future, blends higher than 50% are possible, as well as pure biofuel flights. (Bailey, 2012)

The security of crop availability has to be determined. The crops are subject to external influences that can reduce the yield. It has been outlined that camelina and carinata are both highly resistant to pests and other plant diseases and show good tolerance to drought. These characteristics may reduce the risk of yield reduction, weather conditions still play an important role. A delayed start of spring can reduce the available time for the crops to mature and too much or too little rain can reduce the yield as well. Alternative energy sources have to be on hand to deal with possible problems like these.

Different parameters exist for determining the quality of biofuel. An oxidation stability of the fuel of three hours is required. Neither of the examined biofuels met this requirement. Though, by adding antioxidant compounds, this deficiency can be corrected. Oxidation stability therefore is not considered as an important limiting factor. A second criterion is cold soak filtration, which means that 300 mL of fuel should pass through a cold soak filter in less than 200 s. In general, this will not be a problem. Another indicator of cold weather performance is the cloud point. For camelina and carinata those are respectively 2.4 and 7.1 ^{o}C. The phosphorus concentration must be under 10 ppm, a criterion which is easily met for both. (Blackshaw et al., 2011) Subsequently, the ratio of n-alkanes, iso-alkanes and aromatics is important (Roberts, 2008). This will be explained in the next section. Meeting these quality criteria, the biofuel is suitable for blending with petroleum-based Jet A-1 fuel. An example is shown in Figure 4-1, third column (UOP LLC, 2011).

BIOMASS CONVERSION AND BIOJET FUEL PRODUCTION TECHNOLOGIES.

In converting biomass to fuel, it is important to be aware of the energy content in units of MJ/kg. This is described by S.C. Capareda (2011). When conversion by combustion takes place, the heating value can be calculated. Biomass typically has heating values ranging from 15 - 25 MJ/kg, which is lower than those of their petroleum-based counterparts. The most common ways of determining the heating value of biomass, are through the Dulong equation and the Boie equation. The heating value is closely related to the composition of biomass, as shown in the equations. The most important elements contributing to the heating value are carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and sulfur (S). More generally this could be stated in terms of compositional contents of the biomass, such as lignin, cellulose and hemi-celluloses, carbohydrates and fat contents. In this report the emphasis is on the fat contents, as vegetable oils from camelina and carinata are used.

The Dulong equation is the following.

$$HV\left(\frac{kJ}{kg}\right) = 33{,}823 \cdot C + 144{,}250 \cdot (H - O/8) + 9{,}419 \cdot S$$

C, H, O and N are the elemental mass fractions in the material. This equation is only valid when the oxygen content of the biomass is less than 10%.

The Boie equation is the following.

$$HV\left(\frac{kJ}{kg}\right) = 35{,}160 \cdot C + 116{,}225 \cdot H - 11{,}090 \cdot O + 6{,}280 \cdot N + 10{,}465 \cdot S$$

Where C,H,O,N and S are the elemental mass fractions in the material. (Capareda, 2011)

As sulphur concentrations are generally lower in biomass feedstock, the Dulong equation will be used for calculation the energy content (*Beginner's Guide to Aviation Biofuels*, 2009). This can be used as a parameter in comparing different feedstock types.

RENEWABLE JET FUEL

Honeywell UOP is one of the strategic players actively seeking solutions for a greener aviation industry, together with Chevron Lummus Global, Agrisoma and Applied Research Associates (ARA) (Kinsaul & Wadsworth, 2013). One of these technology-driven solutions is the production of bio-derived jet fuel, or bio-derived synthetic paraffinic kerosene (Bio-SPK) out of sustainable feedstock, using hydro-processed esters and fatty acids (HEFA or HRJ). The process of producing these fuels is Intellectual Property, and therefore not all information can be published here in detail. The process is already licensed to certain production companies.

The first step is extracting the oil from the feedstock. This is a regular process, which is already used in many crushing plants, for example the Canola-industry, around the world. On large scale, this typically takes place using solvent crush technology. The seeds are mechanically crushed under high pressure, this way press-oil is produced. The meal still contains a lot of oil, and is therefore subjected to solvent extraction by washing with hexane. Oils are highly soluble in hexane, and the formed mixture called miscella is filtered. After this process, the protein meal contains less than 1% of residual oil. The hexane, which has an exceptionally low boiling point (69 ^{o}C) (Sigma Aldrich, 2013), is recovered by distillation and will be used again in next extraction processes. This distillation process is carried out under high pressure and heat is added to make sure all chemical residue is removed. Extraction oil is generated.

To produce biojet fuel suitable for use, the press- and extraction oil have to undergo a refinery process. The mixture consists mainly out of triglycerides and free fatty acids, which have to be converted to molecules with a higher energy content. Energy is created by breaking carbon-carbon and carbon-hydrogen bonds and creating carbon-oxygen and hydrogen-oxygen bonds. This is shown in the following generalized chemical combustion reaction. (Hemighaus et al., 2006)

$$C_xH_y + \left(x + \frac{y}{4}\right) O_2 \rightarrow x\,CO_2 + \left(\frac{y}{2}\right) H_2O + heat$$

In order to raise the energy, oxygen atoms have to be removed from the triglycerides and free fatty acids. Also, olefins (alkenes) have to be converted to paraffins (alkanes) in order to stabilize the molecules. (Kinder & Rahmes, 2009) The Ecofining process by UOP typically involves three steps to achieve these modifications: deoxygenation, selective hydrocracking / isomerization and product separation (Holmgren, 2008). This is schematically shown in Figure 5-1 (UOP LLC, 2011).

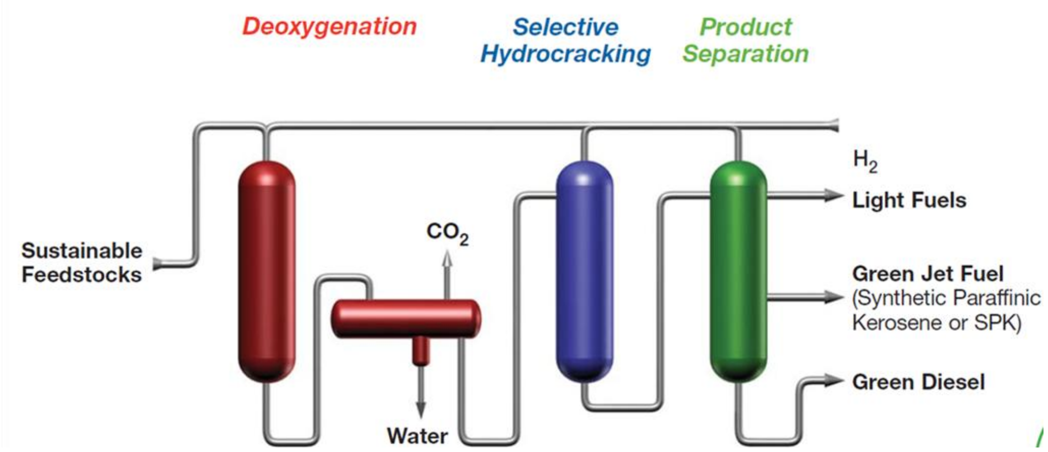

FIGURE 5-1: THE REFINERY PROCESS FOR BIOJET FUEL, CONSISTING OF DEOXYGENATION, HYDROGENATION AND PRODUCT SEPARATION. SOURCE: UOP LLC, 2011

Refinery Process

The refinery process technology is required to be able to process a wide variety of feedstock oils. For example saturated and unsaturated oils plus high and low free fatty acid profiles. This reduces risks in supply/demand dynamics of the oil (Roberts, 2008).

In the first step, deoxygenation, oxygen is removed from the oil. Oxygen has a relatively high molecular weight, which otherwise would lower the energy content of the oil (MJ/kg). UOP has developed a catalyst which facilitates this process. By continuously adding hydrogen to the mixture, a substitution reaction of a hydrogen atom with a

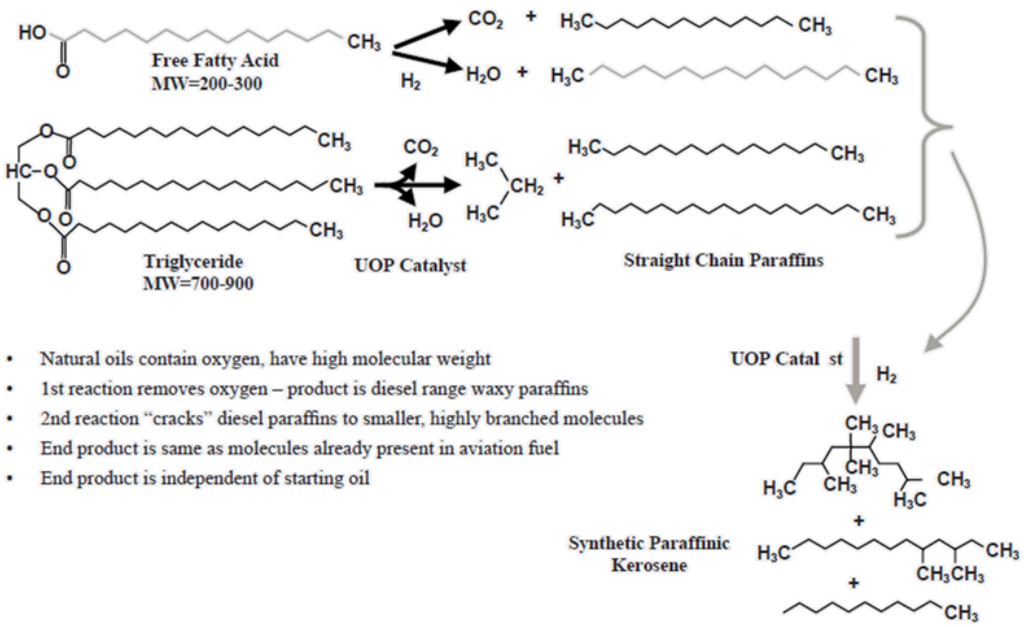

FIGURE 5-2: CONVERSION OF FEEDSTOCK OILS INTO BIOJET FUEL. THIS PROCESS INVOLVES DEOXYGENATION AND DEHYDROGENATION, FOR WHICH TWO DIFFERENT CATALYSTS ARE USED, BOTH PRODUCED BY UOP HONEYWELL. SOURCE: KINDER & RAHMES, 2009

hydroxide-group takes place. Therefore the term hydrodeoxygenation is used often. In this reaction, CO_2 and H_2O are produced as by-products.

The renewable diesel, or straight chain (n)-paraffins, still have to undergo some modification in the form of isomerization in order to be suitable to serve as a fuel. This is the second step, hydrocracking. Hydrogen is removed from the paraffins to produce highly branched (iso)-alkanes with a high energy content, the biojet fuel. These molecules typically have a chain length varying from C_8 to C_{16}. This corresponds with the boiling range of petroleum-derived Jet A-1 fuel (Kinder, 2009). For this process, a successful catalyst is developed as well. (Wang, 2007) In Figure 5-2 the chemical steps of both deoxygenation and hydrocracking are shown. (Kinder & Rahmes, 2009)

The refined product is a mixture of different molecules. Therefore the last step that has to take place is product separation or fractionation. The protein meal has been separated from the oil already before the refining steps. Useful co-products are formed, including green naphtha, green LPG and green diesel or hydrogenation-derived renewable diesel (HDRD). Those co-products have value as well. This mixture is fractionated by distillation, based upon the difference in boiling points of the different products. (Lupton, 2012)

INTERMEDIATE SUMMARY SCIENCE

In this section the focus was on the technological characteristics of the feedstock and the refinery process. Biofuel-feedstock focuses on second-generation non-edible crops. For Saskatchewan these are Camelina sativa and Brassica carinata. Both crops are relatively disease resistant and know an extraordinary drought and heat tolerance (Blackshaw et al., 2011). Together with the possible use as a rotational crop on fallow land, this feedstock is highly suitable to be grown in the Canadian Prairies (Shonnard et al., 2010). For our research outcomes carinata will be used in the form of Agrisoma Resonance® Energy Feedstock (Agrisoma Biosciences Inc., 2013).

The refinery process, as developed by Honeywell UOP, consists of several steps (Kinsaul & Wadsworth, 2013). The first step is crushing the oilseeds and extracting remaining oil by washing with hexane. The triglycerides and free fatty acids in the derived oil have to be converted in high-energy molecules (Hemighaus et al., 2006). This happens in three steps: deoxygenation, selective hydrocracking / isomerization and product separation (Kinder & Rahmes, 2009). The refined product is a mixture of different products, so has to be fractionated. By distillation, the co-products naphtha, LPG and HDRD diesel are obtained (Lupton, 2012).

III. Business and actors: Market analyses and Results

Identification of the need for a framework on biojet fuel in Canada, taking participating stakeholders into consideration.

Before the biojet fuel that is currently produced in small test plants will be produced at commercial scale, a lot still has to be done. One of the main challenges is the high cost, however improvements are being made on the technological level and in operating on larger scale. Canada possesses a large amount of non-food feedstock suitable for biojet fuels, and has the technological knowhow to become a global leader in this field. This is an opportunity for industry and government to work together to power Canadian expertise. However, the country lacks a clear policy focused on the support and development of biojet fuels. Ideally, a department of the federal government should take the lead in developing such a strategy, connecting federal, provincial, industrial and commercial stakeholders. Discussion is occurring, with promising initiatives, but not all stakeholders adequately live up to this. In order to implement the renewable jet fuels over the next five to ten years, a pro-active approach is needed at this very moment (Parliament of Canada - House of Commons, 2012).

In this section, a start is made at the industrial level. Results of analyses are published here. In chapter 6, the support and influence of umbrella aviation organizations will be explored, as well as the motivation and objectives of airline companies itself. Next to these important stakeholders, remaining stakeholders will be mapped and their influence will be determined in the appendix of this chapter. This will lead to an analysis of the power stakeholders have in the market according to Porter's five forces model. Next, a SWOT-analysis will be made. Based on these data, the opportunities for a Canadian framework on biojet fuels will be determined by the design of a supply chain and subsequently a value chain. The European Union can serve as a role model in this, seeing their current position in the field of biofuels. In section II. Socioeconomics and politics, the EU policies on aviation biofuels were discussed. This will be taken into consideration while developing a value chain.

In developing such a pro-active Value Chain, the production of sustainable jet fuel can be accelerated. This way, the aviation industry can achieve significant emission reductions not too long from now. This will strengthen the competitiveness of this industry, meanwhile benefiting the environment.

6. Stakeholders

Objectives of stakeholders regarding sustainable transport and the influence of existing Umbrella Organizations in this.

One of the most important stakeholders in the value chain of biojet fuels is the aviation sector itself. The aviation sector consists of the airlines and their umbrella organizations. Important umbrella organizations are the International Aviation Trade Association (IATA), the International Civil Aviation Organization (ICAO), the Air Transport Action Group (ATAG) and the Sustainable Aviation Fuel Users Group (SAFUG). Airlines can choose to be a member of these organizations, to support their participation in the transition to a greener industry using biojet fuels. These stakeholders and their influence on the development and direction of the aviation sector, will be outlined here. Subsequently, the objectives and policies of the largest European and Canadian airlines will be discussed. These include KLM representing Europe and Air Canada and WestJet for Canada.

Umbrella Organizations

Air Transport Action Group

The Air Transport Action Group (ATAG) is a not-for-profit industry-wide NGO, representing all stakeholders the aviation sector. Among others, these include airlines, airports, plane and engine manufacturers, air traffic controllers, tourism et cetera. ATAG incorporates these individual organizations as its members, and they provide the funding. This diversity in members makes ATAG an independent and credible organization with high influence in international policymaking. Through ATAG, the different organizations can define common positions on main topics, and operate in a coordinated way. ATAG promotes sustainable growth of the aviation sector, taking action on issues concerning the infrastructure and environment harmonized across the industry. Providing information sources and knowhow is an opportunity for their members to develop sustainably. ATAG's Board of Directors consists of representatives of member companies. The Board has set a mandate according to the needs of the global aviation industry, in terms of social, economic and environmental goals. Among others, the aim exists achieve carbon-neutral growth by 2020 and 50% reduction by 2050 (Air Transport Action Group, 2013).

Enviro.aero

Enviro.aero is a global initiative of the aviation industry, developed by ATAG. Within this initiative, the actions of the aviation industry concerning the reduction of emissions are pointed out. As the main developers of this plan are the stakeholders their selves, commitment in succeeding is ensured.

Figure 6-1: Logos of important international aviation organizations

Targets lie within renewable fuel use, fuel efficiency, engine efficiency, design of the aircraft and efficient scheduling of flights .

International Civil Aviation Organization

The International Civil Aviation Organization (ICAO) is developed by the United Nations in cooperation with enviro.aero. It's an intergovernmental body setting global regulations for the aviation sector. In order to achieve environmental targets, it is important to operate at an international level, aligning the national legislations with the international targets. The ICAO is mainly driven by the national governments, so does not have the character of an NGO. Though, next to governments, also companies in the aviation industry are involved in the ICAO. Together the members try to analyze and prioritize areas of interest for further coordinated development. One of these areas is of course reducing emissions in aviation. In a 2010 report, they outlined everything concerning aviation in the environmental field. Improvement of aircraft technologies, operational opportunities, possible economic instruments, alternative fuels and adaptation of the aviation sector. In conclusion, a Programme of Action on International Aviation and Climate change was developed for implementation by all member states and organizations (International Civil Aviation Organization, 2010).

International Aviation Trade Association

Another important body here within is the International Aviation Trade Association (IATA), affiliated with enviro.aero. IATA is the trade association of airlines in the world. In their own words their 'mission is to represent, lead and serve the airline industry' (International Air Transport Association, 2013). IATA represents the interests and goals of the aviation industry in government decisions at the national and global level. Also, IATA has provided standards upon which the aviation industry is nowadays built. This helps achieving efficiency and costs improvements. Third, IATA serves the sector in ensuring safe, secure, efficient and clearly regulated operating possibilities for all stakeholders. In 2012, IATA has set up a report on the current state of the use of alternative fuels in aviation. This report shows what airlines and other involved organizations do in order to receive their targets and what is left to be done (International Air Transport Association, 2012).

SkyNRG

SkyNRG is one of The Netherlands' leading companies in the aviation biofuels sector and is originally founded by KLM, Argos and Spring Associates. They work with World-wide Fund (WWF) and have the support of some of the leading Dutch multinational companies such as Philips, Accenture, DSM, Ahold and Heineken. Those companies can lower their organization's carbon footprint by buying into SkyNRG's green aviation biofuels programme (SkyNRG, 2012). SkyNRG aims to manage the whole chain from sourcing biomass feedstock through to providing the biojet fuel at the airport. They have buy-ins from airlines around the world as well as some aircraft manufacturers such as Boeing. Their initiative is growing towards a world-wide bio aviation chain manager (Faaij & Dijk, 2012).

The company is helping to develop so-called Bio Ports in leading locations in the world where airlines can be guaranteed biojet fuel in sufficient quantity and quality for their needs. SkyNRG has been looking at Canada, considering setting up Bio Ports. (Baguley, 2013).

This is an opportunity for collaboration to develop the Canadian Biojet Fuel Initiative. Discussions with SkyNRG on Value Chain development in Canada have started as a result of this research. This will be outlined further in Chapter 10, Canadian Biojet Fuel Initiative (Osseweijer, 2013).

Airlines

To provide the point of view of the airline companies itself, a telephonic questionnaire has been conducted among the KLM, WestJet and Air Canada. This questionnaire and outcomes of the calls can be found in Appendix D (Osseweijer, 2013).

KLM is an example of a progressive airline. Their influence on the global aviation industry can be of importance (Tweel, 2013). Air Canada and WestJet both are a little more skeptic, but willing to cooperate in the search for alternatives (Ehman, 2013; Tauvette, 2013). In Chapter 10, collaboration between airlines, SkyNRG and biojet fuel suppliers will be discussed (Osseweijer, 2013).

Remaining stakeholders

The biojet fuel industry knows, next to airlines and umbrella organizations, many other stakeholders involved at different levels. There are a lot of mutual links, therefore it is a dynamic industry. A stakeholder analysis is displayed in Appendix E. This analysis applies to a general biojet fuel industry and will be outlined for both the European and the North-American biojet fuel market. This will indicate similarities and points of mutual interest. This stakeholder overview serves to get to know the participants in the industry. Indicated stakeholders are the government, research and development institutes, farmers, franchisiees, non-governmental organizations, financial service providers, joing-venture partners and off-takers. The next two chapters will explore the role and influence of these actors on the development of the biojet fuel market. Chapter 9 will categorize the stakeholders within the value chain that is to be designed for the biojet fuel industry.

An opportunity analysis of the biojet fuel market and its stakeholders

Now that the role of all involved stakeholders in the biojet fuel market are known, shown in Appendix E, it is useful to map their position relative to each other. This will help to indicate the key socio-economic, technological and financial mechanisms that could hinder or promote the implementation of biojet fuels, so-called entry barriers (Vertès, Inui, & Yukawa, 2006). Usually, for these kind of analyses the five forces model of Porter is used (M. E. Porter, 1979). However, in this analysis a sixth force is added, the influence of the government and/or public (Barney, 1991). This because governmental policies could play a significant role in facilitating entering the fuel market. Such a policy could weaken the way supply-and-demand influences the market. Also, the way the model is displayed has been slightly changed. Instead of displaying the competitors in the same category as the market itself, this is displayed as a force on its own. This decision is made because competitors, suppliers and off takers are thought to operate individually and do not necessarily influence each other in their decisions (Barney, 1991).

The six forces are: Suppliers, End Users, Government/Public, Competition, New Entrants and Substitutes/ Complementary Products. Through a strategic analysis, the attractiveness of developing the biojet fuel market in Canada can be determined (Osseweijer, 2013). The division between the different forces can help in determining a strategy. In combination with the SWOT-analysis in Chapter 8, this model will contribute to assessing possible threats and core competences of the market. The six forces model as used in this analysis is showed in Figure 7-1.[1] Porter has first outlined the barriers that exist to enter a new market. These are of major importance, since the biojet market is also new in itself. This is displayed for the biojet market in Appendix F.

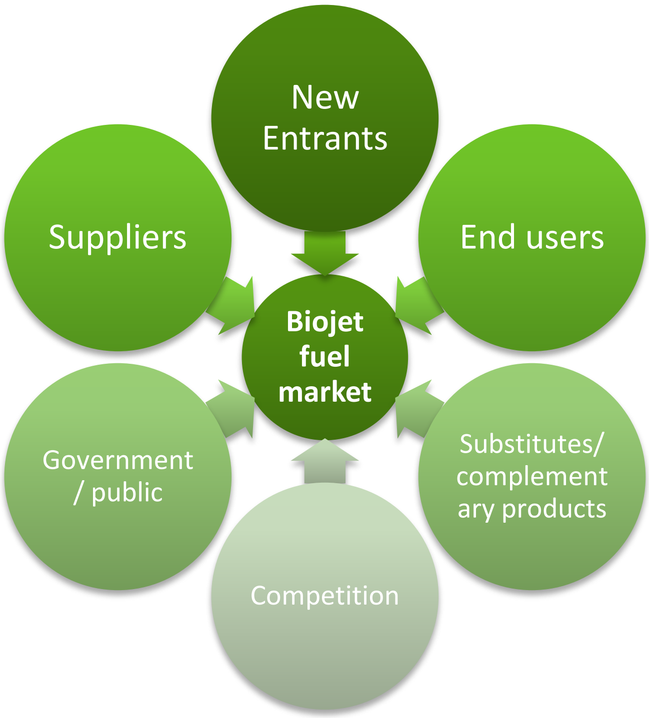

FIGURE 7-1: SIX FORCES MODEL, BASED ON PORTERS FIVE FORCES MODEL. SOURCE: M.E. PORTER, 1979; BARNEY, 1991; OSSEWEIJER, 2013

[1] The opportunities and entry barriers of the biojet fuel market will be indicated using the Six Forces Model. This model is mainly based upon the Five Forces Model that Michael Porter has described in 1979 in his article *How Competitive Forces Shape Strategy* in het Harvard Business Review. This model is used to analyze the business environment and develop a suitable strategy that is company-specific. The sixth force is added according to a review of Jay Barney in 1991, indicating the influence of resources on competitive advantage.

Suppliers

Suppliers in general can exert bargaining power in several ways, for example by threatening with a rise in cost or decrease of quality. The power is dependent on the amount of suppliers, the amount of accessible substitutes, the relative importance of the industry for the suppliers, the switching costs, the standardization of the product, and the possibilities of vertical integration (suppliers are in the position to start producing the industry's product themselves or the industry can start producing the supplied product themselves) (M. E. Porter, 1979).

Along the Saskatchewan biojet fuel production chain, several suppliers are in place. Suppliers of oilseeds, suppliers of feedstock and suppliers of refined biojet fuel. These all have bargaining power. However, because the entire market is new, these actors have to work together to achieve success. This means agreements will have to be made. The market will be dynamic in the short term, which means the product will not be standardized yet. The fact that all production will take place within the same region, vertical integration is a large opportunity. The feedstock producers will be directly involved in the biojet fuel refinery.

End Users

In a general situation, end users can use their bargaining power by putting pressure on the price of products playing upon the competitors. The power is dependent on the share the end users have in the turnover of their suppliers, the importance of the product to the end user, the degree of standardization of the product, the switching costs, the profit of the end user, and the threat of vertical integration (M. E. Porter, 1979).

The end users are the airline companies and most probably also the airports. The degree to which these end users will switch to the use of biojet fuel will depend on their environmental policies, especially in the case that biojet fuel prices are expected to be slightly higher than the currently used Jet A-1 fuels. How many end users there are in place thus depends on the market for Jet A-1 fuels. Subsequently, it is important that the biojet fuel is accessible for the end users. This is not expected to be a problem, as the currently used distribution channel can most probably be used.

Government / Public

The government and the public play a large role in facilitating the implementation of biojet fuels. Because biojet fuels not necessarily provide a cost advantage to airlines, financially they would not switch to this renewable fuel. The government can help in increasing the biojet fuel use in several ways. First of all, government can create awareness of the environmental need with certain policies. They can impose certain mandates in GHG emission reduction on industries, which forces for example airline companies to switch to the use of (a certain amount of) biojet fuels. Governments can also help in providing initial financial support in research and development and the marketing of biojet fuels, in the form of subsidies or tax exemptions (Wiesenthal et al., 2009).

The public, on the other hand, can increase the demand of green and environmental products. This will require the industry to adopt a green image, for example by making use of biojet fuels. Such a decision will satisfy the public, which is positive for sales.

Competition

Competitors are usually very important for the way a new business can manage to evolve itself. The market leaders can be powerful in their price setting or high service levels, making it impossible for newcomers to keep up with this.

However, the biojet fuel market is relatively new. The main current competitors are based from the Jet A-1 fuel industry. The number of competitors will increase in the future, where they can distinguish themselves in their pricing, technology, level of innovation, quality and service. The fact that the market is still new and flexible, brings advantages for those who invest in the short term. In the long term, the market will be comparable to the current Jet A-1 fuel market, except for its regional character. The local value chains will drive down competition, this makes it important to keep an eye on possible abuse of the monopoly position.

New Entrants

New entrants to the market can form a threat for current companies, because they still have the flexibility to correspond to recent changes in the market. They increase the market capacity with their aim to gain a certain market share, which drives down product prices according to the supply and demand principle. However, the chance that new entrants easily enter the market, depends on the costs that are involved in starting a new business and other before mentioned entry barriers. The costs of entering the biojet fuel market are relatively high, due to the technological investments (M. E. Porter, 1979).

The role of biojet fuels in the future is unclear due to other rising technologies, but there will definitely be a significant share. Investments in this market bring at the same time opportunities and risks. The fact that it is possible to enter this sector on a relatively small scale due to the regional character is an opportunity. The degree of loyalty towards a certain brand is relatively small for biojet fuels, which makes it not necessary to invest large amounts of money in brand image. Also, given that the same distribution channels can be used, no further investments in this are needed, however the new entrant still has to mix itself in the established order.

Substitutes / Complementary Products

Substitutes are products that can displace the original product, such as biojet fuels can displace Jet A-1 fuels in the future. This is mainly threatening if the substitute has lower costs or better performance. In this case it suits certain governmental mandates and the wish for airlines to carry out a green image. Complementary products show a positive correlation with the market, their sale will increase the sales of the original product. The introduction of engines more specified upon the use of biojet fuels, will increase the biojet fuel market share (M. E. Porter, 1979).

THE STRENGTHS AND WEAKNESSES OF AND THE OPPORTUNITIES AND THREATS FOR THE BIOJET FUEL MARKET.

A SWOT-analysis is a business-model that can serve as an instrument to determine the strengths and weaknesses of and the opportunities and threats for an organization or market. In this case, the focus is on the aviation biofuel market in general. This way internal and external influences can be mapped, in order to recognize potential expertise to exploit or risks to avoid.

All the knowledge gathered in earlier sections contributes to the SWOT-analysis (Osseweijer, 2013). These results can be used in establishing strategies and designing scenarios. The results of the SWOT-analysis are presented in Table 8-1 (Bailey, 2012; Rutz & Janssen, 2007). This SWOT-analysis will help determining what the Canadian value chain should look like, taking into account the characteristics of the Saskatchewan biojet fuel market. [2]

Within the analysis, a distinction has been made between the factors that apply to biojet fuels in general and to biojet fuels produced in Saskatchewan under the developing Value Chain. The factors applicable to Saskatchewan are mainly derived from a study of Ag-West developed by Stewart Bailey in 2012 (Bailey, 2012). First the internal factors will be discussed, strengths and weaknesses. Main general strengths that influence the willingness to implement biojet fuels to a large extent, are the reduction of GHG-emissions contributing to environmental goals (*Beginner's Guide to Aviation Biofuels*, 2009), the characteristics of the oilseed crops (Blackshaw et al., 2011), the short-term deployability and high potential market. For Saskatchewan and Manitoba specific, the decrease of fossil fuel dependency, the use of agriculture and the possibility of truck delivery are strengths (Bailey, 2012). Weaknesses, however, is the fact that relatively much land is required for feedstock production. Also, external factors such as weather conditions can reduce the yield. The price of fuel depends on the sale of co-products (S. Porter & Saville, 2012). This can be seen as a weakness as well.

External factors are the opportunities and threats for the biojet fuel market. Opportunities are the reduction of crude oil import, outlooks for crop-improvement, the use of biojet fuel blends in the short term and decreasing prices due to process development (S. Porter & Saville, 2012). Another opportunity for Saskatchewan is supply of biojet fuel to the Defense Department, but also to neighboring US states (Bailey, 2012). By engaging early with potential customers and infrastructure owners/managers, it will be easier to successful develop the value chain into an operational cluster (Cey, 2012). A threat in this market is the fact that the biojet fuel market is relatively new and there is not much experience in this field. Also, (in)direct land use change can possibly have negative impacts on the environment (Van Stappen, Brose, & Schenkel, 2011). This is thought not to hold for camelina and carinata to a large extent, but it has to be taken into account (Blackshaw et al., 2011). Another threat can be the introduction of other competing biofuel projects to fill the supply gap (Bailey, 2012).

All in all, the strengths and opportunities definitely offset the weaknesses and threats. In almost all cases, these are expected to decrease due to technological improvements or developments in the market. The biojet fuel market has to be allowed to grow, and by working together within the prospected Value Chain, these weaknesses and threats can be addressed to a large extent, while the strengths and opportunities can be exploited as much as possible (Osseweijer, 2013).

[2] In the 1960s and 1970s Albert Humphrey developed the SWOT-analysis, while he was working for Stanford Research Institute (SRI International) as a business and management consultant. A SWOT-analysis is nowadays still used to develop a strategic fit, by exploring to what degree a firms internal environment matches its external environment. This will help addressing issues in corporate planning and the development of a business strategy.

TABLE 8-1: SWOT-ANALYSIS OF THE MARKET OF BIOJET FUELS FROM CAMELINA AND CARINATA. SOURCE: BAILEY, 2012; RUTZ & JANSSEN, 2007; OSSEWEIJER, 2013

	Positive	Negative
Internal	**Strengths** *Biojet fuels in general* • Deployable in short term • Reduction GHG emissions • Creation of new jobs • Extra distribution link for agricultural products, increase income farmers, less subsidy needed • Decentralized production enforces economies and job opportunities in the rural areas • Production can occur on fallow land • Camelina and carinata are relatively drought and heat tolerant • Production of co-products (meal) wages extra income • Biojet fuels are little or no toxic • Genetic Modification for improvement of feedstock is relatively easy • The carbon cycle is relatively short *Saskatchewan produced Biojet fuel* • Close to Prairie markets with highest jet fuel values in North America • Most potential markets can be served by truck which is least capital intensive • "Made in Prairie" solution could be attractive to certain commercial partners • Prairie GDP is most positive in Canada • Any new jet fuel supply will be very welcome by airlines • A "greener" jet fuel will be welcome by customers, government and general public.	**Weaknesses** *Biojet fuels in general* • Feedstock production requires relatively much land • The production depends on external factors such as weather conditions and pest attacks • Biojet fuels have a lower energy-content per volume than petroleum-derived fuels. • The cycle of nutrients will be disturbed • Perceived quality problems with anything "bio". • Perceived notion that biojet fuel in economic quantities is far into the future *Saskatchewan produced Biojet fuel* • Lack of market understanding for "drop-in" biojet. • Limited access to product terminals • Lack of rail unloading facilities at potential customer locations • Lack of access to the conventional petroleum supply chain • Fuel prices will depend on the sale of co-products
External	**Oppurtunities** *Biojet fuels in general* • A large percentage of Jet A-1 fuel can be replaced • The dependency on crude oil will decrease • The import of crude oil can decrease • An early introduction of biojet fuel facilitates the transition to a bio-based aviation industry • Conversion technologies will be improved and renewed to be more efficient • The EU directive and other strategies promote an increase of the market share of biojet fuels. • Using blends of biojet fuels with Jet A-1 provides short-term opportunities. • Biofuel prices are constantly decreasing through process development • Contribute to IATA's goal of reducing airline emissions *Saskatchewan produced Biojet fuel* • Current short jet fuel market is likely to get shorter • Key commercial airports in AB, SK and MB • Supply to Dept. of Defense in Cold Lake • Smaller, profitable volumes located throughout prairies • Neighboring US states that are short jet fuel • Early engagement with potential customers and infrastructure owners/managers.	**Threats** *Biojet fuels in general* • The biojet fuel market is relatively new • Concerns about food security exist, due to land and feedstock competition • (In)direct Land Use Change can have negative impacts • Demand destruction for any number of reasons including global financial crisis *Saskatchewan produced Biojet fuel* • Other competing biofuel projects that may fill the supply gap • Production is limited due to land availability for feedstock production

IDENTIFICATION OF ACTORS THAT ARE OR WILL BE INVOLVED IN THE VALUE AND SUPPLY CHAIN OF THE BIOJET FUEL INDUSTRY.

The previous chapters indicated all involved stakeholders in the biojet fuel industry. An analysis of their power and impact in the market has been made with the Six Forces Model, and a SWOT-analysis of the market was developed. This chapter serves to categorize those stakeholders within a value chain. In order to map the value chain for biojet fuels, taking into account all involved stakeholders, first the supply chain has to be understood thoroughly. The supply chain is the distribution channel of the product, describing all physical phases the product goes through. It is shown schematically in Figure 9-1 (Newlands & Townley-Smith, 2012; Osseweijer, 2013). The right channels have to be selected in order to gain maximum efficiency. This directly influences other marketing decisions, as chain members usually have to maintain long-term relationships. To make sure the supply chain can function properly, policies have to be developed at several levels. An appropriate policy will create a market pull from the end user, who is situated downstream of the supply chain. This will be illustrated when discussing the involved stakeholders in the Value Chain, which includes those stakeholders discussed here in the Supply Chain (M. E. Porter, 1985). A Value Chain is inherently the same as a Supply Chain, however the emphasis is on the value each link or stakeholder ads up to the product by their activity. The chain of activities gives the product more added value than the sum of independent activities' values.[3]

It should be emphasized that the value and supply chain as described here, are not in place yet in Saskatchewan. This chapter serves to define the value chain as it should be and indicates the gaps that are to be filled at this moment. Later in this report the opportunities of connecting existing pieces of the value chain into an integrated framework, will be explored.

FIGURE 9-1: GENERALIZED SUPPLY CHAIN FOR BIOJET FUELS. SOURCE: NEWLANDS & TOWNLEY-SMITH, 2012; OSSEWEIJER, 2013

[3] The Supply and Value Chain will be mapped and worked out according to the models Michael Porter developed. He described them in 1985 in his book *Competitive Advantage: creating and sustaining superior performance.* His models have been used from there on as standard models in developing business strategies and the design of markets.

Supply Chain

Feedstock production

The first link of the supply chain, are the producers of the feedstock for biojet fuel, the camelina and carinata crops. They take care of the seeding, growing and harvesting of the oilseeds. These concern mainly private farmers who up to now focused on other crops, wherefore their land use will change. As discussed in the Science section, this can have significant impact on the environment. As mentioned earlier, a major part of the camelina and carinata will be grown in the southern brown and dark brown soil zones, whereas these are the drier and warmer regions of Saskatchewan (Government of Saskatchewan: Ministry of Agriculture, 2009). In order to get the feedstock production coordinated, centralization should occur to a certain degree. By working out a tillage system for the full region, farmers and producers know what is expected from them. The total feedstock production can be regulated to address fuel security. To make individual farmers and producers participate in this cultivation system, contracts for price certainty will have to be provided (Cey, 2012). Agrisoma Biosciences Inc. and Paterson Grain already have these agreements in place .

Supply logistics

Once the feedstock has been produced, it has to be transported to undergo further treatment. To do this as efficiently as possible, oilseeds from all adjacent crop farms will have to be collected in one shift. This has to be worked out logistically once all crop farms are mapped. Except for transport, storage of the seeds also is a logistic operation. During storage, pretreatment can take place already, for example drying. Transport could be outsourced to private distributors and repositories. Storage most ideally takes place at or at least nearby the refinery plant, as this would lower extra transportation costs.

Once the oils have been refined and the meal is ready, the products have to be transported to their end consumers. This again is a logistic operation, explained in the fourth link in the supply chain: Distribution.

Conversion

Once the oilseeds have been grown, transported and stored, they are ready to be converted to their intended products. This happens in the refinery plant. Companies most identifiable with this are UOP Honeywell, Chevron, ARA and Agrisoma. Most ideally Saskatchewan knows one or two large-scale plants, instead of several small ones. This will be the most efficient way of refining. As explained in the Science section, the process consists of the following steps: crushing, extraction, oil and solvent recovery, refining / bleaching. In the mean time, the meal is being processed, and other co-products such as green naphtha, green LPG and green diesel or hydrogenation-derived renewable diesel (HDRD are formed). Those co-products have value as well, and are recovered by distillation. For these refinery plants, contracts will have to be provided to ensure off-take and certain prices being paid for the refined fuels.

Distribution

The end products will have to be distributed to their end users. Biojet fuels will mostly be stored on the airports waiting to be used, because the end users all come by here. Distribution from the refinery plant to the fixed airports therefore is a relatively static system, which allows to be coordinated to a large extent. Information should be provided on how much fuel generally is needed in order to make sure there are no shortages, but neither large surpluses. Buying fuel is arranged through the fuel consortium, consisting of all airlines operating at the eight largest Canadian airports. Smaller airports are supplied by Esso and Apron. Certainly in the upcoming years, the fact that the biojet fuel will be blended with petroleum-derived Jet A-1 fuel has to be taken into account. This blending typically happens on the site, as it would logistically not be useful to blend it at the refinery plants. Given that blending is possible, current storage systems are suitable for the biojet fuels. Because biojet fuel will foremost be a regional solution, it should be questioned if the aim is to incorporate it into the pipeline infrastructure .

Next to the fuel, the meal has to be distributed to their end users. Trade in meal is required to make this biojet fuel industry lucrative. The meal also needs to be stored, providing extra costs. The main consuming companies (livestock farms) will have to be identified to regulate this trading system as much as possible, to keep the costs low. This can happen in the form of fixed selling points in each region.

End use

As mentioned, the main customers of the biojet fuel will be airline companies, who buy in their fuel within a fuel consortium. A possible additional player between the refinery plants and the airline companies can be the airports, because this is where the biojet fuel will be stored first. The possibility exists that biojet fuels are economically slightly less attractive than petroleum-derived jet fuels. To be assured of a market, off-take agreements will have to be made with end-users. As long as the price differences are not extremely high this is not expected to be a problem, as most end users (airline companies) have objectives to meet in terms of CO_2-reduction.

Subsequently, end users for the meal are primarily livestock farms. Up to now the meal has not been approved in Canada, so potential markets lie in the United States. It is expected that not long from now, the meal will also have market in Canada. This is required, as a large part of the income is derived out of the meal. The meal will be commercialized as a product through certain fixed selling points within each region. Livestock farms can buy their livestock feed here.

Value Chain

In this part, the value chain of the biojet fuel market will be analyzed. As mentioned in the introduction of this section, the value chain as designed by Porter describes the activities that take place within a certain market. By analyzing the value chain, the competitive strength relative to similar markets can be determined. The central activities in the market can be divided in two main groups. The first group, Primary Activities, describes all actions that are directly associated with creating and delivering the product. The second group are the Secondary or Support Activities. These actions are not directly involved in production and delivery, but do influence efficiency and effectiveness within the supply chain (M. E. Porter, 1985).

By analyzing the value chain, it is possible to identify which activities should be undertaken and by whom. This also depends on the market strategy, which could be cost leadership, differentiation on various fields such as quality and sustainability or being customer friendly. Usually there is a combination of strategic objectives. These objectives determine which activities should be emphasized (Osseweijer, 2013).

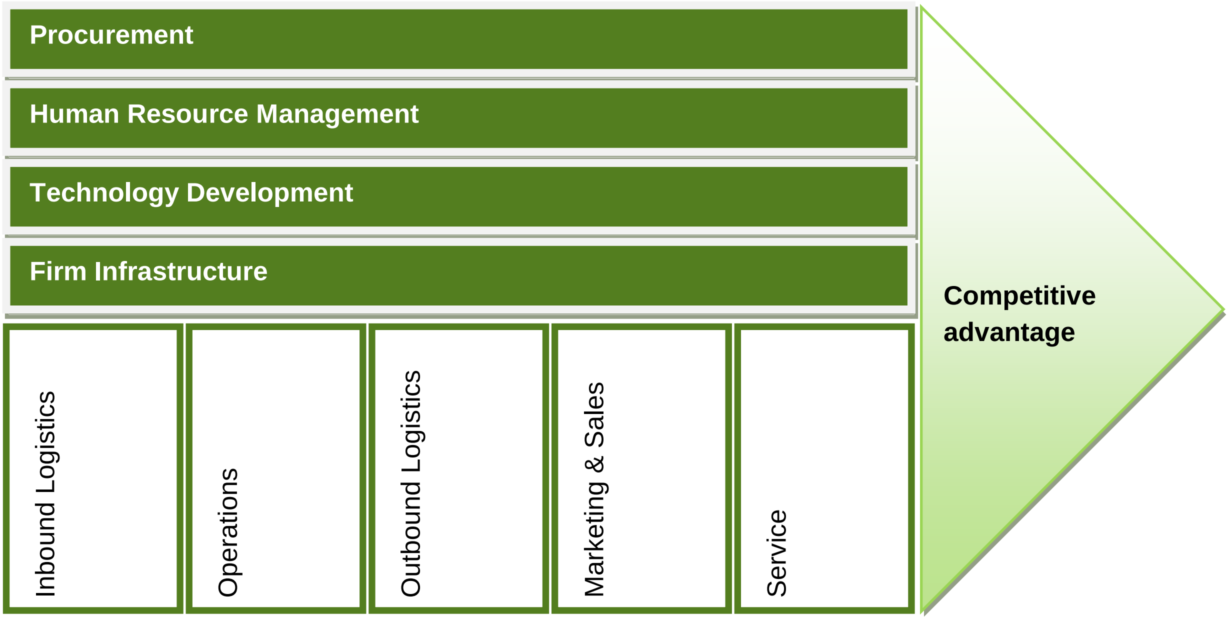

FIGURE 9-2: SCHEMATIC REPRESENTATION OF THE VALUE CHAIN AS DEVELOPED BY PORTER

Primary Activities

The primary activities are displayed in the vertical bars in the diagram. Inbound logistics include all activities dealing with receiving and storing externally sourced materials. This can be broken down into all the individual links in the supply chain. Feedstock producers have to receive and store the seeds, the machinery, the herbicides and other inputs. Next, supply logistics have to receive the product of the feedstock producers, the oilseeds. In order to properly do their job, they need transport devices and fuel to run them. The conversion plant has to receive and store the oilseeds and all materials needed for conversion, such as crushing and refining machinery, and hexane. Subsequently, distribution of the conversed products will take place, e.g. biojet fuel, protein meal and other co-products. For this, also transport devices and fuel is needed. The last link are the end users. The biojet fuel, protein meal and other co-products will have to be stored close to where they will be used. For biojet fuel, this will most probably be at airports, close to the planes.

Operations describe the second set of primary activities. Namely, the manufacture of products and services, or the way in which inputs are converted to outputs. Over the whole market, it can be said that camelina and carinata oilseeds are converted through several processes into biojet fuel. Every link in the supply chain uses the outputs from the preceding actor as its input, and provides input for the next actor in the form of its output by adding value. The feedstock producer's operations are mainly agricultural. Supply logistics and distributions concern transport, though distribution needs an efficient mechanism to reach end users on time and in the right amounts. Conversion plants operate on a highly technological level, explained in the Science section. End user's operations mainly concern the use of biojet fuel to operate their flights.

The outbound logistics concern all activities associated with getting finished goods and services to buyers. The design of a value chain can be very important to ensure offset. A proper value chain allows stakeholders to operate in an integrated environment. By making offset and price arrangements, risks can be reduced for all involved actors.

The fourth primary activity is Marketing and Sales. This is mainly about informing potential buyers and consumers about the products and services that are offered. Important is to pay attention to the type of information that is provided, this determines your image. Basic information, such as price and availability should be offered, but emphasis should also be on the benefits of the product. The green and renewable character of biojet fuel, next to its high quality, moderate price and usability in current infrastructure should be highlighted. Firstly, marketing of the 'idea' is important, so that farmers are motivated to adopt camelina and carinata in their production/rotation schemes. This adoption is stimulated when demand from processing plants is present. Subsequently, the demand of processing plants is influenced by the demand of end users / airlines for biojet fuel. Therefore, marketing starts at the end of the value chain, creating awareness and therewith demand by the end users. This demand ensures producers upstream of the value chain of their offset, which makes them willing to incorporate the product in their production chain. The type of information provided in the marketing strategy is therefore very important.

The last primary activity is service, which includes all activities that are undertaken after the product has been sold, in order to maintain product performance. In the field of biojet fuels, all end products are consumed in using them. Oilseeds are crushed, meal is used as animal feed, refined oil is burnt. The service should therefore mainly be found in the guarantee of product performance as expected. Oilseeds should supply a certain amount of oil, meal should contain a certain amount of protein and minerals, and the oil is expected to have a certain energy content and be suitable for use in regular engines. Service makes sure that these guarantees are monitored.

Support Activities

The support activities are displayed in the horizontal bars in the diagram. The first is procurement, which stands for the way resources are acquired. This includes negotiating with material suppliers and sourcing. For the Canadian biojet fuel industry, the aim is to design a value chain that covers all individual suppliers and off takers, so that no gaps exists. Certain competition should still be there, to stimulate quality improvement and cost-effectiveness. However, in such a new industry it is important to lower the risks of participating in the value chain. Supply and off take arrangements will therefore be made wherever possible.

Human Resource Management (HRM) is a second important support activity. HRM concerns everything that has to do with employees, such as recruiting new employees and motivating, rewarding and developing the existing employees. As the performance of staff significantly influences the performance of a business as a whole, taking care of the employees is a very important factor throughout the supply and value chain.

Technology development concerns all activities that have to do with managing information processing and knowledge. Knowledge should be developed to a large extent, but should at the same time be protected in order to grow and maintain a competitive advantage. The level of technological development varies among the different stages of the value chain. First there is the genetic modification of the oilseeds in order to increase the oil yield and quality. This is an ongoing technological research and development. The production of the feedstock by farmers requires the right equipment, use of herbicides and watering, knowledge about optimal seeding and harvesting dates. The crushing and refinery technologies are continuously being improved, thinking of chemical processes and enzymes that make the production more cost-effective. Lastly, technological development in the jet engines takes place. This leads to an increase in efficiency, which means a decrease in fuel usage. Generally the technological developments will be carried out in research institutes, closely monitored and often funded by the involved stakeholders.

The fourth and last support activity is infrastructure. This generally concerns available transport and support systems for finance, quality control, business planning and other forms of management. The presence of a well-developed infrastructure that is accessible for all stakeholders throughout the supply chain is very important in order to operate as effectively as possible. Every link in the chain needs systems to process certain data or logistically transport products.

Competitive Advantage

By creating the right mix and emphasis of primary and support activities, the market or market segments can develop a competitive advantage. This is visualized in the arrow on the left within the diagram in Figure 9-2, formed by the combination of primary and support activities. The analysis of these primary and support activities of the Value Chain of biojet fuels, proves that to gain a competitive advantage in this field, integrated action along the entire value chain is needed.

The main competitor for biojet fuel is regular Jet A-1 fuel. This fuel has dominated the jet fuel market for a long time, which makes it difficult to break through. The various segments in the biojet fuel market have to collaborate intensively to achieve this. There are several reasons why biojet fuel is a good candidate to fight this competition, these should be used in a strategic approach of the market.

First of all, the concerns of society about climate change keep growing. Next to the European Union, also Canadian governments are discussing the introduction of more ambitious targets in reducing GHG emissions. These targets could become mandatory. The substitution of Jet A-1 fuels by biojet fuels would contribute in achieving these targets.

Within the value chain, the airline companies are the ones most exposed and visible to society. Nowadays, it is important for companies to carry out a green image, following a green and renewable strategy. If airlines can promote that they use biojet fuels in their transport, this will most definitely increase their competitive advantage. Along with technological developments and more efficient aircrafts, the use of biojet fuel can therefore be part of their market strategy.

Despite of the environmental benefits, biojet fuel still has some way to go before it will be used at the same scale as Jet A-1 fuel. A major advantage is that biojet fuel makes use of the same infrastructure as current fuels. This reduces start-up costs. As the liter-price of biojet fuel is aimed to be in the same range as Jet A-1, there are no cost advantages but no disadvantages either. To break through in the market, the stakeholders have to work together closely. The creation of an integrated chain reduces the risks involved in entering the new market. By making arrangements between the actors on prices, stock availability and time slots, a lot of uncertainty can be removed or prevented.

To be able to achieve the creation of a proactive value chain and therewith the implementation of biojet fuel, there is the wish for a guiding policy. Earlier in this report, the organization SkyNRG was discussed. SkyNRG aims to manage the supply chain for the delivery of biojet fuels. Seen the identification of the need of an integrated value chain, cooperation with this organization can be very promising as SkyNRG can fill the current gaps. In order to overcome the so-called Valley of Death, filling these gaps is of major importance. An experienced organization purely focused on coordinating the industry will help efficient operation and continuous development to improve quality and drive down costs, on the policy as well as the technological level. Once the value chain starts taking it’s form, this will entail several advantages. A large and stable value chain will enhance the awareness of the biojet fuel industry and the Saskatchewan agriculture. Also, involved parties will be educated of the need for biojet fuel use. This will facilitate collaboration between end users (airlines), refiners and the agricultural feedstock producers and coordinate the allocation of available resources.

Intermediate Summary Business and Actors

In this section, a start has been made to develop the Value Chain, by first exploring the involvement of the stakeholders. One of the most important stakeholders in the biojet fuel field is the aviation sector itself, consisting mainly out of umbrella organizations and airlines. Umbrella organizations (ATAG, ICAO, IATA) have objectives to grow carbon neutral from 2020 on and reduce their CO_2-emissions with 50% by 2050. Biojet fuels are one of the options to achieve this (International Air Transport Association, 2012). International Supply Chain Manager SkyNRG from The Netherlands has promising objectives, applicable to Canada (Faaij & Dijk, 2012). Personal contact with Canadian airlines has indicated their willingness to cooperate in this renewable project if it is financially attractive (Osseweijer, 2013). Since WestJet is not flying into Europe and therefore not bothered by their environmental policies, incentives have to be provided (Tauvette, 2013). Next to having a public role, airlines are identified as main off-takers. Other identified stakeholders are the government, research institutes, farmers, franchisee companies, financial service providers and joint venture partners (Osseweijer, 2013) .

Within the biojet fuel market, six main forces were identified, taking entry barriers into account (M. E. Porter, 1979). S*uppliers* of oilseed/feedstock and biojet fuel have bargaining power in increasing prices, depending on how many suppliers are in place. *End users* or off-takers are the airlines and airports. Their bargaining power is the use of cheaper alternatives (Jet A-1) instead, to drive down price levels. The *government and public* influence the market by creating policies and imposing mandates on environmental actions. Financial support or tax exemptions is another power to steer the market towards a certain direction. *Competition* within the biojet fuel market is still rare, but main bargaining powers are distinctions in pricing, technology, level of innovation, quality and service. The Jet A-1 suppliers are seen as the main current competitors, as they offer a cheaper and more well-known alternative. The degree of *new entrants* to the market is low, given the high capital investments and level of technology. However, they should be monitored carefully in case they offer advantages. The main current *substitute* is Jet A-1 fuel, which is threatening seen the cost and scale advantages. Future substitutes can be hydrogen or electrical planes, since biojet fuels are still considered to be an intermediate solution. *Complementary* products could be the introduction of biojet specific engines. The existing bargaining powers will be of relatively low influence. This is since the aim is to develop a value chain where all stakeholders work pro-actively together to reach a common goal. Competition among actors will be minimized, and collaboration maximized to increase the chances of success in competing the Jet A-1 fuel market (Osseweijer, 2013).

A SWOT-analysis has indicated significant strengths, such as environmental benefits, short-term deployment and a high potential market. Opportunities are high, seen the decrease in fossil fuel dependency, decrease in import and contribution to existing biofuel goals and policies. Weaknesses to take into account are short-term financial state, requirement of high acreage and dependency of weather conditions. Important threats to monitor are concerns around food security, (in)direct land use change and the financial crisis (Bailey, 2012; Osseweijer, 2013; Rutz & Janssen, 2007).

The supply chain consists of five main links. Feedstock Production, Supply Logistics, Conversion, Distribution and End Use (Faaij & Dijk, 2012; Osseweijer, 2013). The value chain describes the value that is added to the product by every link in the chain through a combination of primary and support activities. This way, a breakthrough in the market can be realized, creating a market pull at the side of the end users. To overcome the valley of death, several gaps in the value and supply chain need to be filled. These will be indicated in the next section.

IV. Collaboration EU and Canada

A step towards sustainable aviation in Canada, with EU-cooperation.

As described in earlier sections, Canada can learn from the policies that are already active within the European Union. However, ideally mutual benefit should be created by the EU gaining something from this collaboration as well. This can take many forms, from the trade of the market products meal and biojet fuel, to the exchange of the processing technologies itself. Research institutes could cooperate, generating knowledge transfer. Knowledge transfer can also take place through collaboration between business contacts, companies or markets representing both parties. There can be thought of knowledge about yield breeding, oil composition, genetic engineering, and crushing, extraction and refinery technologies. In the end, airlines should cooperate as if they represent the world-wide aviation sector together, operating as one market.

In this section we will focus on collaboration on the business level, as an industry approach will at this moment be faster than a governmental approach. The Dutch company SkyNRG provides interesting opportunities to collaborate in the field of biojet fuels in Saskatchewan.

This section will describe what the Canadian Biojet Fuel Initiative might look like, collaborating with parties from the European Union to fill the gaps determined in the previous chapter. The mutual benefits that directly result from this collaboration will be outlined here. Altogether, a proposal on the implementation of the value chain will be developed in the form of a time-line with defined steps that are required to achieve the objective. This will contribute to the implementation of biojet fuel in Canada and strengthen the relation between Canada and the EU in this field.

THE CHANCES OF SUCCESS IN DEVELOPING A COORDINATED PRO-ACTIVE FRAMEWORK ON BIOJET FUEL FOR CANADA.

The speed of implementation of biojet fuels is determined by several factors. First of all, the adaptability of the existing value chain on jet fuel is important. Also, the level of resistance among stakeholders to the emergence of a new value chain will impact the ease of realization. The costs of this change will have to be managed well in order to be minimized. The extent to which minimization is possible will also influence the speed of acceptation and implementation. Lastly, the ability to fit the new biojet fuel within the existing infrastructure will determine to a large extent how much time it takes to develop and implement this in the form of a value chain (Vertès et al., 2006). To minimize the influence of these factors, the development of a coordinated value chain is an important step.

In previous chapters, all stakeholders involved in the Canadian biojet fuel chain have been indicated and analyzed. Chapter 9 proposed a value chain in which all participating stakeholders are classified and know their exact role. However, here it will be indicated that this value chain still shows significant gaps. These gaps need to be filled before biojet fuel can be successfully implemented at a large scale. This chapter serves to indicate the gaps and the possibilities of filling them, and will describe a strategic approach to achieve this.

EXISTING GAPS IN THE VALUE AND SUPPLY CHAIN

The supply and value chain as described in the previous chapter, are descriptions of how the stakeholders should interact. However, at this moment we are still talking about an unresolved puzzle. To a large extent, the different pieces of the chain already exist, but they are not connected yet. This part will provide an overview of the existing gaps that need to be filled. The order in which they are discussed is according to the order they have within the supply chain. Next, a strategic approach to fill these gaps will be outlined. The potential role of SkyNRG in this project has already been indicated.

The first gap in the chain is the lack of operational farmers on the production of the feedstock. However, Agrisoma and Paterson Grain have identified several farmers that are willing to incorporate carinata in their production chains if these crops show profitable results (Lortie, 2013). For the production of 230 MLPY of biojet fuel, 900,000 to 1 million acres of arable land are required. Seed and oil yield improvements will reduce this acreage to about 780,000 acres (Ag-West Bio Inc., 2012a). This can be reached through genetic enhancement to the point that economics are feasible throughout the value chain. To ensure long-term stable production of oilseed feedstock, farmers will have to be contracted. Taking into account that the crops will be incorporated within the rotation schedule, year by year planning and intense communication among the farmers is a must. The structure and negotiations for this are already in place, and the production is expected to start immediately if the demand is there. This situation can thus be described as awaiting a market pull.

Within these farmer-agreements, next to production levels, the price of feedstock needs discussion. Biojet fuel will be, at least the first years, bound to complicated mechanisms to keep the costs down. The feedstock price should not increase too much to maintain development of the sector, and should not be reduced in order to meet farmers expectations and willingness to cooperate. A structure for this is already in place through Agrisoma and Paterson Grain. Again, the most important driver will be the creation of demand to generate a market pull situation.

The primary gap which will require the most time before it is sufficiently filled, is the lack of established processing and refinery plants for the biojet fuel. The technique as described in the Science section is already fully developed, successful test flights on 100% HRJ/HEFA biojet fuel have been done (Kinsaul & Wadsworth, 2013). However, a large scale production plant is needed before biojet fuel can be implemented in an influential amount. Established refiners will not be interested to incorporate this process until compelled to do so by either a mandate or a market pull situation. This is simply a financial case, as investments are needed to build and maintain this new technological process. Therefore sufficient off-take has to be ensured before such a plant will be established. This is why the development of a pro-active value chain is so important.

As mentioned in the previous paragraph, there are no governmental mandates in place to help spur biojet fuel interest on a national scale. The development of such a policy would stimulate renewable growth and investment in aviation at the industrial level. What is happening at this moment, is that industry itself takes responsibility on the environmental subject. This definitely is a good start, however investments will be needed at some point. This is a gap the government could fill in the form of subsidies or the allocation of tax exemptions. Next to national policies, the development of a global policy on the reduction of GHG emissions and/or the use of biojet fuel would facilitate implementation to an even higher extent. Aviation is a global market. This policy could include a global mandate on biojet inclusion rates.

Another gap is the lack of clear agreements with airlines and/or airports to ensure biojet fuel off-take. Airlines have carbon emission reduction targets, developed by IATA. This implies the use of a certain amount of bio-based fuel. In the case of Saskatchewan biojet fuels, airlines have demonstrated their interest in off-take. However, they have not yet completed agreements for fixed volumes and prices. Once this is in place, a market pull situation will exist which will accelerate the development of farmer production and the establishment of refinery plants.

At the moment, no agreements exist on the logistics of distributing the oilseeds in the beginning of the chain and the fuel at the end of the chain. As this is a matter of contracting suitable distribution companies, this will not be a huge gap. However, infrastructure and a coordinated way of supplying the products in certain amounts and at certain times needs to be set-up. This gap can most easily be filled by contracting a project leader who makes sure logistics throughout the value chain are regulated.

A critical gap is the fact that the protein meal is not yet approved for use as livestock feed. However, the Feed Innovation Institute shows positive signs that this approval is forthcoming over the next twelve months in Canada. Once approval is in place, a market needs to be developed for the meal. This is an important gap because the selling of the protein meal generates a significant share of the total income out of biojet fuel and its co-products.

Strategic approach: Canadian Biojet Fuel Initiative

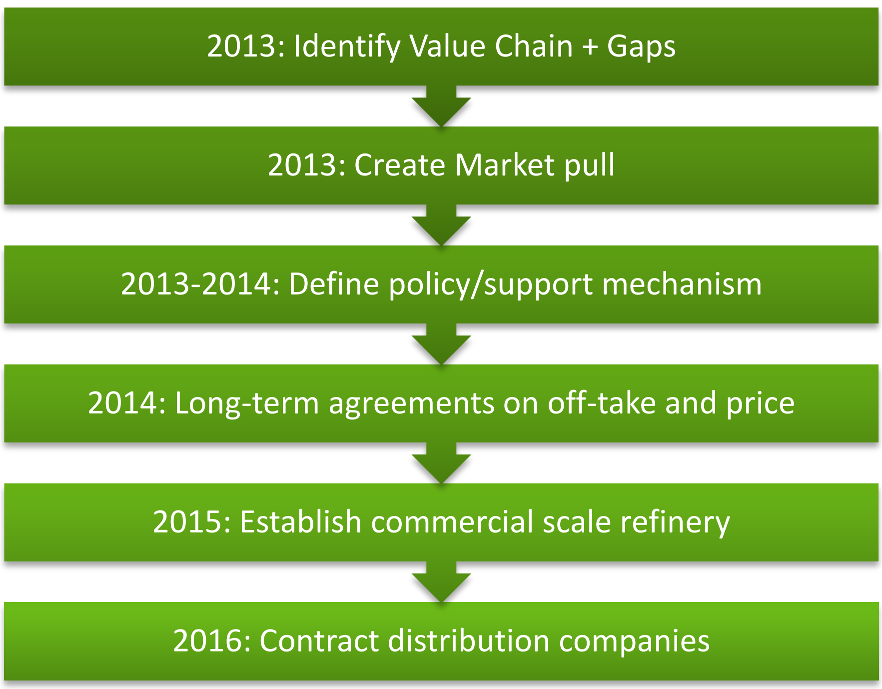

FIGURE 10-1: STRATEGIC APPROACH FOR STEP-WISE IMPLEMENTATION OF BIOJET FUEL. NOT DISPLAYED, BUT THROUGHOUT THE PLAN CONTINUOUS RESEARCH ON OIL COMPOSITION AND SEED AND OIL YIELD IS IN PLACE. OSSEWEIJER, 2013

To fill the gaps in the value chain and create a pro-active environment for biojet fuel implementation, the following approach will be taken. This approach is developed through discussions with main stakeholders, combining their needs to address goals, and experience in the field (Baguley, 2013; Ehman, 2013; Industry Consortium: Mike Cey and Ron Kehrig, 2013; Osseweijer, 2013; Tauvette, 2013). Seen the experience the EU has in this field, SkyNRG is attracted as a main party within the Industry Consortium. All involved stakeholders will cooperate within this Industry Consortium. Up to now, this consortium consists out of Ag-West Bio Inc., Agrisoma Biosciences Inc., Mustard 21, SkyNRG and partner companies of these actors. The Saskatchewan Ministry of the Economy, department on biofuels and bioproducts is also participating in current meetings, as well are airlines Air Canada and WestJet. The role of the actors as defined in the six forces analysis is used to determine their position within the Value Chain. Opportunities as defined in the SWOT-analysis will be exploited to a high extent, an weaknesses and threats addressed and restricted wherever possible. Information on how to develop the Value Chain within this consortium is thus gathered from all analyses conducted earlier in this report.

2013: Identify Value Chain + Gaps

It is important to know who the involved stakeholders are, and what the exact gaps that still need to be filled are. This step has already been undertaken earlier in this report. The stakeholders that will form the value chain together, will be part of the Industry Consortium. The indicated gaps will be filled in the following steps.

2013: Create Market pull

As indicated above, the most important argument for stakeholders not to proceed their operations on biojet fuel, is the lack of demand which increases the risk. This automatically leads towards the first step that has to be undertaken, namely the creation of a market pull. To realize this in a pro-active way, discussions with the end users, i.e. the domestic airline companies Air Canada and WestJet, have already started. Both airlines indicated their interest in the use of biojet fuel, however, with these discussions we want to set-up long-term off-take agreements (Ehman, 2013; Tauvette, 2013). The airlines are incorporated in discussions on this initiative from the beginning, to stimulate their input.

Another party that can create a market pull by their demand, are corporate organizations that wish to fly environmental conscious. When these parties are prepared to pay a premium for their biojet fuelled flights, this stimulates airlines and therewith the development of the biojet fuel value chain. This part will be realized under supervision of SkyNRG (SkyNRG, 2012).

The creation of an off-take market for the protein meal is also important. Livestock and aquaculture farmers in the US and Canada will be approached for this as soon as meal approval is in place.

2013-2014: Define policy/support mechanisms

To reduce risks for stakeholders and create an attractive environment to exploit the value chain, (national) policy and support mechanisms need to be defined. Support of both the federal and provincial leaders is required. The main areas that call for additional support are the production of industrial oilseed feedstock (camelina and carinata) and the refining of these oilseeds to sustainable biojet fuel. For acquiring this support, governmental actors, for example Ron Kehrig, Manager of Biofuels and Bioproducts at the Saskatchewan Ministry of the Economy, are incorporated in the discussions from the beginning. An example of a supportive programme is Sustainable Development Technology Canada (SDTC) offering the NextGen Biofuels Fund™. This fund can help increase the chances of success to market by bridging the financial gap while, at the same time, helping to scale-up the technology towards a commercial refinery plant (Sustainable Technology Development Canada, 2013).

It should be assumed that the cash flow is negative until bio-refineries are built and operating. The use of more efficient technology and improved oilseeds will make the economics feasible throughout the value chain. Next to subsidies, another governmental mechanism to consider is the allocation of tax exemptions.

2014: Long-term agreements on off-take and price

To stimulate development and reduce risk, off-take agreements for oilseeds as well as for biojet fuel in certain amounts and at a competitive price need to be established. Such an off-take agreement is a confirmation of the market pull situation indicated earlier in the strategy.

Within these agreements farmers have to concur on a rotation schedule for the crops. To ensure fixed supply of feedstock, year by year collaboration on this is necessary. Agrisoma has already partnered with Paterson Grain to handle all the farmer contracting for their Agrisoma Resonance® Energy Feedstock (Lortie, 2013). Also a partnership with Canterra Seeds exists to increase the amount of certified seed available. This part of the value chain is well established and solidly in place.

Off-take agreements on biojet fuel will have to be signed by airlines. WestJet and Air Canada have indicated their interest, however Air Canada is now undertaking a biojet fuel feedstock feasibility study. Outcomes of this will determine their degree of participation in this initiative (Ehman, 2013).

2015: Establish commercial scale refinery

The next step will be the construction of a processing plant at commercial scale. The opportunity of converting an existing plant into a bio-refinery plant has to be explored too. As this is the largest financial gap due to high capital expenditure (CAPEX), the support mechanisms indicated earlier will be most useful here. A strategic location has to be indicated, central to existing infrastructure and at the same time close to feedstock sources to minimize distribution costs.

2016: Contract distribution companies

To make sure the biojet fuel is implemented throughout Canada, distribution companies will have to be contracted. They will be responsible for the logistics of distributing the oilseeds in the beginning of the chain and the fuel at the end of the chain. This is considered a possible concrete gap where SkyNRG could step in.

First steps

To make sure this strategic approach will be carried out accurately and within the set time-slots, for each activity an action plan needs to be developed where a responsible party is defined. Our first practical step is the organization of a trade mission in Saskatoon, for August 2013. Ag-West will be responsible for this, in the form of myself, Floor Osseweijer. All involved parties will attend: Ag-West Bio Inc. (host), Agrisoma Biosciences Inc., Air Canada, KLM, Mustard 21, SkyNRG and WestJet. Also stakeholders as Paterson Grain, ARA and (provincial) governmental representatives will be invited. By talking with all involved parties on site, an intelligent pathway to establish a pro-active Value Chain can be elaborated.

During this week, at least the following activities will be undertaken. WestJet and Air Canada will show the airline and airport infrastructure, most likely by touring Calgary airport, Alberta. Actors as SkyNRG can indicate here in what way the Value Chain could fit in here best. In Alberta, also the Paterson Grain state of the art high throughput facility in Gleichen and the 240 acre seed production field nearby Standard will be visited. Subsequently in Swift-current a field tour over the carinata acres and nursery of Agrisoma will be organized. This to show the progress in the front end of the chain, and ensure feedstock growers that the market pull is there. A short seminar about the properties of Saskatchewan and a presentation with the outcomes of this research will be organized. Lastly, meetings in which concrete steps and action plans can be defined will occur to stimulate future progress.

Other steps next to the ones outlined earlier, are undoubtedly the design of a Canadian governmental policy on GHG emission reduction and a special focus for aviation biofuels in this. For this reason, governmental representatives will be included in earlier mentioned meetings. European policies of main interest are the EU Emission Trading Scheme, as this scheme holds the possibility of world-wide implementation. Possible trading patterns between the two parties will be explored as well. First the trade of biojet fuels itself, but also trade in the form of for example knowledge transfer. Research institutes could work together on new crop or refinery technologies. On top of that, potential cooperation between businesses, markets and airlines provides large opportunities for both parties and the aviation sector. These are all recommendations for further research.

Intermediate Summary Collaboration EU and Canada

This section has focused on which steps need to be undertaken to develop a pro-active and operational Value Chain. First of all, existing gaps were indicated. Most important are contracting farmers on production levels and prices, the establishment of a processing and refinery plant, developing governmental policy and support, contracting airlines on off-take agreements, contracting distributors and creating a market for the protein meal once approval for livestock feed use is in place.

A strategic approach to address this has been developed, consisting of several steps (Osseweijer, 2013). Support from the European Union will be incorporated in the form of SkyNRG and possibly KLM. The value chain and existing gaps have already been identified. The next step is creating a market pull, i.e. demand at the side of airline companies. Policy and support mechanisms at the side of government and investors have to be defined. Then, long-term agreements on off-take and price for farmers as well as airlines need to be signed. Next, a refinery plant will be established at commercial scale, followed by the contracting of distribution companies.

The creation of a pro-active Value Chain requires a lot of effort, and external support is needed to achieve this. However, as a result of this research concrete stakeholders representing all focus area's have been defined and approached (Osseweijer, 2013). At this point discussions take place on possible future steps, and within a month from now a trade mission will be organized in Saskatoon to introduce all stakeholders personally and accelerate development and implementation of concrete action plans on biojet fuel implementation for the separate steps of the Strategic Approach. There is a role for the European Union in the form of the Dutch company SkyNRG, who will serve as a supply chain manager and as one of the leaders of this project.

V. Discussion

In this part, the restrictions and boundaries of this research will be discussed. These are important to mention, because outcomes and conclusions may be affected by them.

The goal of the research was to design a Value Chain that would facilitate sustainable implementation of biojet fuels in Canada. In order to do this, first the context has been outlined thoroughly in terms of social, economical, political technological and logistic characteristics of this market. The positions of the relevant stakeholders have been defined and a potential role for the European Union identified.

While writing the plan of action, this Value Chain would be developed by the design of a governmental policy on biojet fuel development in Canada. However, along the way it was indicated that due to lack of intense governmental support the development of such a policy would be time-consuming and without any concrete short-term effects. Therefore instead of a governmental approach, an industry-approach seemed to be preferred. This changed the directions of the research for a bit, as the main focus was on other stakeholders now: the industrial players. This makes the biojet fuel industry more accessible. Another effect of this change in approach, is that cooperation with the European Union on biojet fuels is no longer on the level of European governmental bodies, but businesses and companies. This makes the approach more flexible and promising. On the long term, however, the Canadian government still will have to be incorporated in the plans. From that point on, European policies will become of even more interest.

All in all, the design of a Value Chain lies on the table, stakeholders have not only been indicated but are also approached. The result is an Industry Consortium to work on the Biojet Fuel Initiative within Canada. The European Union is being represented in the form of SkyNRG (NL), experienced in setting up regional biojet fuel supply chains. The involvement of one European expert company as a key stakeholder is considered sufficient to represent European policies, expertise and requirements. However, future cooperation with more European representatives is not ruled out. On top of that, European policies will be used as an example in designing governmental regulations for Canada.

The resulting Trade Mission is considered to be very promising for all parties. This was not an aim of this research, as it was supposed to stick to a plan on paper. However, the fact that real steps are taken now is a good sign that the industry is willing to make progress in the biojet fuel field. The collaboration of SkyNRG is considered very valuable.

In the run towards the design of a strategic approach, several methodologies have been used to map the stakeholders. Thinking of stakeholder analyses, forces analyses and a SWOT analysis. These coordinated mechanisms have helped to get a view of what the industry is all about, and what steps will be relevant to take for the future.

The exact outcomes of the trade mission according to the results of this research yet have to be expected, but that this is a major step for the biojet fuel market in Canada is for sure.

Apart from scientific articles, information in reports composed by and for organizations are sometimes used as a reference. Because they are often focused on one particular project or environmental situation within their interests, they are less objective and determining the validity can sometimes not be an easy task. However, as their aims and targets often correspond with the objectives of this research, it is likely that this will not affect the validity of the research outcomes.

This thesis is written specifically for the biojet fuel industry in Saskatchewan. Certain parts will be applicable to a general type of this industry, but the research as a whole will most likely not be applicable in other specific situations where a Value Chain needs to be developed.

Although the background information about how the EU operates in this field was useful to a large extent, it will be more useful in the future when a Canadian governmental policy will be designed. Here the decision is made to step in to this field at the industrial level, and define the need for governmental support along the way.

In determining the point of view of the Canadian airlines, only the two largest players (Air Canada and WestJet) have been interviewed. They are also participating in further discussions on the biojet fuel initiative. Despite the fact that the two of them own a significant share of the market, their opinion might not be shared by the smaller airlines. In the short-term this will not be a problem since implementation is not yet on large scale, but in the longer term other airlines need to be incorporated as well.

VI. Conclusion

Throughout the research, the centre of attention has been to create a value chain to facilitate biojet fuel implementation in Canada. The focus has been among others on the competitive advantage of the biojet fuel, the adaptability of the current value chain and the collaboration with involved stakeholders. Analyses have been outlined in the four sections 'Socioeconomics and politics', 'Science', 'Business and Actors' and 'Collaboration EU and Canada'. The main research question was:

What are the possibilities and implications in creating a pro-active Value Chain for biojet fuels within Canada?

Two overall sub-questions were:

What are the social, economical, political, technological and logistic characteristics and objectives; what positions do relevant stakeholders have?

What is the role of the European Union; how can collaboration between Canada and the EU help the implementation of biojet fuels?

Here an integrated overview of the Science, Business and Innovation outcomes of the different sections will be provided. This will lead towards answering the initial research question and coming up with a way to facilitate the implementation of biojet fuels in a sustainable manner.

Context

In growing oilseed feedstock, CO_2 from the atmosphere is absorbed. In burning the crop-derived fuel, this carbon dioxide is released again. The next generation of feedstock will absorb this CO_2 for growing. This shorter carbon cycle allows for a relatively carbon-neutral life cycle. Biojet fuel produced out of the oilseed camelina, grown in Saskatchewan, shows an 84% reduction in emissions over the entire lifecycle.

Saskatchewan and Manitoba currently fully rely on import of Jet A-1 fuel. Here lies an opportunity for regionally produced biojet fuel. Once biojet fuel becomes economically competitive with conventional petroleum-based Jet-A1 fuel, this can provide a significant solution for the current fuel shortage and dependency. Current infrastructure is suitable for distribution of biojet fuel, wherein trucking appears to be the most appropriate transport mechanism seen its flexibility in volume and just-in-time delivery and the relatively low capital costs. According to the financial analysis of a 230 MLPY refinery plant, biojet fuels out of camelina and carinata can be competitive with Jet A-1 fuel in the near future, considering crop improvements and further development of refinery technologies. In the short term, Canada is an important region to map, but in the longer run biojet fuel export outside of Canada may be an opportunity as well.

The focus of the biofuel policies of the European Union is on three core principles: *security* (availability of supply), *competitiveness* (referring to price affordability) and *sustainability* (an environmental dimension). The Roundtable for Sustainable Biofuels (RSB) has established twelve criteria that are considered to be at the basis of sustainable biomass production. If biofuels meet these criteria, they operate within the core principles and are approved as renewable fuel source. Subsequently, the EU has set mandatory targets for their Member States within the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD). Among others; by 2020 20% of all energy consumption has to be sustainable, food competition is not accepted and the consequences of (in)direct land use change have to be limited. In order to achieve beneficial effects for the world as a whole, more intense activities outside Europe's boundaries are required. Europe can function as a role model in developing policies to achieve this.

Science

Biofuel-feedstock focuses on second-generation non-edible crops. For Saskatchewan these are Camelina sativa and Brassica carinata. Both crops are relatively disease resistant and know an extraordinary drought and heat tolerance. Together with the possible use as a rotational crop on fallow land, this feedstock is highly suitable to be grown in the Canadian Prairies. For our research outcomes carinata will be used in the form of Agrisoma Resonance® Energy Feedstock.

The refinery process, as developed by Honeywell UOP, consists of several steps. The first step is crushing the oilseeds and extracting remaining oil by washing with hexane. The triglycerides and free fatty acids in the derived oil have to be converted in high-energy molecules. This happens in three steps: deoxygenation, selective hydrocracking / isomerization and product separation. The refined products is a mixture of different products, so has to be fractionated. By distillation, the co-products naphtha, LPG and HDRD diesel are obtained.

BUSINESS

One of the most important stakeholders in the biojet fuel field is the aviation sector itself, consisting mainly out of umbrella organizations and airlines. Umbrella organizations (ATAG, ICAO, IATA) have objectives to grow carbon neutral from 2020 on and reduce their CO_2-emissions with 50% by 2050. Biojet fuels are one of the options to achieve this. International Supply Chain Manager SkyNRG has promising objectives. Personal contact with Canadian airlines has indicated their willingness to cooperate in this renewable project if it is financially attractive. Since WestJet is not flying into Europe and therefore not bothered by their environmental policies, incentives have to be provided. Next to a public role, airlines are identified as main off-takers. Other identified stakeholders are the government, research institutes, farmers, franchisee companies, financial service providers and joint venture partners.

Within the biojet fuel market, six main forces are identified, taking entry barriers into account. S*uppliers* of oilseed/feedstock and biojet fuel have bargaining power in increasing prices, depending on how many suppliers are in place. *End users* or off-takers are the airlines and airports. Their bargaining power is the use of cheaper alternatives (Jet A-1) instead, to drive down price levels. The *government and public* influence the market by creating policies and imposing mandates on environmental actions. Financial support or tax exemptions is another power to steer the market towards a certain direction. *Competition* within the biojet fuel market is still rare, but main bargaining powers are distinctions in pricing, technology, level of innovation, quality and service. The Jet A-1 suppliers are seen as the main current competitors, as they offer a cheaper and more well-known alternative. The degree of *new entrants* to the market is low, given the high capital investments and level of technology. However, they should be monitored carefully in case they offer advantages. The main current *substitute* is Jet A-1 fuel, which is threatening seen the cost and scale advantages. Future substitutes can be hydrogen or electrical planes, since biojet fuels are still considered to be an intermediate solution. *Complementary* products could be the introduction of biojet specific engines. The existing bargaining powers will be of relatively low influence. This is since the aim is to develop a value chain where all stakeholders work pro-actively together to reach a common goal. Competition among actors will be minimized, and collaboration maximized to increase the chances of success in competing the Jet A-1 fuel market.

The SWOT-analysis has indicated significant strengths, such as environmental benefits, short-term deployment and a high potential market. Opportunities are high, seen the decrease in fossil fuel dependency, decrease in import and contribution to existing biofuel goals and policies. Weaknesses to take into account are short-term financial state, requirement of high acreage and dependency of weather conditions. Important threats to monitor are concerns around food security, (in)direct land use change and the financial crisis.

The supply chain consists of five main links. Feedstock Production, Supply Logistics, Conversion, Distribution and End Use. The value chain describes the value that is added to the product by every link in the chain through a combination of primary and support activities. This way, a breakthrough in the market can be realized, creating a market pull at the side of the end users.

INNOVATION

To overcome the valley of death, several gaps in the value and supply chain need to be filled. Most important are contracting farmers on production levels and prices, the establishment of a processing and refinery plant, developing governmental policy and support, contracting airlines on off-take agreements, contracting distributors and creating a market for the protein meal once approval for livestock feed use is in place. A strategic approach to address this has been developed, consisting of several steps. The value chain and existing gaps have already been identified. The next step is creating a market pull, i.e. demand at the side of airline companies. Policy and support mechanisms at the side of government and investors have to be defined. Then, long-term agreements on off-take and price for farmers as well as airlines need to be signed. Next, a refinery will be established at commercial scale, followed by the contracting of distribution companies.

All in all, the creation of a pro-active Value Chain requires a lot of effort, and external support is needed to achieve this. However, as a result of this research concrete stakeholders representing all focus area's have been defined and approached. At this point discussions take place on possible future steps, and within a month from now a trade mission will be organized in Saskatoon to introduce all stakeholders personally and accelerate development and implementation of concrete action plans on biojet fuel implementation for the separate steps of the Strategic Approach. There is a role for the European Union in the form of the Dutch company SkyNRG, who will serve as a supply chain manager and one of the leaders of this project. Their expertise in the field of biojet fuel supply is considered of main importance.

VII. RECOMMENDATIONS

In this part, subjects and focus areas for further research will be provided. These will contribute to the facilitation of biojet fuel implementation.

A main area of further research is undoubtedly the design of a Canadian governmental policy on GHG emission reduction, and a special focus for aviation biofuels in this. European policies of main interest are the EU Emission Trading Scheme, as this scheme holds the possibility of world-wide implementation.

Subsequently, more intense collaboration between Canada and the European Union should be explored. Examples are possible trading patterns between the two parties. First the trade of biojet fuels itself, but also trade in the form of for example knowledge transfer. Research institutes could work together on new crop or refinery technologies to accelerate progress and optimization. On top of that, potential cooperation between businesses, markets and airlines provides large opportunities for both parties and the aviation sector. A start in this further research will be made in the upcoming month by myself and Ag-West Bio, in collaboration with the Ministry of Foreign Affairs of The Netherlands.

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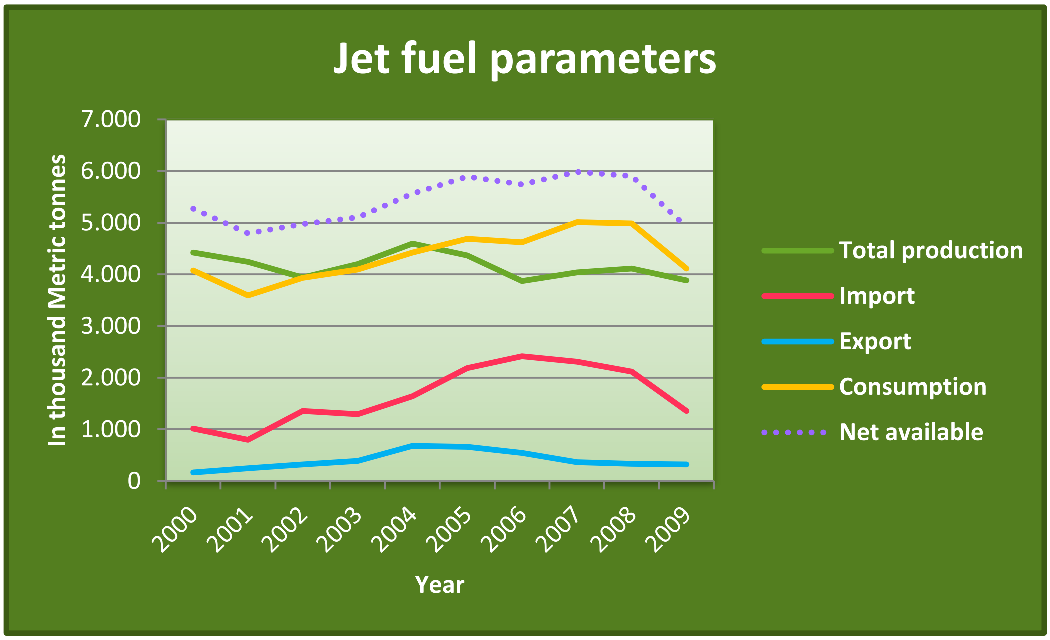
IX. Appendices

A. Current Jet fuel characteristics

The Canadian Jet fuel demand is predicted to grow stable with an increase of 1-2% per year over the next ten years, while the supply of petroleum-based Jet fuel is expected to remain static. This also holds for the Jet fuel market in the United states (Bailey, 2012). Given these points of interest, and the fact that refinery performance is relatively unreliable, a serious opportunity is provided for the development of biojet fuels. The Canadian Prairies are estimated to have a market for at least 350 million liters of biojet fuel per year. Based on historical imports, Eastern Canada and Northern-USA are also potential markets. (Bailey, 2012)

In order to determine the competitive advantage for biojet fuels, it is important to know what the current Jet fuel market looks like. In the short term Canada is an important region to map, but in the longer run biojet fuel export from Canada may be an opportunity as well. This means the worldwide Jet fuel market is of interest and it is important to find out to what extent a competitive advantage exists. In Graph A-1, the parameter trends in the Canadian supply and demand of Jet fuel over the years 2000-2009 are displayed (Osseweijer, 2013; United Nations Statistics Division, 2013). To meet the demand, within Canada fuel is traded to a high extent.



GRAPH A-1: PARAMETER TRENDS CANADIAN SUPPLY AND DEMAND IN JET FUEL. THE NET AVAILABLE AMOUNT OF JET FUEL IS CALCULATED AS FOLLOWS: *TOTAL PRODUCTION + IMPORT – EXPORT*. SOURCE: UNSD – ENERGY STATISTICS DATABASE 2013

Within Canada, the refinery or import of Jet fuels is highly diversified. In Figure A-1 the production and demand values per province are shown. Some provinces do not have their own refineries. To meet regional demand, it is necessary to import from other provinces, the United States and off-shore. This can happen by truck, railway or pipeline. Table A-1 outlines this system and the relative shortages or surpluses for all of the provinces. Striking is that Saskatchewan and Manitoba fully rely on import (Bailey, 2012; Government of Canada, 2013)

FIGURE A-1: PRODUCTION AND DEMAND OF JET FUEL IN CANADIAN PROVINCES IN MILLIONS LITRES PER YEAR (MLPY). THE DEMAND VALUES INCORPORATE ONLY THE DEMAND OF THE RESTRICTED PROVINCE, NOT THE DEMAND FROM NEIGHBORING PROVINCES. SOURCE: BAILEY, 2012

TABLE A-1: JET SUPPLY AND DEMAND BALANCE WITHIN CANADA, INCLUDING MECHANISM FOR SHORTAGE/SURPLUSES. SOURCE: BAILEY, 2012

Region	Production MLPY	Demand MLPY	(Short) Length	Comments
British Columbia	465	1,740	(1,275)	Majority short supplied by marine imports and trucked from AB
Alberta	1,300	929	371	Surplus used to supply BC, SK, MB and Territories. Import from BC coast and US is necessary.
Saskatchewan	0	91	(91)	No Jet fuel production. Supply via pipeline from AB to Regina, then trucked
Manitoba	0	240	(240)	No Jet fuel production. Supply via pipeline from AB to Winnipeg and Regina, then trucked
NW Territories	0	58	(58)	Truck from AB.
Ontario	1,400	2,600	(1,200)	Majority short supplied via rail from import Quebec marine terminal
Quebec	755	1,160	(405)	Majority short supplied via rail from import marine terminal
Atlantic Canada	930	495	435	Majority surplus exported to US. Also competition for imports Quebec and Ontario.
Total	4,850	7,313	(2463)	Especially Western Canada is short on Jet fuels, expecting not to improve in the near future.

The shortage numbers in Figure A-1 and Table A-1 indicate a fundamental opportunity for biojet fuels. Once they become economically competitive with the conventional petroleum-based Jet fuels, they can provide a significant solution for the current fuel shortage. In the near future, the biojet fuel production can occur on larger scale as an alternative for the petroleum-based Jet fuels. Given it's CO_2 benefits, biojet fuels can be a significant pillar in addressing climate change objectives.

B. JET FUEL PRICING 230MLPY REFINERY PLANT

Table B-1 outlines the price composition of the oilseeds. Camelina and carinata will only be included in the crop rotation schedule if they are financially competitive with other oilseed crops. The variable expenses per acre are calculated by summing up respectively current and expected future prices for the seed, fertilizers, chemicals, machinery, labor, utilities and interest on variable expenses (Government of Saskatchewan: Ministry of Agriculture, 2013). Future advances in oilseed composition and process technology, will increase the prices (2017F). The return on a rotation crop is set at the level of canola in the brown soil zone, $37.12 (Ag-West Bio Inc., 2012b). When entering the darker soil zones, these prices will go up. In addition to the production costs, transportation costs have been included to estimate the final oilseed prices. The average transport distance is set at 174km, which is represented by a transportation cost of $16.25/MT. Before processing can take place, the seeds will have to be cleaned. This is estimated to cost $6.45/MT.

The costs for oilseed production in the brown soil zone lie around $230/MT. However, production will also take place in the dark brown soil zone. As this soil is more attractive, prices will go up to $350/MT (Ag-West Bio Inc., 2012b). All the provided results are only correct under the outlined assumptions.

TABLE B-1: PRICE COMPOSITION PER MT OILSEED GROWN IN BROWN SOIL ZONE. SOURCE: PORTER & SAVILLE, 2012; SASKATCHEWAN MINISTRY OF AGRICULTURE, 2013

	Camelina 2012	Camelina 2017F	Carinata 2012	Carinata 2017F
Field Production				
Variable expenses ($/ac)	$123.13	$161.42	$143.12	$173.75
Return over Variable expenses	$37.12	$37.12	$37.12	$37.12
Required revenue farm ($/ac)	**$160.25**	**$198.54**	**$180.24**	**$210.87**
Transportation				
Average cost per MT	$16.25	$16.25	$16.25	$16.25
Production				
Estimated Yield (MT/ac)	*0.82*	*0.95*	*0.92*	*1.00*
Summary				
Required price ($/MT)	$195.43	$208.99	$195.92	$210.87
Transportation cost per MT	$16.25	$16.25	$16.25	$16.25
Seed cleaning per MT	$6.45	$6.45	$6.45	$6.45
Total Cost to Crushing (/MT)	**$218.13**	**$231.69**	**$218.62**	**$233.57**
Price per Bushel (50lbs)	$5.00	$5.50	$5.00	$5.50
Price per Pound	$0.10	$0.11	$0.10	$0.11

Because prices will rather go up than down, seen technology improvements, the average price of $350/MT for both camelina as carinata oilseeds will be used for further calculations. All expenses a camelina processing plant will make in refining the oil are outlined in Table B-2. The oilseeds in 2012 had a 40% oil content, whereas the oilseeds in the future (2017F) are expected to have an oil content of 45%. Therefore in 2017F, less oilseeds are needed for the same amount of biojet fuel. This will decrease the costs per liter. Remarkable is that the relative costs per liter of biojet fuel for hexane, water and effluents, are zero. This is due to the fact that these materials will be re-used in the next refinery processes, wherefore their expenses are negligible.

TABLE B-2: OPERATIONAL INPUTS AND EXPENSES FOR A 230 MLPY CAMELINA REFINERY PLANT. SOURCE: PORTER & SAVILLE, 2012

	Input		Price	in	Annual cost ($)		$/L Biojet fuel	
	2012	*2017F*			*2012*	*2017F*	*2012*	*2017F*
Oilseed	846,450	755,700	350	$/MT	297,990,000	263,340,000	1.30	1.16
H_2	12,193	12,247	1,656	$/MT	20,312,605	20,194,508	0.09	0.09
Hexane	865	722	1,150	$/MT	1,000,234	883,927	0.00	0.00
Electricity	20,364,059	19,815,753	0.06	$/kWh	1,228,989	1,183,753	0.01	0.01
Sour Water, L	17,472,405	17,549,038	2.50	$/1000 USG	11,608	11,541	0.00	0.00
Cooling water, MT	277,741	261,956	2.75	$/1000 USG	202,974	189,494	0.00	0.00
Process Water, MT	5,015	5,037	2.75	$/1000 USG	3,665	3,644	0.00	0.00
Effluent, MT	64,724	60,285	2.50	$/1000 USG	43,000	39,644	0.00	0.00
Fuel gas	729,255	698,455	5.50	$/ MMBTU	4,034,358	3,824,726	0.02	0.02
Total expenses							**1.42**	**1.28**

In Table B-3, the revenues for the refinery plant are calculated and displayed. Revenues are derived from the biojet fuel and the co-products hydrogenation-derived renewal diesel (HDRD), naphtha, LPG and the protein meal. The price for the biojet fuel is targeted at 0.80$/L. In the last column, the co-product revenues relative to biojet fuel are displayed. Remarkable is that only the relative protein meal revenue is dropped in the future scenario. This has to do with the fact that due to the increase in oil content of 45%, there is a corresponding reduction in the dry meal. As the difference in outcomes between camelina and carinata refinery plants are small, the corresponding results for carinata are displayed in Table B-4 and Table B-5.

TABLE B-3: OPERATIONAL OUTPUTS AND REVENUES FOR A 230 MLPY CAMELINA REFINERY PLANT. SOURCE: PORTER&SAVILLE, 2012

	Output		Price	in	Annual revenue ($)		$/L Biojet fuel	
	2012	*2017F*			*2012*	*2017F*	*2012*	*2017F*
Biojet fuel (MT)	175,382	176,152	0.80	$/L	183,428,324	182,361,880	0.80	0.80
HDRD (MT)	28,176	28,299	0.89	$/L	30,765,396	30,586,527	0.13	0.13
Naphtha (MT)	70,256	70,564	0.66	$/L	62,226,025	61,864,246	0.27	0.27
LPG (MT)	27,436	27,556	0.53	$/L	26,825,006	26,669,046	0.12	0.12
Protein meal (MT)	474,012	385,407	265	$/MT	126,347,760	101,686,860	0.55	0.45
Total revenue							**1.87**	**1.77**

TABLE B-4: OPERATIONAL INPUTS AND EXPENSES FOR A 230 MLPY CARINATA REFINERY PLANT. SOURCE: PORTER & SAVILLE, 2012

	Input		Price	in	Annual cost ($)		$/L Biojet fuel	
	2012	*2017F*			*2012*	*2017F*	*2012*	*2017F*
Oilseed	861,300	765,600	350	$/MT	301,455,000	267,960,000	1.32	1.17
H_2	11,700	11,700	1,656	$/MT	19,378,377	19,378,377	0.08	0.08
Hexane	880	782	1,150	$/MT	1,011,864	899,435	0.00	0.00
Electricity	20,565,944	19,919,969	0.06	$/kWh	1,233,957	1,195,198	0.01	0.01
Sour Water, L	17,523,744	17,523,744	2.50	$/1000 USG	11,574	11,574	0.00	0.00
Cooling water, MT	282,614	265,388	2.75	$/1000 USG	205,334	192,818	0.00	0.00
Process Water, MT	5,103	5,103	2.75	$/1000 USG	3,708	3,708	0.00	0.00
Effluent, MT	65,859	61,074	2.50	$/1000 USG	43,500	40,340	0.00	0.00
Fuel gas	738,163	703,719	5.50	$/ MMBTU	4,059,895	3,870,453	0.02	0.02
Total expenses							**1.43**	**1.28**

TABLE B-5: OPERATIONAL OUTPUTS AND REVENUES FOR A 230 MLPY CARINATA REFINERY PLANT. SOURCE: PORTER&SAVILLE, 2012

	Output		Price	in	Annual revenue ($)		$/L Biojet fuel	
	2012	*2017F*			*2012*	*2017F*	*2012*	*2017F*
Biojet fuel (MT)	175,898	175,898	0.80	$/L	182,897,716	182,897,716	0.80	0.80
HDRD (MT)	25,507	25,507	0.89	$/L	27,689,848	27,689,848	0.12	0.12
Naphtha (MT)	59,770	59,770	0.66	$/L	52,631,100	52,631,100	0.23	0.23
LPG (MT)	43,573	43,573	0.53	$/L	42,345,696	42,345,696	0.19	0.19
Protein meal (MT)	482,328	390,456	265	$/MT	127,816,920	103,470,840	0.56	0.45
Total revenue							**1.90**	**1.79**

C. Biofuel Policies EU

A key mechanism to the European Union's policy to reduce GHG emissions, is the EU Emissions Trading System (EU ETS). The system operates within the Clean Development Mechanism (CDM) and works according to the 'cap and trade' principle, which is very cost-effective. The EU ETS is applicable to all industries that operate with or within the EU, including the aviation industry (Zhang & Wei, 2010). Within a certain industry there is a cap, or a maximum amount of GHG emission that is allowed. Companies can sell or buy these allowances from one another, according to their overall emissions which can be higher (buy) or lower (sell) than the set limit. Through this flexible mechanism, the total emissions within the industry are lowered to a certain level in the most cost-efficient way. Since 2012, the aviation sector participates in EU ETS. It is the first and biggest international trading scheme on GHG emissions (Maniatis et al., 2011). It is now legal for the EU to impose tax on international airlines, something which evoked strong resistance among US, Chinese and other airlines (Rosillo-calle et al., 2012). However, especially in aviation there are opportunities for turning this mechanism into a world-wide initiative to globally stimulate emission reduction as cost-efficient as possible. Especially since airlines that do not fly into the European Union are not motivated to reduce their emissions at this moment (Industry Consortium: Geoffrey Tauvette, 2013).

Another important mechanism is the Clean Transport System (CTS) initiative. This is a long-term strategy to substitute fossil fuels by alternative and sustainable sources. This way, GHG emissions in transport are reduced within the time span from present to 2050 (Maniatis et al., 2011). Also the aviation sector is addressed within the CTS. The International Civil Aviation Organization (ICAO), developed by the United Nations, actively contributes in reducing GHG emissions in aviation. For example, they organize conferences and workshops on sustainable alternative fuels (International Civil Aviation Organization, 2013). The European Union has set a long-term vision for its aviation sector in the report 'Flightpath 2050 Europe's Vision for Aviation'. The research priorities and value-adding opportunities are outlined, in order to maintain EU growth, market needs and competitiveness, while addressing environmental challenges. These include improving engine efficiency and aerodynamics of aircrafts and the production of sustainable alternative Jet fuels (High Level Group on Aviation Research, 2011). The total biojet fuel share from 2020 on is aimed at approximately 2 million ton per year in the EU. To achieve this target, an appropriate framework is necessary to ensure environmental progress and financial support and to reduce investments risks. In a 2011-paper commissioned by the European Commission, the *European Advanced Biofuels Flight path Initiative*, implementation steps are outlined within certain time spans. Objectives are set for 2015, 2018 and 2020, summarized in Table C-1 (Maniatis et al., 2011). By using these mandatory objectives, industry itself comes up with the most cost-efficient solutions in reducing GHG emissions.

TABLE C-1: OBJECTIVES SEPARATED OVER TIME SPANS 2015, 2018 AND 2020 TO ACHIEVE COMMERCIAL UTILIZATION OF BIOJET FUEL.
SOURCE: MANIATIS ET AL., 2011

Year	Objectives
2015	▪ Communication strategy towards flight passengers on advantages of biojet fuels without any safety restrictions ▪ Use of effective financial mechanisms to reduce risks for investors en technology developers. ▪ Formulated quality standards and certified (on flight tested) biojet fuel use. ▪ Supply of sustainably produced vegetable oils for existing and new production plants. ▪ Construction of at least 3 biofuel production plants at commercial scale, where utilization of lignocellulosic feedstock is enabled. ▪ Creation of a market for aviation biofuels by an appropriate policy and financial mechanism. Legislation in member states is an example, as well as allocation of ETS revenues to support technological development.
2018	▪ Commercial flights using bio-kerosene blends ▪ Construction of 4 biofuel production plans at commercial scale ▪ Construction of two algal oil producing plants ▪ Supply of affordable algae oils to be used as raw material in processing plants
2020	▪ Commercialization of biofuel production technologies ▪ Full deployment of at least 2 million tons biofuels per annum in aviation in the EU ▪ Approximately all EU airports operate with biofuel blends, it's available at commercial scale.

Another initiative to contribute to the implementation of the EU Flight Path and EIBI objectives, is the Initiative Towards sustAinable Kerosene for Aviation (ITAKA). Within this initiative, the development of aviation biofuels is supported in an economically, socially and environmental sustainable manner. Next to ITAKA, Sustainable Way for Alternative Fuel and Energy in Aviation (SWAFEA) has identified implementation options for biojet fuel. The aim is to develop a full value-chain on drop-in biojet fuel production, up to 50% blends at large scale. For this, supply and demand have to be linked. ITAKA will facilitate relationships between feedstock growers, refinery plants, distributors and airlines. ITAKA will also contribute in the coordination of efforts needed within the initiative, to engage key stakeholders important in establishing a EU framework (ITAKA, 2013).

D. Questionnaire Airline Companies

These questions concern the position airlines take in the transition to a biobased aviation industry. It can help gaining insight in the objectives of airline companies, and how to realize the transition to a green aviation industry on a high level.

1. Do you share the opinion that the aviation sector has the responsibility to contribute to the transition towards renewable energy, seeing as its 2% share in the GHG emissions worldwide? If no, why not? If yes, are you willing to take structural action to reduce the environmental impact of your company, even if it is at a certain cost?
2. What is your opinion on the Emission Trading Scheme the European Union uses to achieve their targets according to the 'polluter pays' principle? Would such a scheme be applicable worldwide for the aviation industry or do you have other possible solutions?
3. What do you, as an airline company, expect from the government with regards to a transition to greener aviation and the use of biofuels? Do you believe aviation biojet fuel supply will emerge in the absence of government policy and direction on a global basis? What does this policy / direction need to look like?
4. What is the influence of umbrella organizations such as ATAG, IATA and ICAO on your policymaking?
5. What actions does your airline already undertake in making the transition to greener aviation and what are the drivers?
6. Some airlines have agreed to compensate for their CO_2-emissions until it is possible to completely avoid them. Does your company participate in this, and, if yes, how?
7. Biojet fuels are safe (drop-in), sustainable and cost-competitive with Jet A1 fuels. Would you consider switching fully to this renewable jet fuel? Do you have any concerns around security of supply and the quality of the fuel?
8. Do you see any role for yourselves in the emerging aviation biojet fuel chain beyond that of primary customer? Would you consider direct investment in refining processing facilities in exchange for long term security of supply?
9. Do you, as the primary customer in the current value chain for Jet A-1, have any strategies in place to help lead your suppliers (current petroleum refiners) towards participation in the emerging aviation biojet fuel economy?
10. Do you believe passengers have any appetite to pay a premium for air travel powered by bio-based fuels? Any thoughts on what that premium might be, if any?
11. Where do you see the aviation industry in 2050, and what would your place be within this industry?

KLM

June 24, 2013 9:00 – 10:00 am (SK time)

Participating: Floor Osseweijer (Ag-West); Eileen van den Tweel (KLM)

About five years ago KLM has started their investment in the development and use of biojet fuels for two main reasons. As approximately 95% of their carbon footprint is caused by jet fuels, the use of biojet fuels will significantly increase the sustainability of the flights. Second, the fuel counts for the largest share of the total company costs. Nowadays, a large dependency of the fossil fuel industry exists. Biojet fuels are believed to be a break through this dependency. KLM believes that once a sustainable Value Chain is being developed, this will in the end drive down the price of biojet fuel. This is why KLM wishes to be part of these developments.

KLM has several criteria for biojet fuel. It has to be developed out of second generation feedstock, satisfy RSB-standards and the criteria of SkyNRG's Sustainability Board. Their supply is arranged through SkyNRG, but it is found that this supply is very limited. Up to now used cooking oil and camelina feedstock are used as sources for biojet fuels, but KLM is open for the use of other materials as long as they satisfy aforementioned criteria. SkyNRG is KLM's only supplier. KLM is one of the founders of SkyNRG, but since the company operates commercially KLM is only the biggest shareholder.

So, the security of supply of biojet fuels is not yet in place. The supply is limited and the price is too high. However, KLM participates throughout the Value Chain to stimulate the development. As an off-taker, KLM has large influence in the media. KLM serves for example in connecting parts of the value chain. They bring technological companies in contact to discuss and develop feedstock, refinery technologies and other biojet expertise. They participate in EU programmes on biobased economies, stimulating development in all parts of the value chain. Refiners often declare to be willing to process bio-feedstock to biojet fuel, though they consider that off-take is not in place and investing in such a plant will therefore be to high of a risk. Off-take agreements between refiners and airlines are therefore created, taking several constructions. KLM is talking with feedstock farmers world-wide, often in collaboration with a local bank. Also, contact with Universities, chemical companies, refineries and other participants of the value chain take place on a high level.

KLM offers its passengers the option to compensate for the CO_2 that is emitted during their flight by paying a premium (around €10,-, depending on the flight duration). However, this option is not very popular by travelers, most likely because there is no direct benefit (such as when using biological food). Next to this premium for private passengers, companies can subscribe on such a premium as well. This is called the corporate biofuel programme. Companies have a contract with KLM according to which they pay a fixed price or a certain percentage of their turnover. This money is used by KLM to invest in biojet fuel and its development. Companies can justify that they travel (at least by air) sustainably. Additional benefits are the creation of demand (market pull) and (financial) stimulation of research.

Together with Schiphol in Amsterdam, JFK Airport in New York and Delta Airlines, KLM organizes a weekly biojet fuelled flight between the two cities. This is partly to symbolically strengthen the relationship between Amsterdam and New York, but also to address the sustainability criteria of all involved parties.

KLM has its own fuel service, Schiphol has nothing to do with this. Logistically the biojet fuel part is managed by SkyNRG, as mentioned before. The biojet fuel is still a very small share of the total fuel use of KLM.

In the end, biojet fuel is seen by KLM as an intermediate solution. Drop-in fuel is the only suitable energy source in current engines. In the long term, new energy sources are expected to be found and new planes will be used. However, in the short term the share of biojet fuel is expected to increase. This depends on the availability of feedstock and progress in refinery techniques, altogether resulting in the development of a pro-active value chain.

Air Canada

June 25, 2013 2:00 – 3:00 pm (SK time)

Participating: Floor Osseweijer (Ag-West); Teresa Ehman (Air Canada)

Air Canada spends about 4 billion dollar a year on fuel. In order to meet 2020 carbon emission reduction goals, they are willing to purchase a certain amount of their fuel in the form of biojet fuel. However, this has to be against an economically feasible price, in other words, a significant premium is not a possibility. In the past Air Canada has already signed off-take agreements on biojet fuel to provide solidity to development of this sector. Among others with the companies AltAir and RemTech.

Last year, SkyNRG has provided Air Canada with biojet fuels for their first bioflights. At this moment there are no supply mechanisms between the two, but they are still in contact to address future possibilities.

Canada knows the construction of a Fuel Consortium, responsible for fuel supply in aviation. This consortium is owned by the airlines, each airline owns the consortium in proportion of their fuel use. Airlines themselves are thus responsible for the purchased fuel. Airports are only involved in infrastructural mechanisms, such as transport at the airport and storage.

Air Canada is conducting an internal feasibility study on the suitability of feedstock available throughout Canada. The feedstock included in their study varies from biomass waste to oilseeds to algae. The study is done by BioFuelNet Canada. BioFuelNet Canada is commissioned to do a feedstock assessment for biojet fuel production in Canada. The goal is to fundamentally understand what makes the most sense in Canada. This feasibility study will most likely be done near the end of 2013. This link provides an article on the conducted study: http://www.biofuelnet.ca/news-and-events/news-2/.

Though the feedstock study conducted by BioFuelNet Canada has no outcomes yet, Air Canada is interested to keep talking with the several parties in the biojet fuel industry. Air Canada understands the need of a demand to create a market pull, providing solidity in the development of the Value Chain. They are also interested in participating in the trade mission we try to set-up in August, but most likely want to wait for the outcomes of their study before signing off-take agreements.

WestJet

June 27, 2013 2:30 – 3:30 pm (SK time)

Participating: Floor Osseweijer (Ag-West); Geoffrey Tauvette (WestJet)

WestJet has already collaborated in last year's feasibility study of Ag-West. Next to fuel supply manager at WestJet, Geoffrey Tauvette is the Chair of the Industry Association Environmental Committee. Air Canada is also part of this committee. Geoffrey indicates that, as WestJet is not flying into the European Union, at this moment there is less pressure on the adoption of biofuels in the supply chain. However, there still are the 2020 targets, so WestJet is willing to cooperate in such initiatives.

Geoffrey indicates the structure of jet fuel in Canada, where the unique situation exists that airlines own the jet fuel supply infrastructure in the form of a fuel consortium. This means that airlines control fuel supply at the eight main Canadian airports. Small airports are supplied by Esso and Apron, but Geoffrey says we can make this work. Biojet fuel will have to be trucked from the refinery plant to the off-take points / airports, as trucking was indicated as most feasible transport mechanism in an earlier study. Geoffrey answers that it has not been explored exactly where, how and to what extent biojet fuel will be implemented, if it will be a blend or a separate storage etc. However it might be an opportunity to incorporate biojet fuel in the conventional jet fuel infrastructure (pipeline), instead of trucking. Probably it is better to hold the objective to provide a regional solution with this biojet fuel, so that the aim is not necessarily to fully integrate with the current supply infrastructure.

E. Stakeholder Overview

Leveled overview of all stakeholders involved in the adoption of biojet fuels.

This section provides a leveled overview of all stakeholders involved in the adoption of biojet fuels, next to airlines and umbrella organizations. The stakeholder analysis in Figure E-1 applies to a general biojet fuel industry. [4]

- **Govern-ment**
  - State Government
  - Ministry of Agriculture / Environment
- **R&D**
  - Research Insitutes and Universities
  - Developmental, quality and suitability studies
- **Farmers**
  - Small and Medium; Camelina and Carinata
  - Seeding, cultivation and harvest
- **Franchi-see**
  - Crop management and Technical assistance
  - Quality monitoring
  - Procurement and distribution
- **NGO's**
  - Project implementation
  - Facilitation and investments
- **Financial Service Providers**
  - Risk management
  - Insurance for farmers and investors
- **JV Partners**
  - Refinery processing firms
  - Oil Marketing Companies: Shell, Esso
- **Off takers**
  - Airlines companies
  - Military

FIGURE E-1: GENERAL STAKEHOLDER ANALYSIS FOR THE BIOJET FUEL INDUSTRY

[4] A stakeholder analysis serves to identify the actors that are involved in a certain industry. A complete synopsis will help in stakeholder and project management, gap indication and policy development. There has not been made use of a certain model in this case, it is just a regular mapping of the industry.

Government

European Union

The European Union is an economical and political partnership within 27 European countries. The governance in the EU is regulated within several bodies. The overall political direction and general priorities of the EU are set by the European Council. Every member country represents itself in the form of their national leaders, as this way the national governments can defend their interests in the Council. The presidency rotates among the member countries. The interests of the EU as a whole are represented by the European Commission, composing of members appointed by national governments. Third, the European Parliament represents the citizens of the EU and is elected directly by them. The European Council, Commission and Parliament together can produce policies and laws applying to every member country. In practice, new laws are proposed by the Commission and subsequently adopted by the Parliament and the Council. Implementation takes place by the member countries, which is controlled again by the Commission (Communication department of the European Commission, 2013).

This political design is highly beneficial in the case of biofuel policies. Because of the commitments of the member countries towards the EU policies, something can actually be achieved. The EU requires it's countries to develop energy sources within the renewable energy objectives, a powerful way of implementing sustainability. The policies and frameworks are required to be clear and predictable, in order to attract investors and motivate stakeholders (European Commisson, 2012). In the European biojet fuel policies and regulations, governmental agencies on the EU as well as the national level have to be taken into account. There are several EU committees specifically for energy, climate change and sustainable transport which have a large interest in these policy developments and implementations (Communication department of the European Commission, 2013). On the national level one has to think of the Ministry of Environment, the Ministry of Agriculture and the Ministry of Economical Affairs. These bodies are responsible for implementation of the EU policy within each country, but are also in place to develop their own more ambitious policy.

Canada

Canada knows a federal government, and provincial governments for the ten provinces. Their power is relatively large. For the environmental policies on biojet fuel, we will focus mostly on the Provincial Government of Saskatchewan. The agricultural sector in which the biofuel feedstock is grown is mainly situated here. The biojet fuel is funded under the Canadian Agricultural Adaptation Program (CAAP), to help the agricultural sector and remain competitive. The project is led by Ag-West Bio Inc., funded by the provincial government (Agriculture and Agri-Food Canada, 2011). This clearly illustrates the difference between NA and the EU. Where the EU sets strict targets and develops extensive policies and implementation mechanisms, the Canadian government limits to outsourcing the problem towards the more private sector by providing funding. Bodies such as Transport Canada, Environment Canada, Agriculture Canada, Natural Resources Canada and the Department of National Defense will be encouraged to contribute to the development of an overarching policy, creating a federal lead department.

Research and Development

In both regions, the R&D is done by various research institutes, Universities as well as government funded and private agencies. The main knowledge and research agency on biojet fuels in Canada is Agrisoma, working closely together with Ag-West Bio Inc. Agrisoma aims to develop sustainable energy feedstock within the agricultural sector. Focus lies on enhanced oilseed yields and oil quality. Agrisoma is in fact a private company, but has close ties with governmental agencies. Agrisoma is responsible for the production of Brassica carinata, trademarked under Agrisoma Resonance. The used conversion and refinery technique, as explained in section II. Science, is developed by the company UOP Honeywell. The National Research Council Canada (NRC) worked closely together on this project. In October 2012 NRC coordinated the first test flight on 100% drop-in biojet fuel (Voegele, 2013).

To make the biojet fuel economically beneficial, research on the co-product meal is also important. This is done by the Feed Innovation Institute (FII) based at the University of Saskatchewan in Saskatoon. Trials on the quality and appropriateness of the meal as animal feedstock are done here (Canadian Food Inspection Agency, 2011).

The research and development on biojet fuels will be valorized by the stakeholders that are engaged in the implementation.

Farmers

An important group of stakeholders is the farmers. They provide the basic feedstock needed to produce biofuels. These concern mainly private farmers who up to now focus on other crops, wherefore their land use will change. As discussed in the Science section, this can have significant impact on the environments. A major part of the camelina and carinata will be grown in the southern brown and dark brown soil zones, whereas these are the drier and warmer regions of Saskatchewan. In Figure E-2, the different soil zones in Saskatchewan are shown (Government of Saskatchewan: Ministry of Agriculture, 2009). Growing camelina and carinata can be an alternative for leaving the land fallow. In 2010, there was 2.67 million fallow acres (Ag-West Bio Inc., 2012b). Because the research and development on biojet fuels is carried out mainly from CAAP, focusing on agriculture, it will be an opportunity for farmers to participate in this sector.

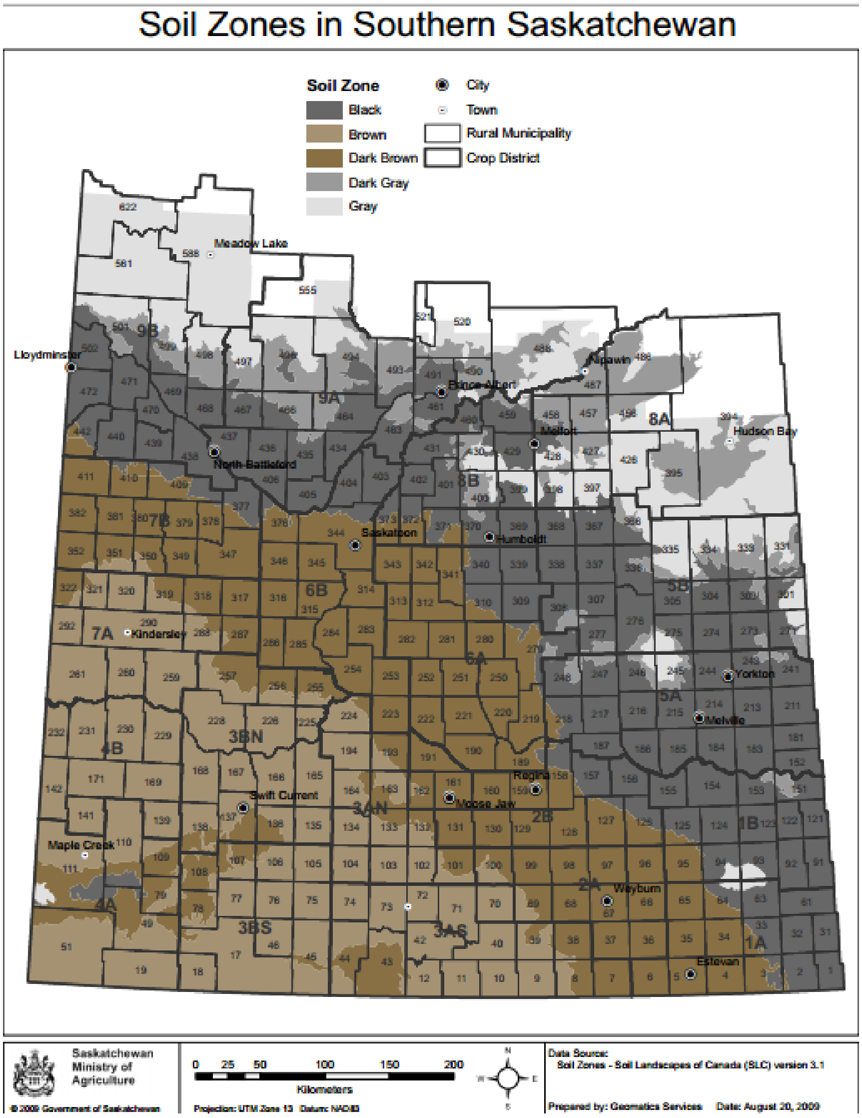


Figure E-2: Distribution of soil zones appropriate for crop growing in Southern Saskatchewan, Canada. Source: Government of Saskatchewan: Ministry of Agriculture, 2009

Franchisee

Franchisee involves various stakeholders who provide a certain service within the value chain, using the business trademark and if necessary knowledge. For example, they can fulfill a role as procurement agent or as distribution link, but also in quality monitoring and crop management. Franchisees can also be allowed to trade the biojet fuel up to certain amounts. The term franchisee thus accounts for a range of stakeholders participating in the biojet fuel value chain which can be on all sorts of levels.

Non-Governmental Organizations

A large amount of Non-Governmental Organizations (NGO's) are dedicated in lowering

GHG emissions and promoting the biofuel policy. Partly stimulated by governmental mandatory policies, but also developed throughout their own perspectives. NGO's exist in various forms, such as private investment companies, organizations to facilitate implementation, private research companies et cetera. Agrisoma (see R&D) is an example of a private research company. Nowadays, they receive subsidies from the government because their research is in the public interest, but it remains an NGO.

International Air Transport Association (IATA) together with International Civil Aviation Organization (ICAO), both headquartered in Montréal, are organizations covering the major part of the airline industry. Air Transport Action Group (ATAG) is another example of such an umbrella organization. All of them stimulate adoption of the use of biojet fuels, to lower the industry's emissions profile to 50% of the 2005 level by 2050.

Financial Service Providers

Investing in such an innovative project can be seen as a risk. Financial Service providers, such as banks, can provide insurances for risk-reduction. Investors as well as participating farmers and organizations can this way operate in image-building projects meeting governmental targets. Next to providing insurances, the financial sector has the opportunity to do investments in certain projects. The GHG emission reduction targets and mechanisms, such as the cap and trade scheme in the EU, also account for the financial sector. They can meet their targets by investing in sustainable projects or by incorporating alternative, more sustainable, policies. The biojet fuel sector is one of the investment opportunities for banks (Geel, 2006).

Investors in the form of private investors, venture capitalists as well as organizations, are an important driver in promoting research and implementation.

Joint Venture Partners

Joint Venture partners, in contrast to franchisees, are fully incorporated in the value chain and not easily substituted by a comparable organization. The oilseed processing and refinery plant is such an example. They are provided with technological knowledge to chemically convert the vegetable oil to appropriate biojet fuel. Financial investments in the development of such a plant are significant. Another example of Joint Venture Partners are the companies who serve in the marketing of the oil, in other words, bringing the biojet fuel to the market. Companies such as Esso and Shell act as such partners, they bring potential end users in contact with the product. Aircraft manufacturers are another important group of JV partners, as they can promote the usage of biojet fuel by their design of the engine and plane.

Off takers

The off takers or end users of the biojet fuel are very important stakeholders. In terms of marketing and economics, they are the ones to create a market pull. This facilitates development and implementation of the product. The end users are the airline companies. In this report, the focus lies on the largest airlines, as they are in the position to implement new policies and function as an example for the smaller airlines. The largest airlines in the EU are KLM, Air France, Lufthansa and British Airways. In Canada, the airlines that are considered most important are WestJet and Air Canada. The objectives and commitment of these airlines are really important to ensure implementation of the biojet fuel and achievement of targets. In the previous chapter, their interests and influences in the aviation fuel industry are analyzed.

F. PORTERS FORCES MODEL: BARRIERS TO ENTRY

As mentioned, when a company wants to enter a market or a new market is ought to be created, this could be hindered in various ways. These hindrances are the so-called barriers to entry. In Porter's five forces model, the six most important barriers to entry a new market are indicated (M. E. Porter, 1979). These will be described here in relation to the creation of a new pro-active biojet fuel market.

- *Economies of scale:* The current Jet A-1 fuel market can be seen as an economy of scale. Operating on such a large scale involves cost advantages. As a newcomer on the jetfuel market, biojet fuel will have to overcome these scale advantages in different ways to be able to provide a cost-competitive product. Biojet fuel will generally be produced regional because of feedstock availability and transportation costs.
- *Product differentiation:* In many markets, established companies are known and appreciated for their brands, which involves customer loyalty. New entrants will have to invest to be able to break through this barrier by differentiating their product. Generally, the currently used Jet A-1 fuel is not much affected by differentiation strategies. Fuel suppliers usually have a monopoly in a certain region, and all the fuel is mainly derived from the same refinery plants. The product is not differentiated. What happens when biojet fuel enters this market, is that a differentiated product is offered. End users can choose between different fuels, based upon their quality , price and environmental friendliness. It will have to be seen if the biojet fuel will be supplied by the same fuel suppliers, acting as a substitute, or if this will happen through a separate distribution network.
- *Capital requirements:* Depending on the sector, entering the market can require a large amount of capital. These investments form a risk, which creates a barrier to entry the market for new organizations. In the case of biojet fuels, a large amount of capital investments is required before returns will be shown. This includes investments in research and technology as well as investments in building refinery plants and an infrastructure.
- *Cost disadvantages independent of size:* Next to capital requirements, other cost disadvantages that are independent of the size of the entering organization can occur. These include for example knowledge and experience, access to resources, subsidies or a strategic and favorable location. Knowledge or technology can also be owned in the form of patents, which offers advantages over competitors. As the biojet fuel market is not yet fully operational, there are advantages in knowledge compared with newer organizations or institutes. Technology is not yet fully operational, but the research is very progressive and first of its kind. Though, seen the established order knows a static structure, despite of these advantages it will be hard to break through. This includes switching costs, the one-off costs customers have to pay for switching their product or organization. If these costs are too high, customers will be harder to convince to switch to the new product or provider.
- *Access to distribution channels:* A new product needs a distribution channel, and so does a new market. Usually, the obvious channels are already used by current organizations and markets, which makes it hard to break through or make use of the established structure. In some cases, a license is needed to make use of a certain distribution channel. However, in the case of biojet fuels it is not expected that a new distribution channel needs to be created, the current Jet A-1 channel is suitable for use. Recalling that the biojet fuel can displace Jet A-1, as long as the change is guided by demand instead of supply no major difficulties are expected.
- *Government policy:* The government is in the position to limit or deny entry for certain organizations or products to the market, using mechanisms as license requirements or trade barriers. However, the upcoming governmental controls on environmental pollution, mainly GHG emissions, will work disadvantageous for the Jet A-1 fuel industry and beneficial for the biojet fuel industry. Government can most likely not be seen as an entry barrier in this case.

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