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Feasibility Study of Converting Rapeseed to Biodiesel for use on a Fishing Vessel

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Feasibility study of converting rapeseed to biodiesel for use on a fishing vessel

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ABSTRACT

The fishing industry is the most important industry in Iceland in addition to the agricultural sector. Biodiesel is a natural, renewable transportation fuel which increases lubrication of diesel engines and decreases carbon emission equal to 3.11 kg for each kilogram of biodiesel used instead of fossil diesel. This research provides a feasibility assessment for biodiesel production in Iceland, including oil extraction, which is an industry in its infancy in Iceland. The main idea is to convert rapeseed into biodiesel for use in marine engines. The profitability analysis is based on usage of 175 ha in the first year with an annual increase of 18% between years. A standard profitability assessment method with a 10-year operation time period provides a Net Present Value (NPV) equity of minus 24 thousand USD and a 14% Internal Rate of Return (IRR). The Minimum Attractive Rate of Return (MARR) is 15% and is, therefore, a project that borders on being feasible. A sensitivity analysis illustrates that with a 10% decreased fixed cost and variable cost for oil extraction, the IRR of equity is 22% and 20%. In the same way, a 10% increase in the price of rapeseed meal and in price of biodiesel means an IRR of equity is 22% and 21%. One of the main assumptions for this result is based on the required price for the fishing company FISK Seafood ltd. (FISK). The required price of biodiesel is 10% lower than marine gas oil (MGO). The conclusion of this thesis corresponds to other studies which conclude that biodiesel production is not feasible without government subsidy. Nevertheless, a government subsidy in Iceland in the biodiesel supply chain is substantial with tax exemption and cultivation subsidies. Other usage, feedstock methods and biodiesel are also considered in this research which in the near future may potentially provide producers with a positive NPV and IRR.

KEYWORDS: Biodiesel; net present value; internal rate of return; rapeseed oil; Iceland; Fisk Seafood Ltd.

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LIST OF ABBREVIATIONS

NPV	Net Present Value
IRR	Internal Rate of Return
EU	European Union
US	United States
UK	United Kingdom
kWh	Kilowatt hour
ISK	Icelandic Krona
USD	US Dollar
FISK	Fisk Seafood ltd.
IMA	Icelandic Maritime Administration
AUI	Agriculture University of Iceland
UAK	University of Agriculture in Korpa
EFE	Environmentally Friendly Energizer
GHG	Greenhouse gasses
MW	Megawatt
RSO	Rapeseed oil
RME	Rape methyl ester
ML	Million liters
NOx	Nitrogen oxide
KS	Kaupfélag Skagfirðinga
FFA	Free fatty acid
NaOH	Natrium soda
KOH	Potassium Hydroxide
TG	Triglyceride
CO2	Carbon dioxide

EU ETS	European union emission trading scheme
VAT	Value added tax
MARR	Minimum attractive rate of return
FAME	Fatty acid methyl ester
MGO	Marine gas oil

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1 Introduction

The importance of the fishing industry in Iceland is significant for the entire Icelandic economic system. A large proportion of Iceland's total exports are fish products. Today, the Icelandic fishing industry is seeking alternatives to decrease costs without decreasing revenues. For the last 20 – 30 years, environmental concerns in all sectors of society around the world have greatly increased, resulting in additional costs for industries in the form of carbon taxes, research and development (R&D), etc. Additionally, governments around the world have encouraged the renewable energy sector with subsidies, tax concessions, grants, etc. Although almost 80% of domestic energy use in Iceland comes from renewable energy sources, the most important industry in Iceland is highly dependent on imported fossil fuel.

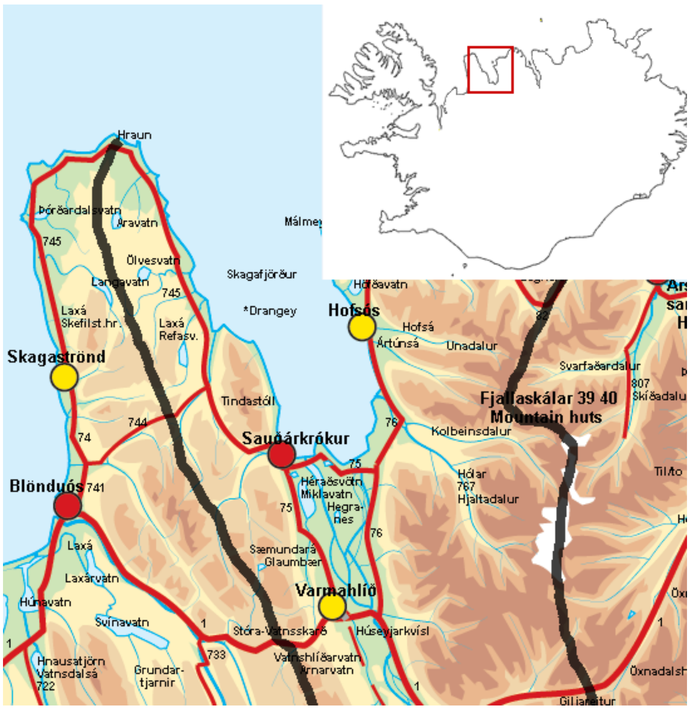


Figure 1 - Skagafjörður and Sauðárkrókur. Source: Adapted from (Icelandic times, e.d.).

The aim of this thesis is to examine the potential to add value to biodiesel production in Iceland and to discuss the pros and cons of domestically produced environmental fuel versus imported fuel, with a special aim directed towards farmers as a producer and the fishing industry as a consumer. To make this thesis as realistic as possible, it is based on a specific area in north of Iceland called Skagafjörður, as seen in Figure 1. FISK Seafood Ltd. (FISK) is the biggest fishing company in Sauðárkrókur, the main village in the Skagafjörður area, which has 2.600 inhabitants out of 4.100 total inhabitants in Skagfjörður area. The owner of FISK is Kaupfélag Skagfirðinga (KS), which is a cooperative company and the biggest company in the Skagafjörður district (Skagafjörður, e.d.). Cooperatives are different from other forms of enterprise in that the primary purpose is to benefit members through their use of the co-op facilities and services. Although return on capital invested in a cooperative form is important, it is not the main purpose nor is it the primary measure of success for its members (Booth, Booth, Cook, Ferguson, & Walker, 2005). The decision for the undertaking of this thesis has some antecedents. In late summer 2009, the author of this thesis read a newspaper article about farmers in Iceland who had harvested a rapeseed plant with the ability of producing oil that can be used in diesel engines. This news item was about the collaborative project that began in June 2008 between the Icelandic Maritime Administration (IMA), Agriculture University of Iceland (AUI) and several farmers. This project is called "Environmentally Friendly Energizer" (EFE). The idea of the project is to produce biodiesel from the rapeseed plant to fuel Icelandic fishing vessels. In January 2010, the author was seeking a project in his course of study. The idea of a project which used the EFE project between farmers, IMA and AUI as a source came to mind. Later on, it was decided to write this thesis by using the EFE project as a source, but with the special aim of conducting a feasibility study of converting rapeseed into biodiesel for use on a fishing vessel. There are three points that are of particular significance to this idea and had a big effect on the author in the final decision of undertaking this thesis subject. The first concerns the farmers who can increase their ability to harvest valuable crops for alternative use with by-products like rapeseed meal. The second point is that there is no need for modification to the ship engines for the use of biodiesel. Biodiesel has a better lubrication effect and decreases wear on diesel engines compared to fossil diesel, which increases environmental effects with regards to greenhouse gas (GHG) emissions. The third point is the idea of linking the agricultural and fishing industry together with the aim of more beneficial environmental and economical outcomes for both sectors. In addition to those three points, cooperative farming also played a significant role in the decision process of the author, as did the desire to make this thesis as realistic as possible. After conversations with various specialists within the cultivation and biodiesel field, it was decided to use the Skagafjörður district as example on which to base this idea. The cooperative farm tradition in the Skagafjörður area is one of the main factors why the Skagafjörður district and FISK are used as a basis for assumption estimations. The cooperative farm in rapeseed cultivation and other oil crop cultivation is well-known in European countries, the US, Canada, Australia, and New Zealand (Booth et al., 2005). Finally is the most important aim of this report, a NPV analysis of producing biodiesel in the Skagafjörður region (and in nearby regions in the future) which can be used as a blend on FISK's trawlers, where the above three points come into play both directly and indirectly.

The world economy must come to terms with the increased demand for energy and at the same time, with environmental issues that play a significant role in economical and energy perspectives. Also to be taken into account is that populations around the world are growing and fossil fuel resources are decreasing. Increased demand for energy, especially renewable energy, in all households and industry sectors has motivated states, institutes, and individuals to increase R&D and financial input in the renewable energy technical sector. The motivation is not only due to an economical point of view, but also an environmental point of view with regards to GHG emission. Several varieties of renewable options are able to decrease GHG emission. Harvesting wind is becoming more feasible, with Germany and Denmark as key manufacturers (Tester, Elisabeth, Driscoll, Golay, & Peters, 2005). Ocean power such as tidal and wave energy is on the threshold of being economically feasible. Hydropower is the most suitable, with regards to technical and economical point of view, that is used today with the creation of over 635,000 MWe capacity which contributes to roughly 19% of the world's total generation of electricity (Tester et al., 2005).

Despite diverse opportunities available to the household, industry, and transport sectors of renewable energy sources, it is only possible for the transport sector to use ethanol or biodiesel for liquid transportation to decarbonize its energy consumption (Demirbas, 2009). More than one hundred years ago, Rudolf Diesel tested the first engine using vegetable oil, but because of cheap petroleum, crude oil was chosen to serve as a fuel (Ma & Hanna, 1999). In 1994, a Dodge turbocharged and intercooled diesel pickup fueled with 100% ethyl ester of rapeseed oil was driven 14 thousand kilometers across America with no problems or unusual complications to the diesel engines (Peterson, Reece, Thompson, Beck, & Chase, 1995). In Iceland there are other options to decarbonize the road transport sector such as using electric cars because the use of renewable energy resources is 100% for electricity generation. In 2008 Iceland had hydroelectric power stations with a total installed capacity of 1880 MW generating 75.5% of the country's electricity production, with the rest being generated by geothermal resources (National Energy Authority, e.d.). Today, Iceland is fairly energy independent compared to other nations. In 1987 approximately 61.6% of the country's total energy supply came from domestic renewable energy sources of hydropower and geothermal energy. The other 38.4% was imported, mainly fossil fuel. In 2008, this portion of domestic renewable energy and imported fuel had increased to 82% of domestic renewable energy. The remaining 18% of Iceland's energy portfolio are non-renewable fossil fuels imported mainly for transport and fishing, with 16% accounting for fossil oil and 2% for coal (Statistics Iceland, e.d.).

In 2007 approximately 180 kilotons of imported fossil oil was used on Icelandic fishing fleets, which was about 25% of the total import of 765 kilotons. In the year 2008, the total import of foreign products accounted for 514,7 billion ISK. Of that, oil accounted for approximately 12% (Statistics Iceland, 2009). Some varied technology alternatives have been researched and tested in Iceland with the aim to decarbonize and hopefully lower the cost of fuel consumption in the future. Some research has been done within the whale watching industry. In 2006, Icelandic New Energy started a project on installing a fuel cell auxiliary system onboard the whale watching boat “Elding”. The system was designed and installed by Icelandic Hydrogen and was launched in April 2008 as a 2-year project. The project was difficult to execute because of the financial crisis but the system was finished and certified and partly operated in 2008 and 2009. Although the project itself was difficult because of a lack of financial support, the main target was reached— hydrogen can be used at sea level but the technology itself is too expensive to be competitive in the coming years (Hallmar Halldórsson, personal interview, August 17, 2010). The Icelandic fishing industry is a very important industry in Iceland, where fuel costs, and therefore other alternatives in energy consumption, play a big role in the total financial outcome of the industry. As such, the use of biodiesel is one of the few options available today to decarbonize the Icelandic fishing industry. Production of biodiesel is a growing industry in the US and Europe and it has been imported for several years by the N1 Ltd. retail and service company for use in heavy equipment, road construction and as a 5% blend (B5) in transport, such as buses and taxis (Magnús Ásgeirsson, personal interview, August 13, 2010). In October 2010, Orkey Ltd. in Akureyri started the first biodiesel plant in Iceland. A letter of intent exists between Orkey and the local authority of Akureyri to use the biodiesel on the buses and vehicles owned by the local authority of Akureyri. The annual capacity is 300 tons/year of biodiesel, which can be increased threefold without increased investment cost. The biodiesel consists mainly of waste oil from restaurants, both from the capital area (Reykjavik) and Akureyri. The total investment cost is an estimated 45 millionISK (Kristinn Finnur Sigurharðarson, personal interview, October 10, 2010). On the other hand, rapeseed oil (RSO) is also used for other purposes other than biodiesel. The Public Roads Administration in Iceland (Vegagerðin) has been using RSO as asphalt thinner for road construction for 3 years. In the past, white spirit solvent was used as a thinner instead of RSO. The reason for this change is variable air temperature in Iceland, which fluctuates around freezing point during winter. RSO makes minerals in the asphalt to increased moisture and therefore macerates the asphalt and decreases the likelihood of cavities and small cracks which prevents water from soaking into the asphalt layer and destroying it at freezing temperatures. The asphalt is blended with 7.5%

RSO and the Public Roads Administration consumes 400-500 thousand/liters per year (Sigursteinn Hjartarson, personal interview, August 15, 2010).

As previously mentioned the IMA began an EFE project in collaboration with the AUI and several farmers in June 2008 and harvested the first research rapeseed crop during the fall of 2009. The aim of the EFE project is to produce environmentally friendly fuel from the rapeseed plant to fuel Icelandic fishing vessels. This harvest had a positive outcome for the possibility of harvesting further oil seed from rapeseed in Iceland (Jón Bernódusson, personal interview, January 15, 2010). From rapeseed cultivation comes valuable by-products like rapeseed meal and straw, which, for example, can be used as material in producing animal food and as fertilizer. From the biodiesel production process comes glycerin, which can be used in chemical, pharmacology and food industries. By crushing the seeds of the rapeseed plant, vegetable oil forms and is called rapeseed oil (RSO). Due to the vegetable composition, made of three fatty acid molecules and a glycerol molecule, the glycerol tends to "disturb" unmodified engines, resulting in poor performance. To avoid this problem esterification is used, which is a chemical reaction that removes the glycerin, allowing the resulting product to be used in unmodified engines. This material is sometimes referred to as Fatty Acid Methyl Ester (FAME) or, when derived specifically from RSO as in this project, it is called rape methyl ester (RME) (Booth et al., 2005).

The structure of this thesis is divided into three parts: technical, regulatory environment and economy. Chapter 2 focuses on a literature review, which illustrates other research conducted within the biodiesel sector, mainly abroad but also domestic. Chapter 2 is important as a base for other chapters and for the total outcome of this thesis and reflects the basic structure of this thesis. To begin with will be looked at report from National biodiesel board (1994) and study from Bender (1999), which is about economic feasibility review for community-scale farmer cooperatives for biodiesel production. Other newer studies will as well be examined with the same point of view to illustrate cost of biodiesel production from various feedstocks over different period of time all the way to 2010. All cost figures will be explained in United States Dollars (USD) by converting Icelandic Krona (ISK), Euros (Euro) and Pound to USD according to time period of each study. Chapter 2 will also contain technical literature reviews explanations and illustration on the main regulatory environment in Iceland, EU (Finland and Germany mainly) and US.

I) Technical – Chapter 3 looks at the domestic cultivation experiment of rapeseed so far with the focus on the result from the EFE project. Those results will be used as a base for possible harvest yields and to estimate the cost of harvesting (included in the feasibility part). In this same chapter, potential cultivation land in the Skagafjörður area for rapeseed cultivation, as well as other possible areas in north Iceland will be looked at. The end of the third chapter focuses on suitable soil, sowing amount, fertilizer and harvesting yield. Chapter 4 illustrates the oil extraction from oil seeds and other alternatives for feedstock and by-products caused by oil extraction with a special focus on rapeseed. The final chapter of this part, Chapter 5, includes the biodiesel production process from world production to environmental effect.

II) Regulatory environment – Chapter 6 explains the legislation, carbon credit, taxes and grants in agricultural and biodiesel production in the US, EU and Iceland in particular.

III) Economic – Chapter 7 includes methodology and assumptions for NPV calculations. The main assumptions are land availability, biodiesel capacity, products price, required rate of return, equipment cost and operation cost. The assumptions for investment costs are based on numbers from specialists in biodiesel installations, both domestically and abroad. Operation costs are partly based on cultivation costs from the EFE project and on domestic assumptions for fixed and variable costs. Revenues are divided into three parts: rapeseed meal, biodiesel and glycerin. Those numbers are put in the NPV model using Microsoft Office Excel software with the aim of answering the question of if it is feasible to convert rapeseed into biodiesel for use on a fishing vessel. Finally, a sensitivity analysis will be used to estimate the most significant factor on the total outcome of the NPV assessment by using impact analysis and scenario analysis. Discussions are provided in Chapter 8 and the conclusion in Chapter 9. The economic part of this thesis is the most important part of the project. However, many of the assumptions and data cannot be fully explained without a clear description and support of the technical and regulatory environment parts.

Although producing environmental friendly fuel for use on fishing vessels produced by the closest farm instead of importing fuel from abroad is promising, there are also several important limitations in this thesis as well. Firstly, the land availability is a limiting factor. The capacity of the biodiesel plant is based on the availability of land in Skagafjörður with the ability of harvesting from the nearest regions on a long-term basis. Secondly, another limiting factor is the fuel standards that must be fulfilled. Vegetable oil, like RSO, can be used directly as a blend in fossil diesel without any engine modification but to fulfill the standard for fuel used on engines, biodiesel process is needed. These standards are included in this thesis and are taken into account. Thirdly, in this thesis, both the oil extractions and the biodiesel processes are described were the main goal of those processes and all renewable teachings are to decrease GHG emission. Nevertheless, one of the limitations in this thesis is that there is no life cycle assessment (LCA). LCA is one of the methods that can be used to assess the environmental merits and demerits of a product, were LCA entails a complete evaluation and analysis of a product throughout its lifespan. For instance, there is no measurement on GHG emission and net energy requirement in biodiesel production for every stage involved from the rapeseed plantation stage up to combustion process of biodiesel in ships engines. Anyway, is important to have some idea from other researches how LCA for biodiesel production from rapeseed cultivation is stated roughly in Chapter 2. Fourth, this thesis does not include the distribution and transportation cost of biodiesel. Neither, does it include possible cost due to repairs, construction or insulation of the building, which is estimated to be rented in the NPV model. Finally, there is no inflation taken into account in this thesis.

2 Literature Review

From feedstock like vegetable oils, animal fats or waste cooking oil, it is possible to produce biodiesel, which is synthetic and diesel-like. It can be used directly as fuel, which requires some engine modifications, or blended with petroleum diesel and used in diesel engines with few or no modifications. Feedstock is one of two huge factors that affect the cost of biodiesel, the other is competition from high-value uses like cooking. The cost is based on various factors such as base stock, geographic area, variability in crop production from season to season, the price of crude petroleum, and other factors. Other important costs are labor, methanol and catalysts which must be added to the feedstock (Demirbas, 2009). This chapter about literature review is effort to cover those factors about cost and technical with addition about regulatory environment. In subchapter 2.1 will be focused on feedstock cost and production cost from various feedstocks, mainly in oil crop sector from the year of 1994 until 2010. To begin with will older studies being examined and illustrated in best possible way. In the end of subchapter 2.1 is a rough summarize on the most important cost factors from each feedstock and period. Subchapter 2.2 will illustrate the technical development in biodiesel production, were the newest technical methods are illustrated both in conversion process and in feedstock, both domestically and abroad. Also, included in subchapter 2.2 is the environmental aspect with aim at GHG emission and engine effect by using biodiesel instead of fossil diesel. The last subchapter 2.3 is about regulatory environment regarding biodiesel production, from cultivation to biodiesel production.

2.1 Feedstock- and Production Cost

In 1994, the National Biodiesel Board (NBB) made a report to provide a comprehensive review of the commercial development associated with biodiesel. This report does not show production cost of biodiesel from various feedstocks but it stated that cost of vegetable oil feedstocks, gross biodiesel costs have ranged as high as 4.0 USD/gallon. The gallon is a system of measurement in the US; the liquid gallon is the customary unit and is equal to 3.79 liters (Tester et al., 2005). Therefore, 4.0 USD/gallon in gross biodiesel cost corresponds to 1.05 USD/L. That is the price of vegetable oil feedstock (corresponds to RSO) for biodiesel production. This cost does not include the potentially revenues from glycerin by-product that forms in the biodiesel production process (also called conversion process). The conversion cost is about 0.6 USD/gallon for EU biodiesel producers and 0.3 USD/gallon for US biodiesel producers. These costs corresponds to 0.16 USD/L for US producers and 0.08 for EU producers (National biodiesel board, 1994).

In a study made by Bender (1999), were twelve economic feasibility studies reviewed and results showed that the production cost for biodiesel from oilseed or animal fat have a range of 0.30 - 0.69 USD/L. Table 1 contains those feedstocks and illustrates three out of those twelve studies the cost in USD/L.

Table 1 - Production cost of 1/L biodiesel made from various feedstock

	Feedstock				Real annual capital	Operation	Chemicals	Glycerin credit	Meal			Total
Capacity (Ml/year)	Type	Amount kg/L	Price USD/kg	Cost USD/L	USD/L	USD/L	USD/L	USD/L	Amount (ton/L)	Price (USD/ ton)	Credit (USD/L)	USD/L
2	Soybeans	8,70	0,20	1,74	0,19	0,28	0,02	0,06	0,0078	240	1,87	0,30
2	Canola	3,70	0,17	0,63	0,15	0,16	0,02	0,06	0,0024	210	0,50	0,40
2	Sunflowers	3,00	0,24	0,72	0,15	0,16	0,02	0,06	0,0024	150	0,36	0,63
2	Animal fats	1,00	0,26	0,26	0,13	0,09	0,02	0,06	none	none	none	0,44
7,5	Rapeseed	2,40	0,29	0,70	0,09	0,19	0,08	0,10	0,0016	170	0,27	0,69
12	Animal fats	0,90	0,29	0,26	0,06	0,09	0,02	0,06	none	none	none	0,37
115	Animal fats	0,90	0,29	0,26	0,03	0,07	0,02	0,06	none	none	none	0,32

Source: Adapted from (Bender, 1999).

Table 1 includes three scales for the biodiesel facility in million liters annually (Ml/year). It is community scale with a capacity of 2 Ml/year, industrial scale of 7.5 – 12 Ml/year and large industrial (much more than 12 Ml/year or about 115 Ml/year). The feedstock cost from various feedstocks is described in kg/L which is multiplied with price of USD/kg that gives outcome cost in USD/L. In the real annual capital cost is expected economy of scale demonstrated, that is with a bigger plant is the cost/L decreased. On the other hand does cost of operation not reflect economy of scale because scale-dependent expenses such as labor are only a small part of the operating cost. Because canola and sunfowers have an oil content of 40% and soybeans only 20%, costs for capital and operation for the former oilseeds are lower than those for the latte, mainly due to less capacity needed for the extruder and oilseed press. Waste grease and animal fats have lower capital and operational costs than the oilseeds because the press and extruder are not required. The cost of chemicals is mainly cost of alcohol and catalyst. The cost depends on the price of catalyst and process. In the cost for rapeseed is lower alcohol recovery estimated in the biodiesel process than for other feedstock which illustrates why chemical cost in biodiesel production is higher than for other feedstocks. In the same way is estimated higher recovery of glycerin by-product from rapeseed than for other feedstocks, therefore is credit for glycerin 0.1 USD/L instead of 0.06 USD/L for other feedstocks. The other by-product from oil extraction is meal. Table 1 show that from 1 L of RSO comes 0.0016 ton of meal which is multiplied with market price (170 USD/ton) with a total credit of 0.27 USD/L. Total cost is the sum of feedstock, capital, operation and chemical, minus the credits for glycerine and meal. The total cost of biodiesel production is 0.69 USD/L made from rapeseed as feedstock (Bender, 1999) as Table 1 shows. An earlier study from 2001, a 190-liter biodiesel pilot plant was built. It produced biodiesel with transesterification process and the feedstock was soybean oil, yellow grease and brown grease. The estimated costs for biodiesel was 0.42 USD/L (1.58 USD/gallon) made from soybean oil, 0.32 USD/L (1.20 USD/gallon) made from yellow grease and 0.24 USD/L (0.911 USD/gallon) made from brown grease. The authors of the study did not include profits from the sale of the by-product glycerin, and did not estimate or include capital costs like the cost of the plant, labor, or transportation for their operation (Canakci & Gerpen, 2001). In Bender´s study (1999) it is stated that prices of feedstock and meal were the most important factors in the cost of biodiesel production. In 2005, a model was designed to assess the effects of estimated biodiesel production costs of changes in feedstock and glycerin prices, in chemical or process technology employed, or in equipment specified for the facility. The result of 0.53 USD/L was obtained, and the raw material costs constitute the greatest component of overall production costs. Soy oil feedstock is the by far biggest contributing cost factor, constituting 88% of the overall production cost. Therefore product cost is predicted to vary linearly with soy oil cost, with each change of 0.022 USD/kg in feedstock costs causing a roughly 0.020 USD/L increase in the production cost of biodiesel (Haas, McAloon, Yee & Foglia, 2005). Research on the economic evaluation of biodiesel production from oilseed rape grown in north and east Scotland examined the potential to add value to oilseed rape grown in the north and east of Scotland by conversion to biodiesel. The study was done by Aberdeenshire Council, Angus Council, Fife Council, Highland Council, Moray Council, Perth and Kinross Council, Highlands and Islands Enterprise and the Scottish Enterprise Energy Team. The aim of the study was to compare the production of biodiesel and bioethanol and determine the feedstock availability as the oil extraction and biodiesel technology. It also assessed market evaluation, environmental assessment, infrastructure determination, business aspects and economic analysis. Five options of RSO processing plants were examined from a farm scale, where a farmer has the ability to convert his own RSO into either unmodified vegetable oil or biodiesel for his own use. The biggest plant is a large-scale processing plant with at least 250,000 tons of produced biodiesel per year. The cost of feedstock varies by the size of the processing plant. Table 2 illustrates the difference of costs depending on the size of processing plant. The study containes the cost in British pound but, nevertheless in Table 2 have those cost figures being exchanged to USD according to average currency rate in 2005 (X-rates.com, 2005), that is the same year as Booth et al.

(2005) was made. Table 2 clearly shows that the cost decreases significantly with increasing capacity of plant except for maybe group scale size plant. As Table 2 shows, the sizes of processing plants are divided into 5 parts. Farm scale number 1 is able to produce 41 tons of vegetable oil (rapeseed oil) per year. Number 2 produces 102 tons of biodiesel per year. Number 3 is a small group processing plant which is able to produce 390 tons of pure vegetable oil annually. A group scale processing plant is capable of producing 5,340 tons of biodiesel annually. The largest plant number 5, a medium-scale plant which produces 33,300 tons of biodiesel annually (Booth et al., 2005). Table 2 contains cost of feedstock in USD/L and net cost illustrates the final cost regards to profit from by-products meal and glycerin, capital cost, labour, power, maintenance and overhead. Of all these options, the medium-scale plant was the most feasible with a full 10-year cash flow as the budget for that option. Sensitivity analysis was carried out which showed there were considerable risks involved. Of the variables considered, the full utilization of plant capacity and the cost of feedstock were shown to be the key factors affecting production costs. Other values like glycerin by-product were not that significant but the value of rapeseed meal by-product was an important factor for the outcome. However, the glycerin market is known to be volatile. Income from the sale of glycerin on the market can mean an estimated 6% reduction in production costs. A 0.01 USD/L reduction in glycerol value means an approximate 0.008USD/L rise in production cost (Haas et al., 2005). Investment appraisal analysis for the medium-scale plant showed an IRR of 14.1% with payback at the end of year five. It was noted that the value of the biodiesel produced had a major bearing on the overall project viability. If the price of biodiesel increased by only 2.4% over the budget net cost 0.41 £/L (equivalent to 0.75 USD/L), then the IRR increased to 18.9% with payback in year four (Booth et al., 2005). The recent study from Demirbas (2010) illustrates the cost of RSO 0.39 USD/L (1.46 USD/gallon) and production cost of RME is about 0.66 USD/L (0.5 Euro/L) according to average exchange rate of USD versus Euro in 2010 (X-rates.com, 2010). It includes the price for glycerin and meal, also cost of capital and operation cost.

Table 2 - Feedstock- and net cost between different size of processing plant in Scotland

Size of processing plant	Cost of feedstock USD/L	Net cost USD/L	Produced ton/year
Farm scale[1]	1,31	1,06	41
Farm scale[2]	0,98	1,12	103
Small group[3]	0,75	0,72	390
Group scale[4]	0,79	0,99	5.340
Medium scale[5]	0,51	0,75	33.300

Source: Adapted from (Booth et al., 2005) & (X-rates.com, 2005).

The above studies demonstrate biodiesel production costs made from feedstock like animal fat, soybean, canola, sunflower, and rapeseed over a different period of time. Table 3 contains a summerize of those studies and show different cost

Table 3 - Summary of various feedstocks over different time period with various cost of feedstock, operation and total cost in USD/L

	Feedstock		Operation	Total
Capacity (Ml/year)	Type	Cost USD/L	USD/L	USD/L
not inc.	Vegetable oil (1)	1,05	0,16	not.inc
not inc.	Vegetable oil (2)	1,05	0,08	not.inc
2	Soybeans (3)	1,74	0,28	0,30
2	Canola (3)	0,63	0,16	0,40
2	Sunflowers (3)	0,72	0,16	0,63
2	Animal fats (3)	0,26	0,09	0,44
7,5	Rapeseed (3)	0,70	0,19	0,69
12	Animal fats (3)	0,26	0,09	0,37
115	Animal fats (3)	0,26	0,07	0,32
190/l/pr/batch	Soybeans (4)	not inc.	not inc.	0,42
37,8	Soybeans (5)	not inc.	not inc.	0,53
0,041	Rapeseed (6)	1,31	not inc.	1,06
0,13	Rapeseed (6)	0,98	not inc.	1,12
0,39	Rapeseed (6)	0,75	not inc.	0,72
5,3	Rapeseed (6)	0,79	not inc.	0,99
33,3	Rapeseed (6)	0,51	not inc.	0,75
not inc.	Rapeseed (7)	0,39	not inc.	0,66

Source: Adapted from (1) (National biodiesel board, 1994); (2) (National biodiesel board, 1994); (3) (Bender, 1999); (4) (Canakci & Gerpen, 2001); (5) (Haas et al., 2005); (6) (Booth et al., 2005) & (Demirbas, 2010).

of feedstock, starting with the oldest study (marked as 1 & 2 in Table 3) from National Biodiesel board (1994). Number 1 is for vegetable oil cost in US and number 2 is for vegetable oil cost in EU, were the operation cost is different between US and EU. In the bottom of Table 3 is the most recent study in this thesis from Demirbas (2010) marked as 7 in Table 3. In Demirbas study (2010) is stated that biodiesel includes energy security reasons, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector. The production and utilization of biodiesel is facilitated first through the agricultural policy of subsidizing the cultivation of non-food crops. Second, biodiesel is exempt from the oil tax. Therfore, in some EU countries, biodiesel is thus currently not economically feasible, and more research and technological development is needed (Demirbas, 2010).

2.2 Technical

It is interesting to compare the ability of imported feedstock, like palm oil, with rapeseed plant cultivated in Ireland. A technical and environmental comparison of Irish indigenous rapeseed with palm oil from Thailand demonstrates the net provide energy difference is almost 300% higher for biodiesel produced from imported palm oil even. This analysis is based on an existing small-scale biodiesel facility in Ireland with a capacity of 1 million liters annually. Imported palm oil provides a higher yield of plant oil of 3,570 L/ha annually while rapeseed provides 1,350 L/ha annually. Because of the higher energy output of palm oil and greater yield of plant oil compared to rapeseed, it provides producers the opportunity to use the palm oil residues to satisfy all thermal and electrical demands at a palm oil mill. In terms of the environmental aspects, the (GHG) reduction from rapeseed oil is 29%, while it is 55% for palm oil (Thamsiriroj & Murphy, 2008). The fore mentioned studies in subchapter 2.1 have mostly concerned economical factors like cost of feedstock, electricity and credit due to by-products. The technical development in biodiesel process has been with the aim of decreasing the processing cost with more efficient equipment and biodiesel processing methods. The bath process is the most simple of methods used today, other processes have a higher investment cost, but on the other hand, they are more efficient (Gerpen, Shanks, Pruszko, Clements, & Knothe, 2004). The supercritical transesterfication process reduces the biodiesel process dramatically (Kusdiana & Saka, 2003). One of the main “enemies” in biodiesel processing is the formation of soap which can be a reaction due to catalysts. In the batch process, catalysts are important to separate glycerin and esters (Gerpen et al., 2004). The super transesterfication process method of producing biodiesel consists of no need for catalysts. This simplification is due to the use of close to stoichiometric proportions of oil and alcohol and by decomposing the glycerin by-product in smaller molecular fuel components at high reaction temperatures. Super transesterfication uses a diesel-powered generator to provide power and heat for the upstream processes or a highly efficient fired heater which consumes a fraction of the produced fuel (Deshpande, Anitescu, Rice, & Tavlarides, 2009). Not included in the Deshpande et al. study (2009) is the retail cost of biodiesel and other measures of process profitability such as rate of return, pay back period and NPV. However, it was found that biodiesel processing cost through supercritical transesterfication process could be half of that of the actual conventional methods. That is 0.07 USD/L versus 0.13 USD/L (Deshpande et al., 2009). A technical development in feedstocks for biodiesel production has also been researched. The use of other oil crops, like camelina, has given a positive promise of cheaper feedstock. In comparison, the fertilizer amount used in the cultivation of camelina is half of what rapeseed cultivation is demanding (Ehrensing & Guy, 2008). According to the Icelandic experimental project called "Environmentally Friendly Energizer" (EFE), a collaboration between Icelandic Maritime Administration (IMA), Agriculture University of Iceland (AUI) and several farmers around the country, the cost of fertilizer is almost the half of cost for total cultivation (Jón Bernódusson, 2010). Finally, to highlight the importance of available feedstock for biodiesel production, both in regards to oil content and growth, research into other feedstocks like algae has been undertaken. In the Demirbas study (2010) it is stated that algae will become the most important biofuel source in the near future. Algae appear to be the only source of renewable biodiesel that is capable of meeting the global demand for transport fuels. Algae can be converted to bio-oil, bioethanol, bio-hydrogen and bimethane via thermochemical and biochemical methods. Algae are theoretically a very promising source of biodiesel (Demirbas, 2010).

As for environmental aspects, the emission of biodiesel compared with fossil fuel indicates that the biodiesel impacts on exhaust emissions varied depending on the type of biodiesel and on the type of conventional diesel. Blends of up to 20% biodiesel mixed with petroleum diesel (B20) fuels can be used in nearly all diesel equipment and are compatible with most storage and distribution equipment. A study by Demirbas (2009) shows that using biodiesel or a blend of it in a conventional diesel engine substantially reduces emissions of unburned hydrocarbons, carbon monoxide, sulphates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons, and particulate matter. However, biodiesel increases nitrogen oxide (NOx) emission when biodiesel is used in diesel engines (Demirbas, 2009). In Montreal, Canada, the BioMer project, which is a joint undertaking by Maritime Innovation Sine Nomine Group and Rothsay (biodiesel manufacturer), was conducted. The 12 boats which were used in the project were all passenger boats, the biggest of which had a capacity of 750 passengers. Four cruise companies in Montreal provided boats and the project ran from mid-May to mid-October 2004. The biodiesel was made from offal and waste cooking oils. The outcome was a 2.3% increase in engine performance for B5 and B20 and a 3.3% increase for B100. There was a fractionally small decrease in biodiesel energy content per unit of volume and in fuel consumption for B5 and B20. Interestingly, there was a 3.3% increase in fuel consumption for B100 which can be explained in part by the fact that engines were not modified for using pure biodiesel before testing (Hojem & Opdal, 2007). Another joint study aiming to investigate the positive and negative side with regards to the use of biodiesel in recreational boats in the United Kingdom (UK) was undertaken in 2003. It concluded that fuelling recreational boats in the UK with biodiesel, made with rapeseed-based biodiesel, could be feasible if rapeseed cultivation reached a certain level, which is not illustrated further in the study. The study also claims the most obvious obstacle to using biodiesel is the price of biodiesel compared to fossil fuel (Zhou et al., 2003).

2.3 Regulatory Environment

The European Union (EU) encourages biofuel production with its biofuels policy, where the aim is to reduce the EU's dependency on foreign sources of energy, decrease GHG emission and support farmers' incomes by providing a new outlet for agricultural products (Kutas, et al. 2007). In Iceland, grain farmers can receive a 10 thousandISK grants for every hectare (ha) of corn they cultivate to a maximum of 20 ha which cooresponds to 81 USD by estimated currency rate is the one-year average rate from November 23, 2009 to November 23, 2010 (Landsbankinn, e.d.). The qualification for the grant is that generally acceptable seed that can be developed in Iceland be used for harvesting and that spring seed is cultivated before May 20th. A farmer who cultivates 20 ha of land and harvests 4 tons/ha annually will get 2.5 ISK/kg or 0.02 USD/kg (Landsbankinn, e.d.) for corn. An appending example is the corn harvesting in Finland and how the grant system works there. Almost all support from the EU is unattached to the production of corn and a mixed method is used for grant calculation annually. The country is divided into six parts: A, B, C1, C2, C3 and C4, where A is the most southern area and C4 is the most northern. For example, grants for barley are mostly given for areas A and B because those areas are more suitable for harvesting barley than other areas. For areas A and B, the grant is 97-111 USD/ha. A grant for grain farming, with special emphasis on environmental affairs, is 123 USD/ha. A livestock farm, also with emphasis on environmental affairs, is about 142 USD/ha. There is also a possibility of additional grants, for example, by decreasing the use of fertilizer, better use of land and increased multiplicity in cultivation. This additional grant is from 13 USD/ha (decreased use of fertilizer) to 32 USD/ha (increased multiplicity in cultivation) (X-rates.com, 2010). The amount of the grants is variable depending on cultivation form and emphasis on environmental affairs (Intellecta, 2009). In other countries like the US, there is special assistance with annual payment to grain farmers. It is a maximum payment of up to 75% of the cost of establishing an eligible crop and it also includes matching payments of up to 45 USD/ton for two years of collection, harvest, storage, and transportation to a biomass facility (Economic Reasearch Service, 2008). The US government has a goal of increasing biofuel production with a subsidy of 0.264 USD/L for corn, soybean and tallow biodiesel (Szulczyk & McCarl, 2010). Although biodiesel is environmental friendly and EU has encourage biodiesel production with various subsidies in the whole biodiesel supply chain, meaning from cultivation of feedstock for biodiesel production to biodiesel consumption (see appendix 4), in Germany has energy tax for B100 (only biodiesel, no blend with fossil diesel) increased from from 0.20 USD/L to 0.24 USD/L (Kutas et al., 2007) & (X-rates.com, 2007). In Iceland diesel fuel is subject to different taxes, namely a value added tax (VAT) of 25.5%, an oil tax of 0.43 USD/L (Landsbankinn, e.d) (52.77 ISK/L) and carbon tax of 0.024 USD/L (Landsbankinn, e.d) (2.9 ISK/L). The oil tax is also for imported biodiesel as well as petroleum diesel. The fishing industry, and therefore marine engines, are exempt from the oil tax and only pay a carbon tax and VAT for the use of MGO (Magnús Ásgeirsson, personal interview, August 13, 2010).

In this thesis, the author will apply this research in the NPV model and sensitivity analysis with regard to the Icelandic financial, legislation and marketing environments. The final aim is to research the economical feasibility of biodiesel production for use in Icelandic fishing industry.

3 Cultivation

Grain farming has been pursued since 1960, or for fifty years. Grain farming has increased from 200 ha in 1991, to 3.600 ha in 2007, an average annual increase of 18%. Figure 2 shows where the main grain cultivation areas are in Iceland, marked with circles. There are many factors that affect which areas are suitable for grain cultivation, such as weather, harvest, options of equipment sharing and drying options.

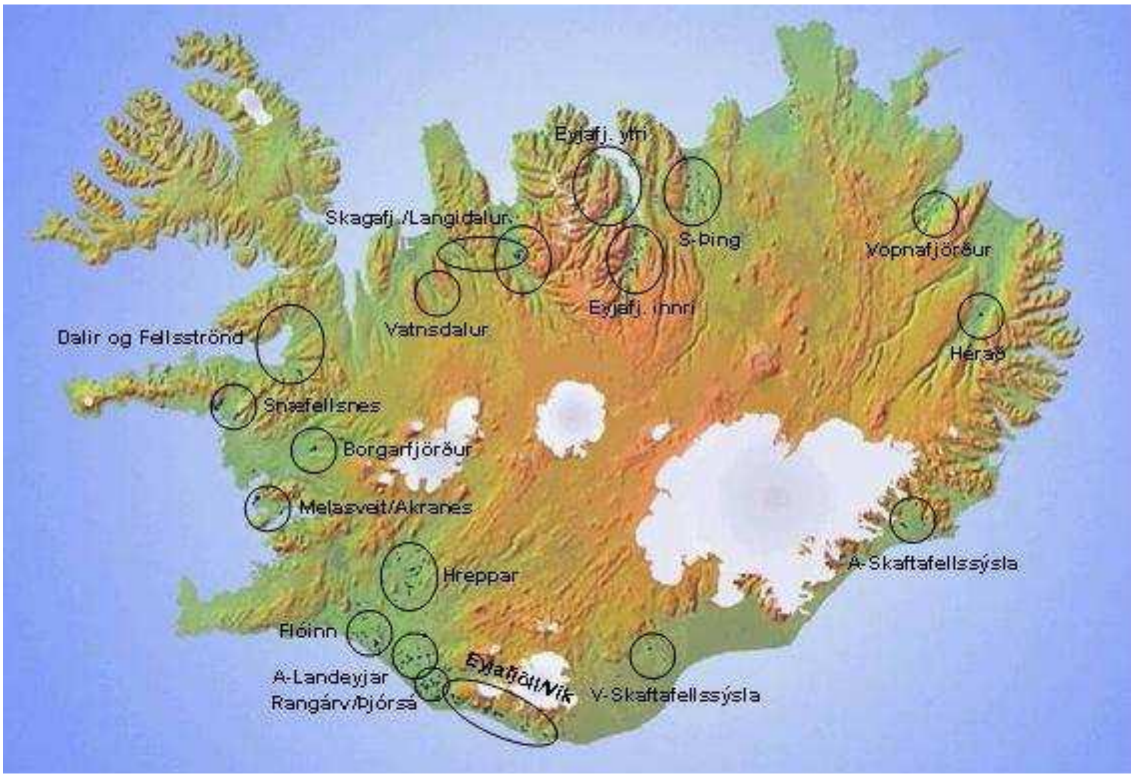


Figure 2 - The main grain cultivation areas in Iceland. Source: (Intellecta, 2009).

Due to GHG, climate change will occur in Iceland as in other countries. According to developing climate forecasts in Iceland, in the 21st century it is estimated that temperatures will increase by 3 degrees Celsius on average. This means that spring will begin earlier and autumn later with an increase of precipitation by 10 – 15%. This is beneficial for grain cultivation, where barley has been by far the most popular type of crop that has been cultivated in Iceland through the years (Intellecta, 2009). Wheat has also been cultivated in Iceland, especially under the Eyjafjallajökull glacier. Lately, rapeseed has been cultivated as an oil crop. Rapeseed is derived from two species of cabbage called Brassica napus var. oleifera (napus) and Brassic arapa var. oleifera (rapa). They are well-known and popular types of forage plants in Iceland and in agricultural edge regions around the world, where they are used for grazing livestock. In other regions, where cultivation conditions are more feasible, rapa and napus are cultivated because of the high amount of oil in the rapeseed. Before the 1980s, rapeseed was only used for industry production (e.g., high quality lubrication oil) or for lighting. It was because of erucic acid, which is a monounsaturated omega-9 fatty acid (C22H422O2), that rapeseed was not useable for human nutrition. A new variation of rapa and napus was invented with a low content of erucic acid (<2%), and low content of glucosinlate, which is an organic compound of glucose and amino acid. This is called a 00 (double low) variation, also known as canola. Today RSO is the second-most produced vegetable oil in the world after soybean oil (Jónatan Hermannsson & Þóroddur Sveinsson, 2009). Those raw materials for biodiesel production have been in use in different countries. Soybean oil is commonly used in the US while RSO is used in many EU countries, Canada and China, and coconut oil and palm oils are used in Malaysia and Indonesia (Demirbas, 2010). In Iceland at the experimental station of University of Agriculture in Korpa (UAK), several experimentations in the cultivation of rapa and napus seed have been conducted. Summer variations of those species were cultivated but the results showed that the development of the seeds was too little due to low summer heat. In the year 1999, 5 species of winter-rapa and winter-napus were sown in Korpa and only 23-55% of the plants survived and the crop was not measured. In summer 2001, 6 species of winter-napus were planted and the goal was to measure the crop of developed seed for use in vegetable oil production. In the autumn, when the corn was supposed to be cut, the plant was still green and not fully developed. The conclusion was that cultivation of winter-napus needs a longer time than barley and it is not possible to cultivate it except if it is sown very early in the spring. (Anna Þórdís Kristjánsdóttir & Hólmgeir Björnsson, 2001). In summer 2006, two species of winter-rapa and two species of winter-napus were sown, both of which survived the winter. The average crop was 3 tons/ha, however the proportion of solid matter gives an indication that winter-rapa was not fully developed in summer 2007 at the experimental station of UAK (Anna Þórdís Kristjánsdóttir, 2007).

The Icelandic Maritime Administration (IMA) started a project in collaboration with The Agriculture University of Iceland (AUI) and several farmers in June 2008 that is called "Environmentally Friendly Energizer" (EFE). The EFE project is an experiment led by the IMA that was part of Iceland's transportation strategy for the years 2007 – 2010. The main goal was to experiment with different locations, as Figure 3 shows, to test the border of feasible cultivation land and therefore suitable soil.

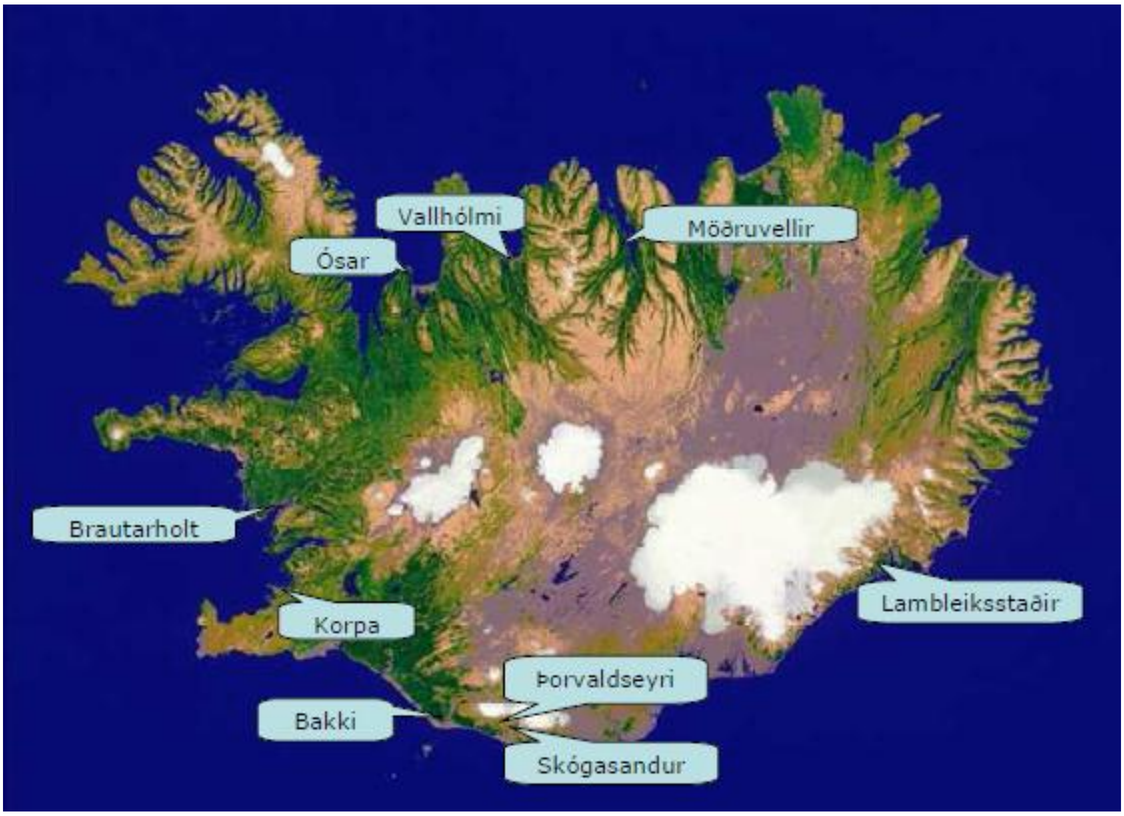


Figure 3 - Different cultivation locations for EFE project. Source: (Jónatan Hermannsson & Þóroddur Sveinsson, 2009).

Table 4 illustrates four locations where harvest has succeeded. The other five locations were not successful because of unfavorable locations with regards to soil, weather and other unexpected factors like sheep eating the harvest. Table 4 contains successful harvest locations in the EFE project in 2008. The location marked with "a" is a total purification of seed harvest. There was no harvesting of rapa in Korpa and the proportion of napus was below 10%. In Möðruvellir, Ósar and Þorvaldseyri, marked with "b",is seed harvest without purification (as it comes out of the threshing machine). The harvest ton/ha for Þorvaldseyri and Möðruvellir are also marked with "c", where it was not managed to be threshed in time and therefore was a loss in total harvesting amount.

Table 4 - Successfull harvesting in EFE project

Location	Species	Seed 2008	Harvest 2009	Growing - days	Solid matter %	Harvest ton/ha
Korpa[a]	napus	19 .July	22.sep	430	55	0,3
Möðruvellir[b]	napus	24. July	13.sep	416	82	3,4
Möðruvellir	rapa	24. July	16.oct	449	87	1,6[c]
Ósar[b]	napus	23. July	6. oct	440	70	3
Ósar	rapa	23. July	6. oct	440	62	3,2
Þorvaldseyri[b]	napus	26. July	24. aug	394	80	1,8[c]
Þorvaldseyri	rapa	26. July	15.sep	416	80	4,1
average				426	74	2,5

Source: Adapted from (Jónatan Hermannsson & Þóroddur Sveinsson, 2009).

Another interesting point to consider is that harvest time in Iceland is approximately 14 months long, while it is around 12 months in most other countries. As Table 4 shows, cultivation of those species can be very difficult. Location, seeding amount, fertilizer and cultivation technique are very important factors for the outcome of the crop. The napus grows faster than the rapa and has higher winter resistance, but the total harvesting and the proportion of oil is higher in the rapa plant. It depends very much on quality of circumstance as to which one is better, however the equipment and method of cultivation are the same for both (Jónatan Hermannsson & Þóroddur Sveinsson, 2009).

3.1 Location Decision – Soil

The most suitable soil for rapeseed cultivation is ventilating soil that is water conductive with high amounts of mould. Sandy soil is not suitable for winter-rapa. The post roots need to go deep in the soil and become well developed (store) before the winter to maximize winter endurance and formation of flowers in the spring. The frost resistance is considerable but ice and water resistance is very limited (Jónatan Hermannsson & Þóroddur Sveinsson, 2009). In the Skagafjörður area, 10,500 ha are used for hayfield, forage plant cultivation and grain farming, as Table 5 illustrates, and of that, 550 ha are used for grain farming. It is possible to add 500 ha to this area to be used under oil crop cultivation according to county consulant. Of that possible 500 ha addition, 200 ha are owned by Kaupfélag Skagfirðinga (KS), the owner of FISK. Those 200 ha are used for hay cultivation but according to the county consulant, this land would be suitable for rapeseed cultivation. Table 5 also shows possible cultivation addition in regions near Skagafjordur, which include the Húnavatna district and the northeast region. However, it is important to mention that for the assessment of feasible added corn cultivation land, aerial

Table 5 - Cultivation regions in Iceland

Regions	Hayfield- and forage plant (ha)	Grain farming (ha)	Total cultivation (ha)	Possible cultivation addition (ha)	cultivation addition in oil crop(ha)	Possible cultivation addition in (%)
South	37.000	2.500	39.500	26.500	6.000	67
Vest	21.000	520	21.520	4.000		19
Húnavatna-distric	11.000	200	11.200	4.000		36
Skagafjördur	10.000	550	10.550	1.500	500	14
North-east	21.000	800	21.800	3.000	500	14
East	11.000	200	11.200	3.000		27
Total/average	111.000	4.770	115.770	42.000	7.000	36

Source: Adapted from (Þóroddur Sveinsson & Jónatan Hermannsson, 2010).

photographs of the Skagafjörður area were used. From those photos, feasible cultivation land was evaluated but no samples were taken from the soil and feasible cultivation land was mapped by that method. Therefore, this assessment of evaluating additional cultivation land was not done scientifically, but is the best available approach today (Eiríkur Loftsson, personal interview, May 19, 2010). Table 5 illustrates the hayfield- and forage plant cultivation in ha and grain farming in the third column. The total cultivation is sum of hayfield- and forage plant and grain farming cultivation. In Skagfjörður region it is 10,550 ha in total. Possible cultivation addition is 1,500 ha for Skagafjörður region were oil crop cultivation contributes 500 ha out of those 1,500 ha. The possible cultivation addition in percentage is therefore 14% for Skagafjörður area.

3.2 Sowing – Sowing Amount

The most suitable way of seeding is to drill the seed in at 12 – 25 cm intervals but it is also possible to spread the crop seed with a fertilizer spreader (Jónatan Hermannsson & Þóroddur Sveinsson, 2009). The seeding amount is about 10 kg/ha and germination of the seeds is 60-80% (Jón Bernódusson, 2010). Swedish research shows that a small amount of seed (2-3 kg/ha) gives a higher harvesting yield than a larger amount of seed. An explanation for this is that a small amount of seed results in fewer but more dynamic plants with high winter resistance and huge flower formation in spring. It is not necessary that this conclusion applies to Iceland (Jónatan Hermannsson & Þóroddur Sveinsson, 2009). Another study defines the use of 5 kg/ha for large-scale oilseed rape crushing and 4 kg/ha for small-scale oilseed rape crushing. The amount of seed for sowing depends on germination, fertilizer, soil and location (Stephenson, Dennis, & Scott, 2008).

3.3 Fertilizer

Table 6 illustrates the amount of primary fertilizer that is used on each ha for rapeseed cultivation. The efficiency of the chemicals is 80% for sand soil but for mould soil it is 60%. In total, 400 kg/ha is used while sowing the seeds and 500 kg/ha in the spring (Jón Bernódusson, 2010). According to a study of improving the sustainability of the production of biodiesel from oilseed rape in the UK, it is claimed that if the nitrogenous fertilizer were reduced from 211 kg/ha (the UK average) to 100 kg/ha, this would mean an 8.5% reduction in harvesting yields (Stephenson et al., 2008). This could mean a lower cost of fertilizer. Another alternative way to decrease fertilizer cost is to use fish slime from FISK ships. For example, the two freezing trawlers Málmey and Örvar have 800 tons/year of slime refuse. The wetfish trawler Klakkur has about 400 tons/year of slime refuse (see appendix 1). Just a little proportion of the amount of this slime could be beneficial for rapeseed cultivation.

Table 6 - Amount of primary fertilizer/ha for rapeseed cultivation

Amount of primary fertilizer/ha of rapeseed	Nitrogen N	Phoshor P_2O_5	Potassium K_2O
By seeding (middle of July)	40-60 kg	30 kg	60-80 kg
At spring (Mai)	120-140 kg	50 kg	120-160 kg
Total amount	180 kg	80 kg	200-220 kg

Source: Adapted from (Jón Bernódusson, 2010).

3.4 Harvest – Harvesting Amount

As previously mentioned, the harvest time in Iceland is approximately 14 months, from sowing to harvesting, while in other northern European countries it is about 12 months. Therefore an interconvert cultivation method is used where the hayfield is tilled after the first sowing. An interconvert cultivation method is also possible beside other corn cultivation like winter-barley. In northern Europe, farmers use the interconvert cultivation method, despite a 12 month harvesting time, to protect the land from over exploitation. Therefore, even if harvesting time in Iceland were 12 months, the interconvert cultivation method would always be used. Winter–rapa gives very positive signs when used in crop rotation with grass and corn, and that kind of cultivation system results in concrete increases in harvesting yields compared to no rotation (Jónatan Hermannsson & Þóroddur Sveinsson, 2009). Each hectare of cultivated land gives on average about 6 tons of biomass which is divided into 3 tons of straw and 3 tons of rapeseed. One hectare binds 6 tons of carbon dioxide as nutrition while the plant is growing. Finally, the quality of seeds is a very important factor in rapeseed cultivation. Each seed species can last for a few years and every year a new one is developed on the market. Therefore it is important to cultivate rapeseed that has a higher than 45% oil content, with early germination after seeding and good winter resistance (Jón Bernódusson, 2010).

4 Oil extraction

Chapter 4 starts with an overview of the important steps in oil extraction from seed cleaning to the refining of vegetable oil. When threshing is complete, the next important step is seed cleaning, where the seeds are cleaned and foreign matter, in particular stalk leftovers, are removed. This is often done by blowing air into a specific container. After seed cleaning the seeds are dried down to 6 - 8% moisture, which is important to avoid the formation of bacteria when the seeds are being stored (Jón Bernódusson, 2010). Fossil diesel has been most often used as fuel for drying but recently farmers have used hot water for drying where geothermal energy is available. The workload of the drying process can be greatly increased with the use of a dryer which uses hot water for drying. It is also possible to use the straw for drying by burning it in a special oven. It is estimated that 20-25% of the straw is enough to dry all of the corn harvest (Intellecta, 2009). The drying process takes place in a specific dry oven with 80 °C air blowing for 24 hours or more. But if the seeds are pressed soon after the threshing, then it is often not necessary to dry them as much or even at all. Dried seed can be stored in sacks or closed containers for years in heated buildings (Jón Bernódusson, 2010). At this step the seeds are ready for oil extraction. Figure 4 explains the steps from seed cleaning to the refining of vegetable oil. Step 1 and 2 are the cleaning and drying of the seeds, as mentioned before. Step 3 is when the crushing of the seeds takes place. Basically there are two methods of pressing: cold pressing and extraction with solvent. Solvent extraction is a complex and costly operation and it is not suitable for small-scale processing (Kurki, Bachmann, Hill, Ruffin, Lyon, & Rudolf, 2008). Nevertheless, the use of solvent oil extraction is more economically feasible as it allows for the extraction of a greater proportion of the oil. Even so, no solvent extraction crushing plant of less than 1.000 ton/day has been built in western Europe (Booth et al., 2005).

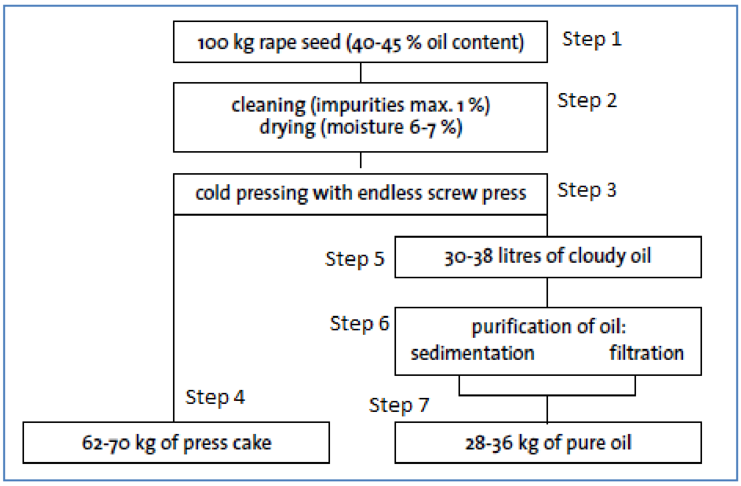


Figure 4 - The steps from seed cleaning to refining of vegetable oil. Source: Adapted from (Karl Strähle GmbH & Co. KG Maschinenbau, 2008).

To begin with, the seeds are fed from a storage silo to a preheater before being pressed in the screw press at a temperature of 15 °C. If the temperature is up to 90 °C it is called cold press (Kurki et al., 2008). Figure 5 illustrates a typical cold press where the screw forces the seeds through the press cylinder with gradually increased pressure. The seed is heated by the friction and electric heaters, or a combination of the two. On the bottom of the press are small holes where the oil escapes. Finally, the press cake or the meal emerges from the end of the cylinder. Both the pressure and temperature can be adjusted for different kinds of feedstock. The design of the expeller press is divided into two parts, a single cylinder press cake out in pellet form and a traditional cage-style screw press that expels the meal out in large flakes (Kurki et al., 2008). The refuse of oil pressing is step 4 in Figure 4, where a press cake is collected together in containers or sacks. The amount of press cake is about 62 – 70 kg of the total 100 kg of rapeseed which is put through the press. In step 5, the outcome is crude vegetable oil, which is 1/3 of 100 kg seed or about 30 – 38 liters. The purification of oil can either be with sedimentation or filtration. In the final step number 7, the oil is stored in a clean oil tank (Booth et al., 2005).

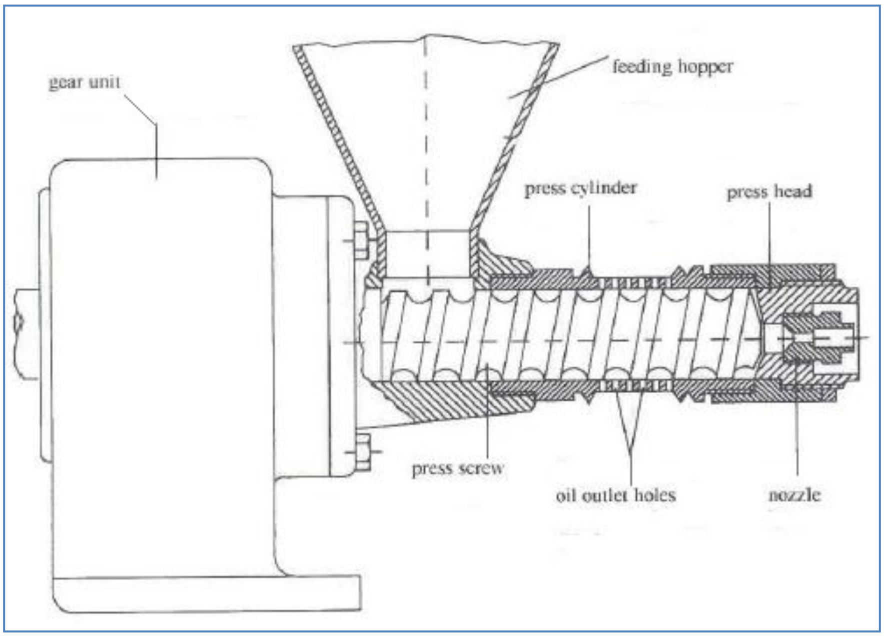


Figure 5 - Sectional view of single cylinder expeller. Source: (Kurki et al., 2008)

4.1 Feasible Feedstock

The most commonly accepted biodiesel raw materials include the oils from rapeseed, soy, canola, corn and palm. The most widespread animal fats that are used for biodiesel production are from poultry, beef and pork (Demirbas, 2010) but animal fats need additional processing steps in the biodiesel process. It is also possible to use fish oil as a raw material for biodiesel production (Framleiðsla lífdísils úr úrgangsfitu, 2006). In Europe, rapeseed is most used for biodiesel production while in the US it is soy and in Malaysia and Indonesia it is coconut oil and palm oil (Demirbas, 2010). The next subchapters will focus on rapeseed as a feasible feedstock and for domestic biodiesel production. Also, attention will be drawn to camelina as a feasible oilseed crop to be cultivated in Iceland.

4.1.1 Rapeseed

In Chapter 3 there is a detailed description about a cultivation experiment done by IMA, AUI and several farmers in 2008 – 2009. In that experiment project, two spices of rapeseed, that is winter–rapa and winter–napus, were cultivated. The "father" of this plant is said to be a Western–Icelandic man called Baldur Rosmund Stefánsson. He was a specialist in plant science from the University of Manitoba from 1952. He was born in Manitoba in 1917 to Icelandic parents. In the years 1964 – 1985, he developed a number of soy and rape species for Canada. He managed to breed winter–rape, which has a low content of erucic acid (<2%), and low content of glucosinlate, which is an organic compound of glucose and amino acid. Simply put, it means that rapeseed is well-suited for human nutrition and as a high quality by-product for animal food. Today the oil from rapeseed in Canada is called canola, which is popular for use as vegetable oil in salad, butter and cooking oil. From erucic acid variant it is also possible to produce some plastic materials such as nylon and rubber (Jón Bernódusson, 2010).

4.1.2 Camelina

Camelina (Camelina sativa L.) has a long history dating back to the Bronze Age in Finland Romania and east to the Ural Mountains. In those days the seed of the plant was used for food, medicinal purposes and lamp oil. After World War II its presence declined in Europe, mostly because of farm subsidy programs that favored the major commodity grain and oilseed crops. Due to heightened interest in vegetable oils in recent years, camelina production has increased. However, very little breeding or crop production improvement has been done on camelina, so the full potential of this crop has not yet been explored (Ehrensing & Guy, 2008). In Chapter 3 there is a description on the interconvert cultivation method for rapeseed, which needs approximately 14 months (about 426 days, marked as ii in Table 7). For comparison, camelina only needs 2.5 – 3 months (85 – 100 days) to mature, as Table 7 shows, marked as "i". The seed germinates at a low temperature and seedlings are very frost tolerant. Therefore it is well adapted to production in the temperate climate zone, as no seedling damage has been seen at temperatures as low as -11 °C (Ehrensing & Guy, 2008). Like rapeseed, camelina can be used both for edible and industrial products. As Table 7 shows, seed oil content for camelina is 34%, while it is 43% for rapeseed. As with other oilseeds, like

Table 7 - Comparison of camelina and rapeseed

Performance of 1 ha	Camelina	Rapeseed
Total Seeds Yield/kg	1700	3400
Seed oil content %	34	43
Content oil/ha kg	578	1360
Content oil/ha L	628	1496
Remaining meal/kg	1122	2040
From sown to harvesting/days	85-100[i]	426[ii]

Source: Adapted from (Greenerpro, 2009), (Ehrensing & Guy, 2008) & (JónatanHermannsson & ÞóroddurSveinsson, 2009).

rapeseed, there is a considerable variation in oilseed content among camelina plants from wild collections and old European varieties. Today the highest oilseed content is under breeding development (Greenerpro, 2009).

4.1.3 Other Oilseed Crops

Table 8 - Oil productivity of major oil crops in the world 2005

Oil crop:	Oil production (million tons)	Total production (%)	Average oil yield (tons/ha/year)	Planted area (million ha)	Total area (%)
Soybean	33,58	31,69	0,36	92,10	42,24
Sunflower	9,66	9,12	0,42	22,90	10,50
Rapeseed	16,21	15,30	0,59	27,30	12,52
Palm oil	33,73	31,84	3,68	9,17	4,21
Others	12,76	12,04	-	66,55	30,52
Total	105,94	100,00	-	218,02	100,00

Source: Adapted from (Yee, Tan, Abdullah, & Lee, 2009) & (Basiron, 2007).

Table 8 shows the most common oil crops and their productivity that is used today for vegetable oil and for biodiesel production in 2005. Soybean and palm oil were the most produced vegetable oils in 2005 with approximately 33 million tons being produced. The advantage of palm oil is the high amount of oil content in the plant. The yield of palm oil is 3.570 L/ha (Thamsiriroj & Murphy, 2008) compared to 1.360 L/ha for rapeseed, as Table 7 shows. Table 8 shows the high productivity of palm oil which is 3.68 tons/ha/year and therefore confirms the high productivity of palm oil yield. It also shows the land required for palm oil cultivationis ten times less than for soybean, although the total amount of oil production is the same. Interestingly, the average oil yield for rapeseed is only 0.59 tons/ha/year. That is much lower than in the EFE project and other studies from abroad. Still, a big disadvantage of using palm oil in diesel engines in colder climate areas like in northern Europe is a high pour point. Palm oil methyl ester has a 14 ˚C pour point, which means at 14 degrees Celsius, the oil starts to develop cloud or haze of wax (or in the case of biodiesel, methyl ester) crystals when it is colder than 14 degrees Celsius. Table 9 illustrates some properties of vegetable oils commonly used in biodiesel production. For better understanding is important to know the meaning of certain words in Table 9. They are as follows: Viscosity: A measure of the resistance to flow of a liquid.

Table 9 - Some properties of vegetable oils commonly used in biodiesel production

Vegetable oil type	Viscosity (mm_2/s at 40˚C)	Density (g/cm^3, at 21˚C)	Cetane number	Flash point ˚C	Cloud point ˚C	Pour point ˚C
Soybean	33,1	0,914	38,1	254	-3,9	-12,2
Rapeseed	37,3	0,912	37,5	246	-3,9	-31,7
Sunflower	34,4	0,916	36,7	274	7,2	-15
Corn	35,1	0,91	37,5	277	-1,1	-40
Safflower	31,6	0,914	36,7	246	-3,9	-31,7
Cottonseed	33,7	0,915	33,7	234	1,7	-15
Peanut	40	0,903	34,6	271	12,8	-6,7
Tallow	51,2	0,92	40,2	201	-	-

Source: Adapted from (Canakci & Sanli, 2008) & (National Renewable Energy Laboratory, 2009).

Density: The density of the liquid. Cetane number: A higher cetane number means shorter ignition delay and therefore better ignition quality. Flash point: The lowest temperature at which vapors from a fuel will ignite when a small flame is applied under standard test conditions. Cloud point: The temperature at which a sample of a fuel only shows a cloud or haze of wax (or in the case of biodiesel, methyl ester) crystals when it is cooled under standard test conditions. Pour point: The lowest temperature at which a fuel will only flow when tested under standard conditions. Soybean and rapeseed have the same cloud point, but rapeseed has a higher pour point, which means the lowest temperature at which a fuel will only flow when tested under standard conditions (National Renewable Energy Laboratory, 2009).

4.1.4 Other Feedstocks

Algae biomass contains three main components that are: Carbohydrates, protein and natural oils. From this combination is possible to produce few different fuels which can be used in modern world of today. Choices are biodiesel, methane gas and ethanol. It is also possible to just burn this biomass and run a steam engine to gather energy. (Sheehan, Dunahay, Benemann, & Roessler, 1998). Both oil crops and algae use photosynthesis, which is process of using solar energy to combine water and carbon CO_2 to create hydrocarbons. Photosynthetic organisms are plants, some bacterial species and finally algae. Algae are a very large and diverse group of simple organisms which are generally grow in aquatic environments, both marine and freshwater (Oilgae, 2009). Algae are made up of eukaryotic cells which are simply cells which have nuclei. All algae have so called plastids which are the cell organs which contain chlorophyll. Chlorophyll is a pigment which gives photosynthetic organisms their green color and the plastids are responsible for photosynthesis. There are different types of chlorophyll (chlorophyll A, B and C) and different categories of algae have different combinations of chlorophyll (Oilgae, 2009). Algae grow very fast, at rates 30 times the growth rate of land plants (Chisti, 2007). Although, the photosynthesis is the same for plants and algea and the theoretical efficiency is same, the environment is different. Algae have significantly higher average photosynthetic efficiency than typical terrestrial plants due to the aquatic environment they grow in which provides them with better access to water, CO_2 and nutrients (Vasudevan & Briggs, 2008). By dry weight, algal biomass contains roughly 50% carbon which is generally derived from carbon dioxide. Then carbon dioxide must me continually fed to the algae during daylight hours and the amount needed is very high. For example in order to produce 100 tons of algae approximately 183 tons of carbon dioxide is needed. It is possible to minimize the loss of carbon dioxide by controlling the carbon dioxide fed to algal mass, by using pH sensors, to trigger carbon dioxide release (Chisti, 2007). Figure 6 shows how biodiesel made from algae, can be set up. The biomass is made in so-called open ponds where algae uses carbon dioxide from the power plant, sunlight

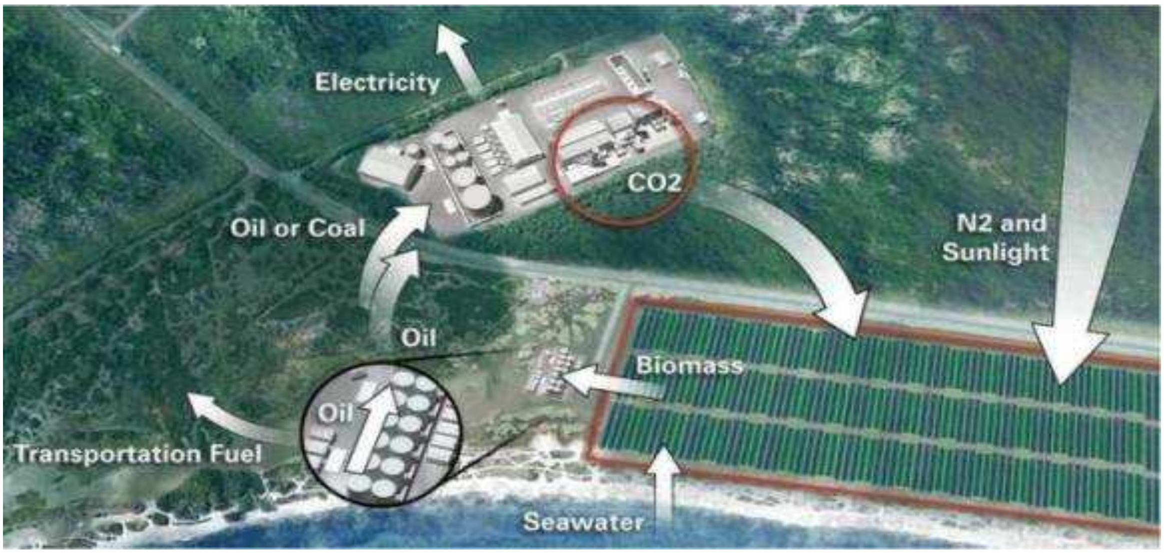


Figure 6 – Cycle of biofuel produced by algae. Source: (Demazel, 2008).

and seawater to grow. Algae can produce 30 to 100 times more energy per hectare compared to terrestrial crops. For a better understanding, since the whole organism converts sunlight into oil, algae can produce more oil in an area the size of a two – car garage than an entire football field of soybeans. However, biodiesel from algae is expensive, or about 5 to 10

USD/kg but R&D is being conducted with the aim of researching commercially viable options in the coming future (Demazel, 2008).

4.2 By-Product

The refuse meal out of oil extraction (called meal or rapeseed meal) is a valuable by-product in the oil crushing process. Sunflower seeds are usually used as feed additive for chicken, pig or cattle feed (Kurki et al., 2008). Rapeseed, soy and safflower meals are also used as animal feed supplements. The meal has a high protein content and good energy value. For comparison, crude protein content in rapeseed meal is from 37.2 – 40 % (Booth et al., 2005). The protein content depends on the oil extraction method, like cold pressing for small-scale production or industrial production for biodiesel production to fulfill, for example, international standards for biodiesel fuel (see Chapter 5.5). For example, canola meal with solvent extraction contains 43.6% crude protein content while canola meal with mechanical extraction on farm press contains 36.9% (Kurki et al., 2008).

5 Biodiesel Production

Rapeseed is the preferred material producing rape methyl ester (RME) in Europe. Soy oil is, on the other hand, the most used feedstock in the US, producing soy methyl ester. In Southeast Asia, palm oil is the most popular material to produce biodiesel. Each raw material has its own specification, as illustrated in Chapter 4.1 and subchapters. For example, palm oil would not be very suitable for use in Europe due to a very high freezing point which could lead to difficulties in cold climates like in Northern Europe (Booth et al., 2005).

The first trial with rape methyl ester was conducted in Austria in 1982. This trial showed promising results and was followed in 1985 by a pilot plant. In 1990 the first industrial biodiesel plant was constructed with a capacity of 10,000 tons. This was followed up by 150,000 tons of biodiesel/year in France in 1993 and in Germany the commercial-scale biodiesel production began in 1995 (Booth et al., 2005). From 1991 until 2001, the world production of biodiesel had grown to approximately 1,000 million liters/year. Most of this production was in Europe, made from vegetable oils. Since 2004, governments around the world including North America, Southeast Asia, Europe and Brazil have encouraged the development of the biodiesel industry. Subsidies and tax concessions have played a key role in increasing world biodiesel production almost tenfold, to 9,000 million liters between 2001 and 2007 (Demirbas, 2009). Of those 9,000 million liters, Europe's contribution was about 5,500 million liters in 2007, as Figure 7 illustrates. In 2005, biodiesel production in the European Union (EU) accounted for nearly 89%

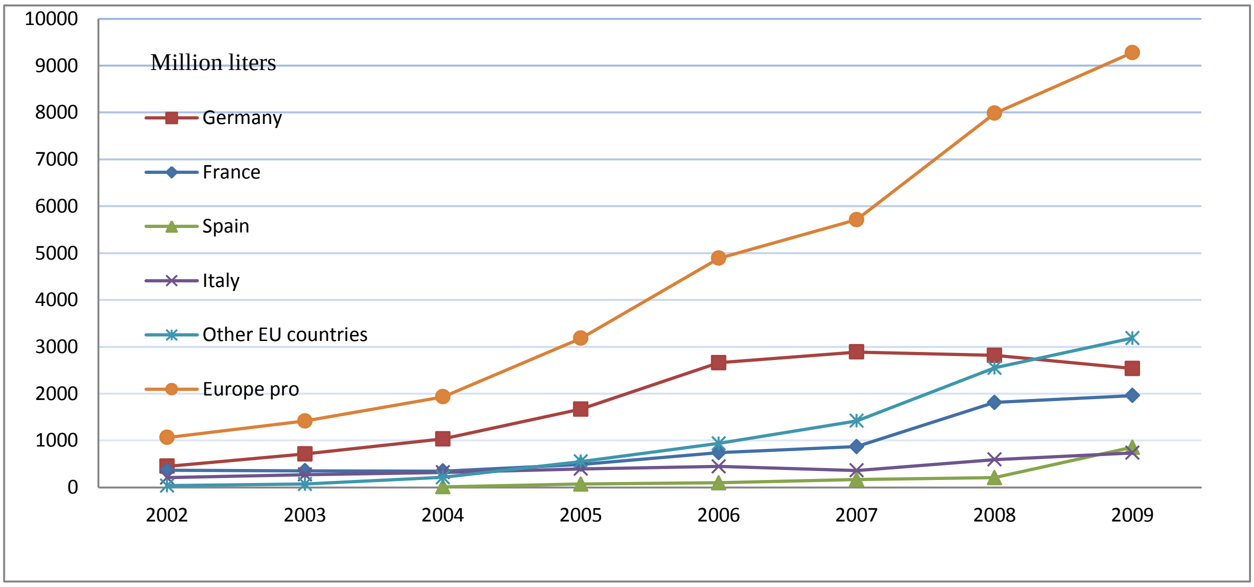


Figure 7 – Biodiesel production in Europe 2002 – 2009. Source: Adapted from (European biodiesel board, 2010).

of all biodiesel production in the world (Demirbas, 2010), which means that both the US and other countries in Asia have greatly increased their production proportion since 2005. In 2009, EU contribution decreased to almost 60% of worldwide production. Germany is the biggest producer of biodiesel in the world with 2,500 million liters produced in 2009, which is 27% of the total production in Europe in 2009. Figure 7 illustrates clearly the biodiesel production growth in Europe for the last 8 years. It illustrates the four main biodiesel producer countries (Germany, France, Spain and Italy) in Europe 2002 – 2009 in million liters on y-axis. The top line shows the total production in Europe 2002 - 2009. Figure 7 also shows the total production in Europe. The other EU countries are Austria, Denmark, UK, Sweden, Czech Republic, Poland, Slovakia, Lithuania, Slovenia, Estonia, Latvia, Greece, Malta, Belgium, Cyprus, Portugal, Netherlands, Romania, Bulgaria, Ireland, Finland and Hungary (see appendix 2). Between the years 2007 and 2008, the total production increased by 35.7% and between 2008 and 2009 it increased by 16.6% (European Biodiesel Board, 2010). Figure 8 confirms Demirbas's (2009) study that in 2004 there is clearly growth in production of biodiesel all around the world, especially in the US. This growth is followed by South America, mainly Brazil and Argentina, which accounted for almost 95% of South American contribution. In Asia, China, Indonesia, Malaysia and Thailand were the biggest producers.

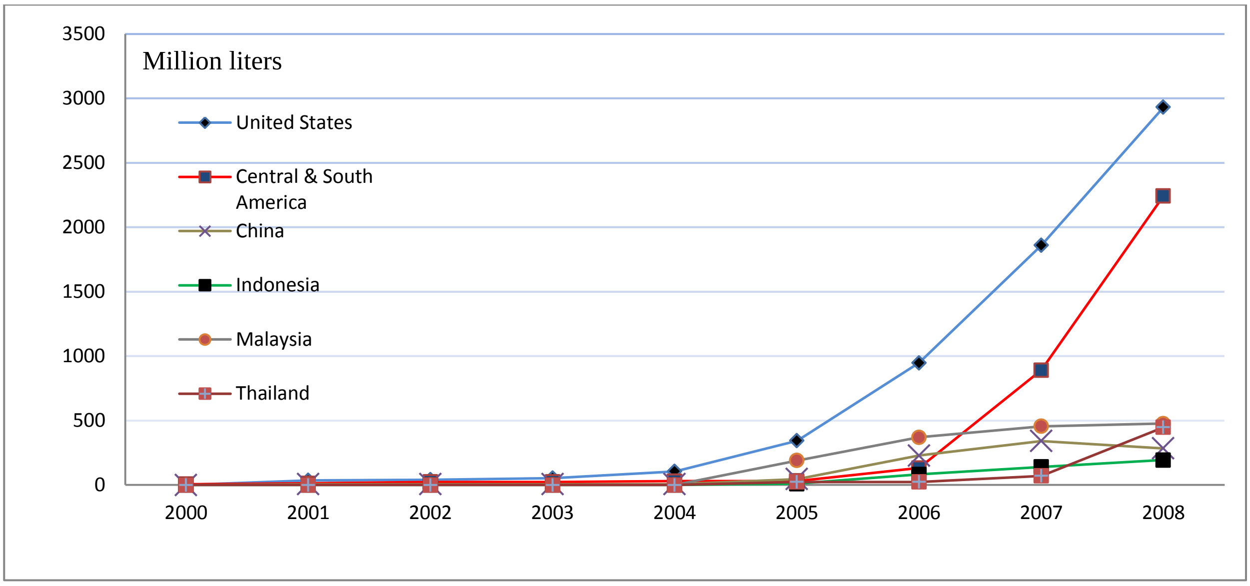


Figure 8 - Illustrates the main biodiesel producers (except Europe) 2000 – 2008. Source: Adapted from (U.S. Energy Information Administration , e.d).

In 2010, it is expected that the US will be the largest market for biodiesel consumption, or about 18% of worldwide biodiesel consumed (Demirbas, 2010). Figure 9 illustrates clearly the most important consumers around the world. In 2008, Germany was the biggest consumer of biodiesel with 3,100 million liters consumed in 2008. France is also a big consumer with

2,500 million liters consumed in 2008. It is interesting to look at the consumption of countries which are rarely compared with the EU and the US. Central and South America consumed about 1,500 million liters in 2008 and Brazil accounted for more than 90% of the contribution for that continent. The left y–axis shows million liters consumed, except for the European and world total, which are illustrated on right y–axis, also in million liters per year.

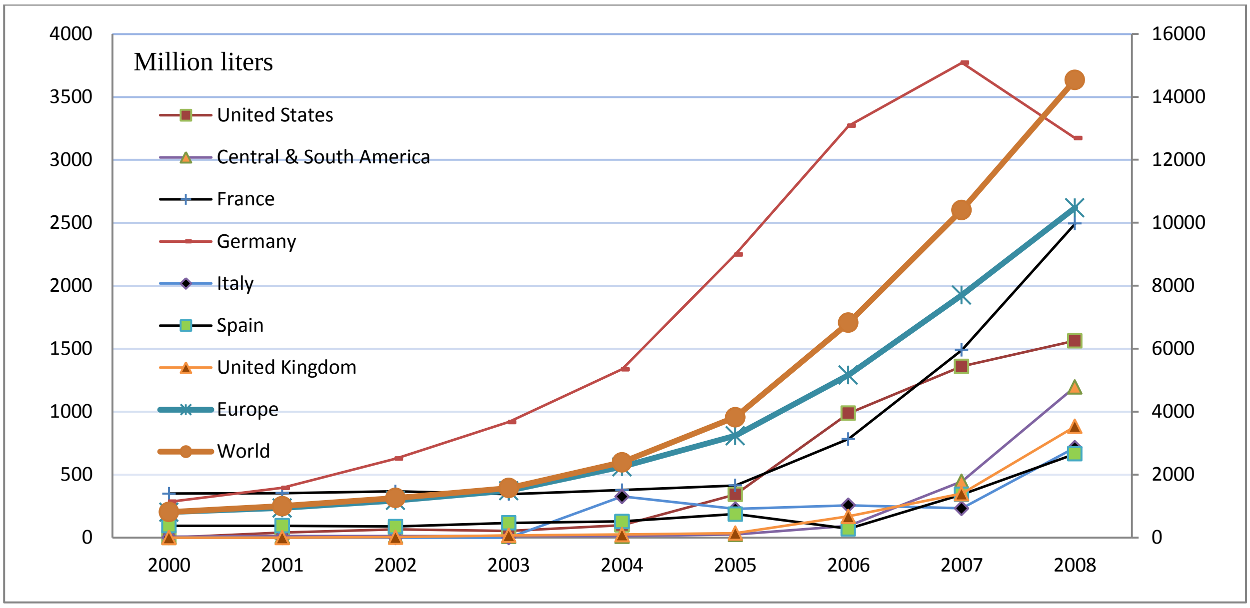


Figure 9 - The world's biggest biodiesel consumers. Source: Adapted from (U.S. Energy Information Administration , e.d) & (European biodiesel board, 2010).

5.1 Chemical Reaction

Biodiesel can be produced from any material that contains fatty acids, be they linked to other molecules or present as free fatty acids. Thus various vegetable fats and oils, animal fats, waste greases, and edible oil processing wastes can be used as feedstock for biodiesel production. The choice of feedstock is based on such variables as local availability, cost, government support and performance as a fuel (Haas, McAloon, Yee, & Foglia, 2005). The process of producing biodiesel from vegetable oil is known as transesterification and happens when triglyceride oils are converted to methyl (or ethyl) esters. The word "methyl" indicates that methanol has been used in the process, therefore the end product is often called "methyl ester". If ethanol were used in the process, it would be called "ethyl ester" (Hojem & Opdal, 2007). Figure 10 illustrates the chemical formula for the chemical reaction of producing biodiesel from vegetable oil, where 100% vegetable oil (triglyceride) and methanol are used. R1, R2 and R3 represent fatty acid chains. To begin with, it is important to understand the fundamental reasons for the disadvantages of using vegetable oil in diesel engines. The main reasons for some engine problems are the high viscosities of vegetable oil which are caused by molecular weights and chemical structure. The molecular weight of vegetable oil is more than that of fossil diesel. Figure 10 shows triglyceride, which comprises about 90 – 98% of the total mass of the molecule (Canakci & Sanli, 2008). For three molecules of methanol, one molecule of glycerol (glycerin) is gained. In the transesterification process, alcohol reacts with the oil to release three “ester chains” from the glycerin backbone of each triglyceride. The glycerin is one of the by-products (see Chapter 5.4) which can be further purified for sale to the pharmaceutical and cosmetic industries. The reaction requires heat and a strong base catalyst like caustic soda (NaOH) or hydroxide (KOH). These compounds belong to a class of materials known as bases and are also inorganic compounds (inorganic compounds are often used in organic chemistry for carrying out or catalyzing reactions). Other bases are also suitable for the transesterification reaction. The counterparts of bases are known as acids. Many acids can also be used as catalysts in the transesterification reaction, also called acid-

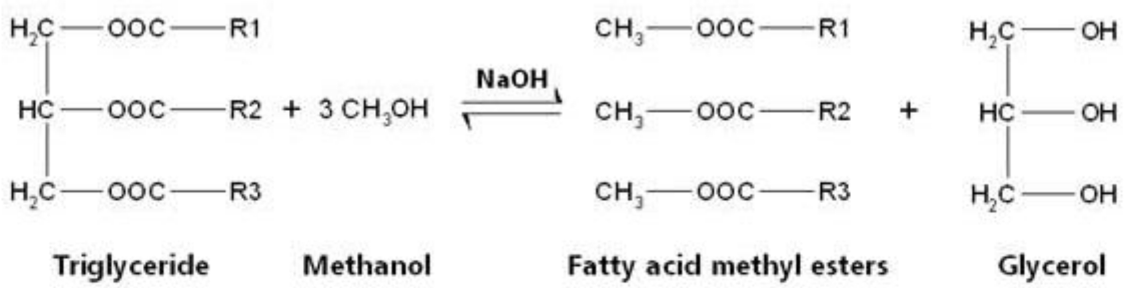


Figure 10 – The chemical formula of chemical reaction of producing biodiesel from vegetable oil. Source: (Sheehan, Dunahay, Benemann, & Roessler, 1998).

catalyzed reactions (Gerpen et al., 2004). However, the base-catalyzed reaction has advantages such as a higher reaction rate. Catalysts are important to achieve complete conversion of the vegetable oil into the separated esters and glycerin. But the catalyst can react with acid to form soap, which is undesirable as excessive soap in the products can inhibit later processing of the biodiesel, including glycerin separation and water washing. Excessive soap may gel and form a semi-solid mass that is very difficult to recover (Gerpen et al., 2004). The mono–alkyl esters become the biodiesel, with one–eighth the viscosity of the original vegetable oil. Each ester chain, usually 18 carbons in length for soy esters, retains two oxygen atoms, forming the “ester” and giving the product its unique combustion qualities as an oxygenated vegetable-based fuel. Biodiesel is nearly 10% oxygen by weight (Hojem & Opdal, 2007). In the next subchapters the process of producing biodiesel from vegetable oil is illustrated in detail along with the product outcomes.

5.2 Biodiesel Process

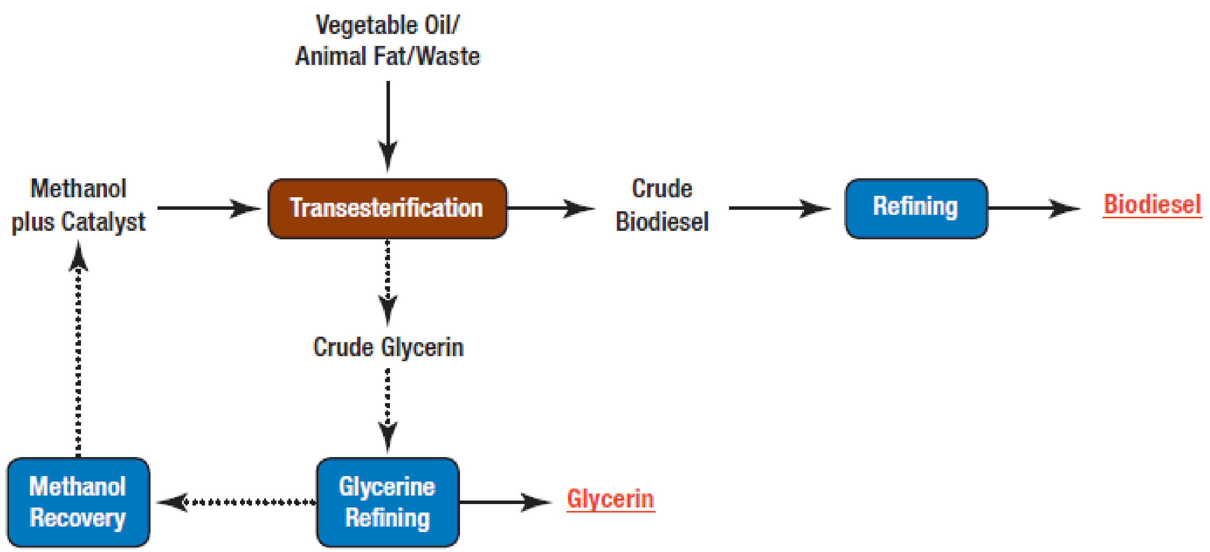


Figure 11 - Transesterification process from triglyceride to methyl or ethyl esters and glycerin. Source: (National Renewable Energy Laboratory, 2009).

Figure 11 illustrates the transesterification process which is an important step because vegetable oil, animal fat and waste oil/fat has too high of a viscosity for diesel engines, which are designed for fossil fuel. It is important to reduce the thickness of the vegetable oil by replacing the glycerin with smaller molecular size of alcohol. This process of converting the vegetable oil ester into the biodiesel ester separates the larger glycerol molecules from the fatty acids within the vegetable oil. The outcome is a more free-flowing biodiesel because methanol combines with the fatty acids and produces smaller methyl esters. The oil and fat content contain different proportions of free fatty acid and water. Waste cooking oil/fat always needs to go through preprocess to decrease the content of free fatty acid (FFA) and water before the transesterification process. This is because FFA and water decrease the efficiency of the chemical reactions in the transesterification process. Many of the low cost feedstocks contain higher amounts of FFA than, for example, refined vegetable oil. The following range of FFA are commonly found in biodiesel feedstocks: refined vegetable oils <0.05 %, crude vegetable oil 0.3 – 0.7 %, restaurant waste grease 2 – 7 %, animal fat 5 – 30 % and tap grease 40 – 100%. If the FFA level is less than 1%, the FFA can be ignored and no pretreatment process is necessary (Gerpen et al., 2004). Given that 100 liters of oil (vegetable oil, animalfat/waste oil) is blended with 10 liters of alcohol (usually methanol) among a catalyst like caustic soda (NaOH), the outcome would be 100 liters of biodiesel and 10 liters of glycerin (National Renewable Energy Laboratory, 2009). In addition, the methanol recovery is 75% (Guðbjartur Einarsson, personal interview, November 24, 2010).

5.3 Biodiesel Process Options

Biodiesel can be produced in multiple ways. The choice of technology depends on desired capacity, alcohol and catalyst recovery and most importantly, feedstock type and quality. All those technology options have many possible set up options, where they are combined under various conditions and feedstocks in an infinite number of ways. Batch processing is the simplest method of producing biodiesel. The most common temperature is 65 °C but temperatures from 25 °C to 85 °C have also been reported. As mentioned before, the reaction requires a strong base catalyst like caustic soda (NaOH) or hydroxide (KOH) with a catalyst loading range from 0.3 % to about 1.5 %. A continuous system of batch processing is also used, where there are at least two stirred tank reactors instead of one. This gives better efficiency to the whole process because composition of the product line throughout the reactor is essentially constant. Smaller capacity plants are suggested to use the batch system without the continuous system. This is due to higher operation costs related to increased staffing because of the 24/7 shifts. (Gerpen et al., 2004). Figure 12 illustrates the batch process in a simple way. First the oil is heated to 65 °C and added to the system. Then the catalyst and alcohol are also added to the batch reactor. During this step, the system is agitated during the reaction time and the oil is maintained at the reaction temperature. When the agitation is stopped, the reaction mixture is allowed to settle in the reactor but sometimes it is pumped into a settling vessel, where esters and glycerol separate. They can also be separated by using a centrifuge. In the next step, the alcohol is removed both from glycerol and ester stream using an evaporator or a flash unit. Both the ester and glycerol streams are methanol and salts, and then dried. The glycerin stream is neutralized by washing it with soft neutralized. The esters are washed with warm and slightly acidic water to remove residual

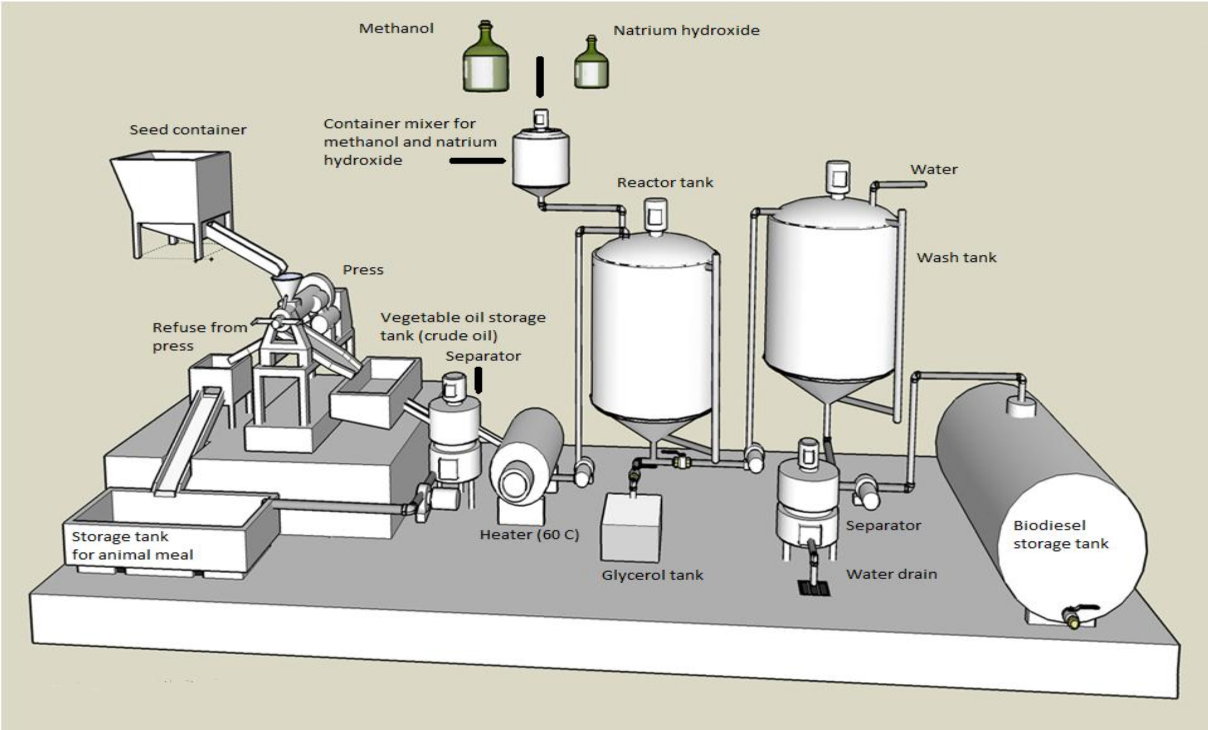


Figure 12 – A seed press and batch process in biodiesel production. Source: Adapted from (Gerpen et al., 2004).

water (Gerpen et al., 2004). Another interesting method of washing the esters is with the dry washing system. After the glycerin has been drained off biodiesel is passed through a special dry wash resin tower. The resin in the tower cleans the biodiesel with the so-called ion exchange process. The dry washing process occurs due to an atom of hydrogen being attracted to the contaminants in the biodiesel, but not the biodiesel itself. This strong attraction usually results in an atom of hydrogen being replaced (exchanged) with an atom of a contaminant. The contaminant is now attached to the resin in place of the hydrogen and the hydrogen is left in the biodiesel (Sabudak & Yildiz, 2010). Figure 13 shows the supercritical esterification process. Compared with conventional acid/base catalytic methods, as Figure 12 shows, there is no triglyceride (TG) pretreatment required regarding FFA or water. The supercritical esterification process is also capable of reducing the transesterfication process from several hours to a few minutes (Kusdiana & Saka, 2003). The supercritical methanol process is believed to be more effective and efficient than the common commercial process like batch processing. It involves non-catalytic, simpler purification, and lower reaction time, as mentioned before, and is less energy intensive (Demirbas, 2010). In Kusdiana and Saka's (2003) study, a refined RSO was chosen to investigate the effect of water on the yield of methyl esters in transesterification of TG. For comparison, used frying oil, crude palm oil and waste that contained FFA and water were

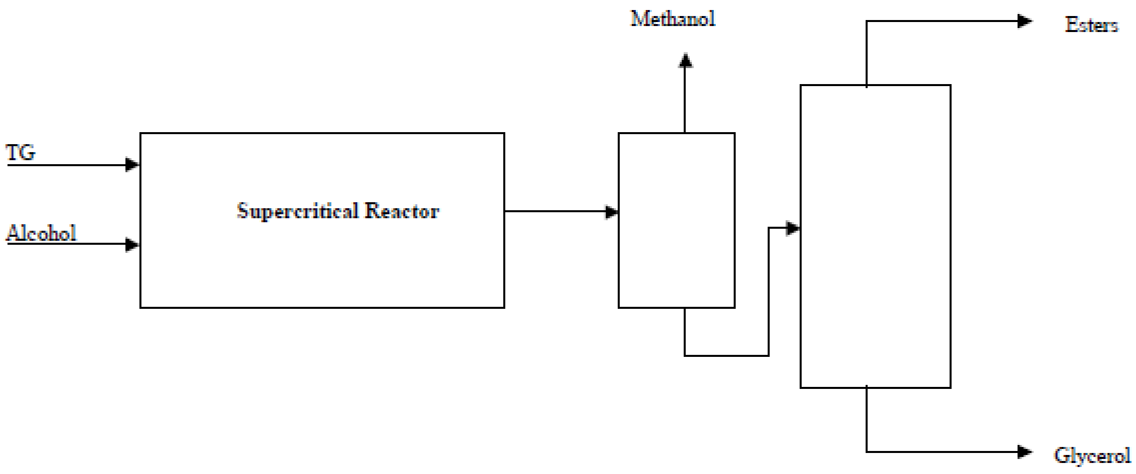


Figure 13 – Supercritical esterification process. Source: (Gerpen et al., 2004).

also used. The experiment was carried out in the batch-type supercritical biomass conversion system. To begin with, the reaction was started by a given amount of rapeseed oil and liquid methanol being charged into the reaction vessel. This vessel has the ability of 200 MPa and capability to provide heat from 250 to 550 °C. As Figure 13 shows, TG as rapeseed oil and methanol were added to start the reaction and to give a molar ratio of 42 in methanol. Finally, the treated rapeseed oil was allowed to settle for approximately 30 minutes to separate into three parts, methanol, water and glycerol. Water was removed by evaporation and methanol and glycerin were removed as liquid. Figure 14 illustrates the effect of water on various methods in the transesterifaction of rapeseed oil. Even though the water content was 5% in the supercritical process, the yields of methyl ester were unchanged. Rapeseed oil was also mixed with methanol containing 10%, 18%, 25% and 36% with no change in yield of methyl esters in the supercritical process. For a better understanding of figure 14, the different methods are marked with a circle to represent supercritical methanol, a black box for alkaline-catalyzed and a triangle for acid-catalyzed. The alkaline-catalyzed method used 1.5%

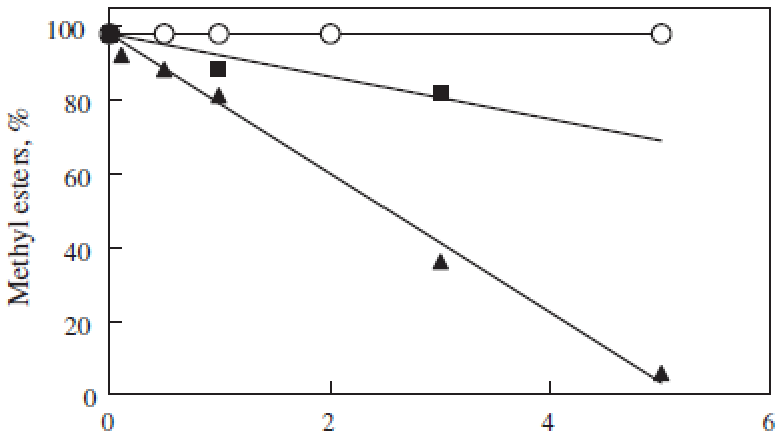


Figure 14 – Yields of methyl esters as a function of water content in transesterification of triglycerides. Source: (Kusdiana & Saka, 2003).

sodium hydroxide as a catalyst in methanol but in acid–catalyzed, 3% sulfuric acid in methanol was added to the reaction system. The acid–catalyzed method is very sensitive to water, only 0.1% of water added to methanol led to a reduction of the yield of methyl ester. There are two interesting conclusions in Kusdiana and Saka's (2003) study. Firstly, in the supercritical methanol method, water presumably acts as an acid catalyst more strongly than methanol itself and secondly, the water-added supercritical methanol method has a feature of easier product separation, since glycerin, a co-product of transesterification, is more soluble in water than in methanol.

5.4 By-Products

Glycerin is a versatile chemical which can be used in food products, cosmetics, toiletries, toothpaste, explosives, drugs, animal feed, plasticizers, tobacco, and emulsifiers. However, it needs to be pointed out that most of the multiform potential for utilization is based on glycerin that is at least 99.7% pure. It is relatively easy to raise the purity level of the crude glycerin to 80%-90%. This can be accomplished by adding hydrochloric acid to the crude glycerin until the pH is acidic (around 4.5). This splits the soaps into fatty acids and salt. The fatty acids will rise to the top of the glycerin where they can be removed. The methanol can then be removed by evaporation to yield 80%-90% pure glycerol. The actual level will depend on the purity of the original oil because contaminants tend to concentrate in the glycerin. To increase the purity of glycerin to 99.7% requires either vacuum distillation or ion exchange refining. Vacuum distillation is capital intensive and probably not practical for small biodiesel plant operators. Ion exchange columns involve less capital but generate large volumes of wastewater during regeneration so they involve additional wastewater treatment costs for large operators (Gerpen et al., 2004). The cost of biodiesel can be lowered by developing novel technologies and with increased economic return on glycerin production. At that point it is important to find other uses for glycerin, which at the momentis sold for little value due to oversupply (Demirbas, 2009).

5.5 Standards for Diesel & Biodiesel Fuels

The original diesel engine, made by Rudolf Diesel, was designed to run on plant oil. However, there are three basic specification standards for diesel and biodiesel fuels in the EU. They are EN-590, DIN-51606 and EN-14214 (see appendix 3). EN-590 allows up to 5% biodiesel blending with fossil diesel – a 95/5 mix. Diesel fuel must meet those standards in the EU countries, Iceland, Norway and Switzerland where EN-590 describes the physical properties content in diesel fuel. DIN-51606 is a German standard for biodiesel and is considered to be the highest standard that currently exists. This standard is used by a vast majority of biodiesel produced commercially. EN–14214 is broadly based on DIN–51606 and has now recently been finalized by the European Standards Organization (Biodiesel filling stations, ed). The American Society for Testing and Materials (ASTM) measures the property specification and sets the standards for biodiesel. The standard for biodiesel is ASTM 6751-02. ASTM standards define biodiesel B100 as pure biodiesel. A blend of 20% biodiesel with 80% petrodiesel, by volume, is termed B20. A blend of 5 % biodiesel with 95% petrodiesel is B5, and so on. In the US, B20 is the most commonly used biodiesel blend because it provides a good balance between material compatibility, cold weather operability, performance, emission benefits, and costs. According to Energy Policy Act of 1992 (EPAct) B20 is allowed as a minimum blend for equipment that includes compression-ignition (CI) engines, fuel oil and heating oil boilers, and turbines (National Renewable Energy Laboratory, 2009). ASTM standards define biodiesel as: "a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100. A "mono-alkyl ester" is the product of the reaction of a straight chain alcohol, such as methanol or ethanol, with a fat or oil (triglyceride) to form glycerol (glycerin) and the esters of long chain fatty acids." (Gerpen et al., 2004).

In addition to the EN-590 fuel standard that is used in Iceland there is also another standard for marine distillate fuels and for marine residual fuels, called ISO-8212 (Det Norske Veritas, 2010). Table 10 illustrates some of the main properties of diesel fuel and biodiesel fuels produced from different feedstocks marked as "i" and "ii". Those feedstocks are compared with ASTM (ii) – and ISO-8212 standards (iii). The density of ISO-8217 (iiii) is for a temperature 15 degrees Celcius but not for 21, as Table 10 illustrates.

Table 10 - Properties of diesel fuel and biodiesel fuels produced from different feedstocks compared with ASTM – and ISO-8217 standards

Fuel type	Viscosity (mm_2/s at 40˚C)	Density (g/cm^3, at 21˚C)	Cetane number	Flash point ˚C	Cloud point ˚C	Pour point ˚C
Diesel fuel [i]	2,0-4,5	0,82-0,86	51	55	-25	-25
Soybean methyl ester [i]	4,08	0,884	50,9	131	-0,5	-4
Rapeseed methyl ester [i]	4,83	0,882	52,9	155	-4	-10,8
Sunflower methyl ester [i]	4,6	0,88	49	183	1	-7
Tallow methyl ester [i]	5	0,877	58,8	150	12	9
Yellow grease methyl ester [i]	5,16	0,873	62,6	-	9	12
Soapstock methyl ester [i]	4,3	0,885	51,3	169	-	-
Palm oil [ii]	4,71	0,864	57,3	-	16	12
ASTM standard [ii]	4,33	0,854	46,3	130	-5	-6
ISO-8217 [iii]	2,0 - 6,0	0,89 [iiii]	40	60	-	-6

Source: Adapted from (Canakci & Sanli, 2008), (Benjumea, Agudelo, & Agudejo, 2007), (Det Norske Veritas, 2010) & (National Renewable Energy Laboratory, 2009).

The reason why palm oil, for example, is not as suitable as feedstock for biodiesel production in Northern Europe, especially in the winter season, is because of the high cloud point for palm oil, which is 16 °C. That is due to a high content of long chain, highly saturated methyl esters. At this temperature, crystals could form which may plug filters and fuel lines. On the other hand, rapeseed oil as a feedstock for biodiesel production is more suitable for that area and the winter season (Benjumea et al., 2007).

5.6 Engine Effects

The next two subchapters will illustrate the advantages and disadvantages of biodiesel due to lubrication and mechanical power.

5.6.1 Lubrication

Biodiesel methyl ester improves the lubrication properties of the diesel fuel blend. Lubricity properties of fuel are important for reducing friction wear in engine components normally lubricated by the fuel rather than crankcase oil. Since 1993, law in the US requires that only fuel that is low in sulfur among other materials can be used in engines (strictly for fossil fuel). Due to this change, the quality of lubrications of the fuel decreased and truck drivers in California protested with a one-day strike in December 1993. Research where 10 million miles were driven by trucks with a biodiesel blend revealed significant decreases in engine wear after running 100 thousand miles on a blend of biodiesel (Wedel, 1999).

5.6.2 Mechanical Power

With conventional diesel fuels, the inherent energy content of the fuel (typically measured in British thermal unitys (Btu) per gallon) is the largest factor affecting the fuel economy, torque, and horsepower delivered by the fuel. Between suppliers and seasons (winter, summer), the energy content of conventional diesel can vary up to 15%. This variablility is due to changes in its composition determined by the petroleum feedstock, as well as refining and blending practices. With biodiesel (B100), the refining (esterification or transesterification process) and blendin methods have no significant effect on energy content. For comparison has typical petroleum diesel about 18,300 Btu/lb heat of combustion while canola methyl ester (same as rapeseed plant in Canada) about 15,861 Btu/lb heat of combustion. Compared with most of petroleum diesel in the US, B100 has a slightly lower energy content, or about 2% per liter. The energy content of biodiesel blends and diesel fuel is proportional to the amount of biodiesel in the blend and the heating value of the biodiesel and diesel fuel used to make the blend. For example, B20 users experience a 1% loss in fuel economy on average and rarely report changes in torque or power (National Renewable Energy Laboratory, 2009). The power output of the engine decreases very little, if at all, according to studies about biodiesel consumption in the US and Europe. Two studies were done on marine engines, one from Germany and another from the US. In the German research, a Deutz four–cylinder marine diesel engine (direct injection), which is often used in fishing boats in Europe, was used. The German study confirmed similar results obtained by Mercedes Benz showing that the maximal torque curve for an engine under load remains essentially unchanged for rapeseed methyl esters relative to pure petrodiesel. It also showed that despite a lower volumetric heating value and the resulting lower maximum power output of biodiesel, the practical results are roughly the same. At a 20% blend, there are no noticeable differences in power output. In the US research, a four–cylinder direct injection engine was also used and the power produced decreased by 2 to 7% by using 100% soy methyl ester biodiesel instead of petrodiesel depending on load-speed point. However, at or near maximum throttle (3,800 rpm), the two fuels performed the same. Interestingly, at the lowest engine speed (1,855 rpm) at full throttle under a heavier load, there was a 13% increase in power with biodiesel as compared to petrodiesel (Wedel, 1999).

5.7 Environmental Effect

The carbon reduction to the atmosphere due to the use of biodiesel instead of fossil diesel is not an exact one-to-one replacement. Because of the recycling of CO_2 by future rapeseed plants, biodiesel is environmentally friendly. For each kilogram of fossil diesel not used, an equivalent of 3.11 kg of CO_2, plus an additional 15 + 20% for reduced processing energy, is not released into the atmosphere (Peterson & Hustrulid, 1998). A study about the investigation of using biodiesel/marine diesel blends and the outcome on the performance of a stationary diesel engine shows decreased particulate matter, carbon monoxide, hydrocarbon and nitrogen oxide emissions and resulted in a slight increase of the volumetric fuel consumption. The strong advantage of the use of biodiesel seems to be the fact that independently of the raw material used for the production, its addition into the marine fuel improves all the emissions and specifically particulate matter. The engine type was a single-cylinder Petter engine, model AV1-LAB. The engine was fuelled with pure marine diesel and mixtures containing 10%, 20%, and 50% of two types of biodiesel, with methyl esters produced from sunflower oil and olive oil. The emission tests included HC, CO, NOX and PM emission measurements under various loads of up to 5 hp, the load being measured by shaft output. The volumetric fuel consumption was checked as well (Kalligeros et al., 2003).

6 Legislation, Taxes and Grants (Subsidies)

The subject of this chapter is an important issue for the biodiesel industry and farmers. Legislation, taxes and grants can have a significant impact on the outcome of biodiesel production and those issues affect farmers, biodiesel producers and distributors. This chapter illustrates how regulatory environment, from cultivation to distribution, works. It also shows what the situation is in the US and Europe.

In the year 2003, the European parliament and the council of the EU came up with directives to encourage biofuels production. This EU biofuels policy pursues three objectives: to reduce the EU's dependency on foreign sources of energy, to decrease GHG emission, and to support farmers' incomes by providing a new outlet for agricultural products (Kutas et al., 2007). One of the ambitions is to have 5.75% biofuels in transportation by 2010 (Thamsiriroj & Murphy, 2009). The 2009/28/EC directive of the European Parliament and Council of March 2007 reaffirmed the community's commitment from 2003, with a mandatory target of a 20% share of energy from renewable sources in overall community energy consumption by 2020 and a mandatory 10% minimum target to be achieved by all member states for the share of biofuels in transport petrol and diesel consumption by 2020. The parliament of Iceland, Alþingi, has come out with environmental- and tax legislation. The law nr. 129/2009 is a regularization of taxation vehicles and fuel with the aim of encouraging the use of environmental friendly fuel, conservation of energy, decreased emission of GHG and increased use of domestic energizer. Also, in the first article of the environmental- and resource taxes from Alþingi is a special tax put on liquid fossil fuel for petrol, diesel, airplane fuel and fuel oil (which are used on marine engines).

6.1 The agricultural grant system in the EU

The grants system of the EU in agricultural has changed significantly since 2003. Instead of grants which depend on the amount of harvesting, they also aim to take into account an environmental point of view. This regulation is called "Single Payment Scheme" (SPS) and the member states of the EU have been introducing it to their own countries' law for the last years. Each member state has some flexibility in the process of its introduction and can therefore continue with some grants based on yields to preserve some specific production. Implementation is therefore different between member states. The aim of the change is firstly to give the farmer freedom of producing according to demand on the market. Secondly, it is to encourage sustainable environmental and feasible farming. Thirdly, it is to simplify the grant system, both for the farmer and the government. Finally, the aim is to strengthen the EU in its negotiations with WTO (World Trade Organization). Each member state has a determined maximum sum to be used for its agricultural grants.

The Common Agricultural Policy (CAP) of the EU is based on two principles, marketing control and regional development. Marketing control is supposed to control production and business with agricultural products inside the EU, with the aim of stabilizing the market, increasing farmers' quality of life and increasing productivity in agriculture with corn. The grant for the regional development inside the EU are based on the idea that agricultural has a multifarious role and is more than just the production of products. The aim of CAP is to increase environmental agricultural and support inclement areas, education of farmers, support young farmers and to increase R&D. Table 11 shows different grant amounts depending on location, environmental aspect, technical use of material like fertilizer and use of possible cultivated land in USD/ha annually (X-rates.com, 2010). This example is from Finland, where the land is divided into 6 areas: A, B, C1, C2, C3 and C4. Area A is in the most southern part of the land and C4 is the most northern. The amounts of grants are higher in area A than C because that land is more suitable for this type of harvesting (Intellecta, 2009).

Table 11 - Grant amounts to grain farmers in Finland

Areas	A USD/ha	B USD/ha	C2 USD/ha	C3 USD/ha	C4 USD/ha
Grant for barley malting	97-111	97-111	93	none	none
Grant for cultivation of animal feed barley	5-8	5-8	none	none	none
other grants that are not defined by areas:					
Grant with special aspect on environmental affairs (grain farming)					123
Grant with special aspect on environmental affairs (livestock farming)					142
other additional grants are:					
Grants due to decreased use of fertilizer					13
Grants due to more accurate use of nitrogen					31
Grants due to decreased cultivation land					15
Grants due to nutrion stabilized cultivation land					24
Grants due to multiplicity in cultivation (more species)					32

Source: Adapted from (Intellecta, 2009) & (X-rates.com, 2010).

The structure of the grant system in the EU can be different between countries. For example, Ireland offers government grants of 166 USD/ha (under the Energy Crop Scheme and Bioenergy Scheme) to farmers who grow oilseed rape anually (Thamsiriroj & Murphy, 2008).

6.2 The Agricultural and Biodiesel Grant System in the US and EU

According to Economic Research Service (ERS) in the US, which is a primary source of economic information and research of the U.S. Department of Agriculture, the grant system is based on a program to support the establishment and production of eligible crops for conversion to bioenergy. Also, the program is supposed to assist agricultural and forest landowners with collection, harvest, storage, and transportation of these crops to conversion facilities. This assistance includes annual payments to support production with a maximum payment of up to 75% of the cost of establishing an eligible crop. It also includes matching payments of up to 45 USD/ton for 2 years for collection, harvest, storage, and transportation to a biomass facility. Contract terms are up to 5 years for annual and perennial crops (Economic Reasearch Service, 2008). In US is subsidy of 0.264 USD/L (equal to 1 USD/gallon) for corn, soybean, and tallow biodiesel and 0.132 USD/L for yellow grease biodiesel production. In 2006, total transfers in support of biofuels associated with policies of the EU and the member states were approximately € 3.7 billion in 2006. Of that, biodiesel support was € 2.4 billion (Kutas et al., 2007).

6.3 The Agricultural Grant System in Iceland

In Iceland, a grain farmer can get a 81 USD grant out of each hectare cultivated (Landsbankinn, e.d). The minimum area of cultivated land must be 2 ha and the maximum is 20 ha to justify this grant to a grain farmer. This means that the maximum grant can be 1,620 USD (Landsbankinn, e.d) if 20 ha of land are cultivated. Farmers who cultivate grain will, on average, get 4 ton/ha of corn. This means 0.02 USD/kg (Landsbankinn, e.d) for corn in support from the government (Intellecta, 2009). On the other hand, farmers who cultivate rapeseed on 20 ha of land can receive grants of 0.027 USD/kg (Landsbankinn, e.d) due to an average of 3 ton/ha of seeds. Another requirement for the grant payment to the grain farmer is the kind of seed species and time factor. The seed species must be accepted and able of grow domestically and it must be sown before May 20th (Intellecta, 2009).

6.4 Taxes and Carbon Credits

In January 2008, the German government started collecting 0.20 USD/L for B100 versus 0.62 USD/L for fossil diesel (X-rates, 2007). The current legislation required an increase of the effective energy tax for B100 from 0.20 USD/L to 0.24 USD/L to take effect on January 1, 2009 (Lieberz, 2008). In the US, fuel taxes for biodiesel are approximately 0.5 USD/gallon (Demirbas, 2010), which means 0.13 USD/L. As previously mentioned, the law nr. 129/2009 from Alþingi is meant to encourage the use of environmentally friendly fuel and to decrease

GHG emission. This tax is in addition to present excise taxes which are already in place for diesel and petroleum. Such a tax already exists in most European countries, including Norway, Denmark and Sweden. The fee collection is based on the carbon content of each type of fuel and is based on the auction market European Union Emission Trading Scheme (EU ETS) which was established January 1, 2005. The main purpose of the market is to reduce emissions as efficiently as possible by encouraging nations and companies to identify the advantages of selling unexploited carbon credits on the international market (KOLKA - Carbon finance & consulting, 2010). Carbon quotas are not part of the Kyoto protocol, therefore heavy industries in Europe distributed the quotas to the government of each country. The Icelandic carbon credit constitutes about 1.7 million tons annually, which means 8.6 million tons of credit for the period 2008-2012. The aluminum industry in Iceland has distributed quotas from the government. In 2012, all of the airlines will participate in the legislation for carbon quotas. The exception is the US, because they are not participating in Kyoto. It is estimated that a second carbon license will be distributed in 2013 after the second revision of the Kyoto protocol, estimated in 2012. Most of the fishing industries and shipping companies will probably be included in the European legislation before 2020 (Eyrún Guðjónsdóttir, personal interview, November 15, 2010). The price of carbon emission was 13 €/ton for CO_2 but the Icelandic legislation is based on 32.5 USD/ton (Landsbankinn, e.d) or corresponds to 4000 ISK/ton. This means higher tax for diesel instead of petrol due to higher carbon content in diesel than in petrol. The tax for diesel is 2.9 ISK/L but for petrol it is 2.6 ISK/L. In Iceland diesel fuel is subject to three different taxes, namely a value added tax (VAT) of 25.5%, an oil tax of 0.43 USD/L and a carbon tax of 0.024 USD/L (Landsbankinn, e.d). The oil tax is also for imported biodiesel as well as petroleum diesel but not for domestically produced fuel. A producer of domestically produced fuel has to pay VAT (Kristinn Finnur Sigurðsson, personal interview, October 7, 2010). Due to law nr 87/2004 from Alþingi, the Icelandic fishing industry, and therefore ships, are exempt from oil tax but not VAT and carbon tax for the use of MGO (Magnús Ásgeirsson, personal interview, August 13, 2010).

7 Profitability Assessments

Chapter 7 includes a profitability assessment of biodiesel production from rapeseed cultivation in the Skagafjörður region. After providing an illustration of the technical and legislation environment, the economical portion is described in the following chapter and subchapters. Some parts are based on the technical and legislation information, but assumptions for the financial, investment, and operational parts are the main source for the final outcome of the project. Chapter 7.1 explains the methodology and location assumptions of the profitability assessment. This thesis is restricted to the Skagafjörður region with regards to the land availability for the possible cultivation of rapeseed. Also, the building suitable for supporting the estimated rapeseed cultivation, due to an ongoing experimental project that is operational in this building, is available in the aforementioned area as well. Chapter 7.2 describes the investment cost, which is roughly divided into the biodiesel plant, oil extraction equipment, other equipment and other costs. Chapter 7.3 illustrates the financial cost, where basic numbers, for example interest rate, operation time, and dividend are explained. Chapter 7.4 describes the operational cost, which is the variable cost of oil extraction, variable cost of biodiesel conversion, and fixed cost. Revenues in Chapter 7.5 are based on market price for rapeseed meal and glycerin but biodiesel price is based on the required price, based on information from the technical manager of FISK. In Chapter 7.6, the results of the profitability assessment are stated. The following chapter, Chapter 7.7, is a sensitivity analysis on some factors to explore and try to better understand to what extent uncertainties might affect the project. Chapter 7.8, the last chapter of the profitability assessment section, includes additional thoughts about the result of the profitability assessment.

7.1 Methodology and Assumptions

The Net Present Value (NPV) method is used for the profitability assessment in this thesis with a 10-year lifetime. According to a similar feasibility study done in Scotland, the profitability analysis is usually 10 years (Booth et al., 2005). The NPV method is basically where the present worth of all cash inflows is compared to the present worth of all cash outflows associated with the investment project. An investment is worth making if it has a positive NPV or if the investors do not have a better investment option (Park, 2007). To simplify, the immediate payment is known with certainty and in this case immediate payment is the total finance, for example equipment, building, and other investments. What is uncertain is the inflow for the next years to pay salaries, dividends, loans, and other operation costs. Thus, it is important to know the relationship between the value of a dollar today and that of a (possibly uncertain) dollar in the future before deciding on the project (Ross, Westerfield, & Jaffe, 2005). The uncertainty lies in the inflow which can be estimated according to the market situation. Estimated inflow is then discounted according to given Minimum Attractive Rate of Return (MARR).

The formula for NPV is: (7-1)

$$NPV = -C_0 \frac{C_0}{1+r} + \frac{C_1}{(1+i)^2} + \ \dots + \ \frac{C_T}{(1+r)^T}$$

$$= -C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i}$$

where

C_i = Net cash flow at the end of period T,

r = MARR

T = The planning horizon of the project.

According to Ross et al (2005), the decision rule for NPV is:

If NPV > 0, accept the investment;

If NPV $= 0$, remain indifferent to the investment;

If NPV < 0, reject the investment.

To evaluate the capital expenditure proposals, the Internal Rate of Return (IRR) is calculated both on project and equity. According to Ross et al. (2005) is the basic rationale behind the IRR method, that it provides a single number which summarizes the merits of a project. It is called internal rate of return because this single number does not depend on the interest rate prevailing in the capital market. Simply put, it means the number is internal or intrinsic to the project and does not depend on anything except the cash flow of the project (Ross et al., 2005).

(7-2)

$$IRR = 0 = -C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i}$$

For a better understanding, it is possible to explain the IRR method with following example: Consider a simple project with a 100 USD cash outflow and a 110 USD cash inflow. This example can be described as follows:

(7-3)

$$NPV = -\$100 + \frac{\$110}{1+r}$$

Where *r* is equal to the discount rate. To find out what the discount rate needs to be to make the NPV of the project equal to zero, an arbitrary discount rate of 0.08 is used, which yields

(7-4)

$$\$1.85 = -\$100 + \frac{\$110}{1.08}$$

Since the NPV in equation 7-4 is positive, a higher discount rate is used, for example 0.12. This yields

(7-5)

$$-\$1.79 = -\$100 + \frac{\$110}{1.12}$$

Finally, since the NPV in equation 7-5 is negative, the discount rate is lowered to 0.10. This yields (7-6)

$$0 = -\$100 + \frac{\$110}{1.10}$$

This example illustrates that the NPV of the project is zero when *r* equals 10 percent, according to given assumptions in this example. Thus, it can be stated in this example that 10 percent is the project's internal rate of return (IRR). In general, the IRR is the rate that causes the NPV of the project to be zero. The implication of this example is very simple. The general investment rule is as follows, If:

IRR $> MARR$, accept the project

IRR $= MARR$, remain indifferent

IRR $< MARR$, reject the project (Ross et al., 2005).

Other methods to measure the financial feasibility of investment projects are Modified Internal Rate of Return (MIRR) and Annual Equivalent Worth (AE). The AE method is a variation of the NPV method. All cash flows are converted into a series of equal cash flows over a specified period of time, instead of discounting all cash flows to present value. The same is done with the MIRR method, a variation of the IRR method, except that the MIRR does not assume that all cash flows are reinvested at the calculated IRR, but instead assumes that all cash flows are reinvested at another rate (i.e. an external rate of return) (Björnsdóttir, 2010).

In the subchapters 7.1.1 and 7.1.2, locational assumptions for land availability and building in Skagafjörður are described in further detail.

7.1.1 Land Availability

In assumptions for available land for rapeseed cultivation, it is estimated to use 175 ha in the first year, 2012. Kaupfélag Skagfirðinga KS, owner of FISK, is the owner of 200 ha of land in Vallhólmi that is used today for hay cultivation. Half of that land will be used in the first year with a 75 ha addition from other grain farmers. After interviewing farmers and specialists in grain farming and cultivation, it seems to be agreed that successful rapeseed cultivation will not happen unless careful and realistic assumptions according to factors like variation of the seed, land availability, and suitable soil are made. Table 12 shows how the estimated amount of land will be used.

Table 12 - Estimated land used for rapeseed cultivation and harvesting growth between years 2012 – 2022

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
harvesting growth			15%	18%	20%	25%	20%	18%	15%	15%	15%
	2012 (ha)									average	18%
sowing	175	201	237	285	356	427	504	580	667	767	879
land used	175	376	439	522	641	784	932	1.084	1.247	1.434	1.646
harvest	0	175	201	237	285	356	427	504	580	667	767

Source: Made by author.

In spring 2012, 175 ha for 2013 autumn harvesting will be sown. In spring 2013, an additional 201 ha will be sown, which is a 15% increase in land use. Of those 201 ha, 100 ha owned by KS, the other 101 ha is from local farmers. In spring 2013, there will be a total of 376 ha of land being used for rapeseed cultivation, this is 175 ha from sowing the previous year with an addition of 201 ha sown in spring 2013. In 2014, there will be total 439 ha of land used for rapeseed cultivation and so on. The first years of the cultivation are based on available land area in the Skagafjörður area as Table 13 shows. Later, in 2017 or 2018 and after, it is estimated that feedstock will be obtained from the nearest area such as the North-east region and the Húnavatna district. The harvesting growth is based on average growth of grain farming in Iceland from 1991 – 2007, which is 18% on average between years. Table 12

Table 13 - Land availability in three regions in north Iceland

Regions	Grain farming (ha)	Possible cultivation addition in oil crop(ha)
Húnavatna-distric	200	
Skagafjördur	550	500
North-east	800	500
Total/average	1.550	1.000

Source : Adapted from (Jónatan Hermannson & Þóroddur Sveinsson, 2009) shows a 15% increase from 2013 – 2014 and the growth increases due to better experiments with rapeseed cultivation. This is due to better R&D in seed variation, where it is very important to sow suitable seed variation that suits different soil types and possible long-term climate. In 2017, the growth will be 25%, after which it will decrease to 18% and 15% due to increased competition, but will stabilize to 15% from 2020 to 2022 due to better climate conditions in Iceland. The average growth between years is therefore 18% from 2013 – 2022.

7.1.2 Biodiesel Production Facility

It is estimated to use a building (Vallhólmi) that is in an area called Varmahlíð, located about 25 km away from Sauðárkrókur. Figure 15 shows the location of Vallhólmi in Skagafjörður (Varmahlíð in smaller picture). The figure also shows the building estimated to be feasible for biodiesel production in the Skagafjördur area.Vallhólmi is mainly divided into two parts, 1) 1400 m^2 storehouse and 2) a factory building for complementary feedstuffs that is 360 m^2. This plant is partly in use today, but all the equipment for making

Figure 15 – Vallhólmi in Skagafjörður. Source: Adapted from author & (Icelandic times, e.d.).

complementary feedstuff is available and is only partly in use. In addition, there is equipment for grain drying and silo tanks. In the autumn it is used by grain farmers for drying corn which is stored in big sacks in the storehouse. The only operation taking place in the building is an experimental project of drying straw and adding it to waste paper for use in bedding for horses. In addition to the storehouse and factory building, there is a 177 m^2 facilities building (see appendix 5). There is one employee who takes care of the buildings in Vallarhólmi and he gets assistance when there is production in the building. The owner of the building is Kaupfélag Skagfirðinga (KS), who also owns FISK. The building is not insulated and there is no hot water available. KS has estimated constructing a 2.2 km pipeline from a 98 °C well to Vallarhólmi. It is possible to divide the storehouse into 2 or 3 parts (Björn Hansen, personal interview, December 3, 2010), where the estimated biodiesel plant can use approximately 400 m^2 of area (Guðbjartur Einarsson, personal interview, December 6, 2010). In an assumption for economical feasibility, it is estimated that 400 m^2 of the Vallhólmi building will be rented from KS.

7.2 Investment Cost

In the following subchapters assumptions for investment cost will be illustrated. The final subchapter is a summary with results, including a table illustrating the total investment cost according to sources, will be provided.

7.2.1 Plant Capacity

The plant capacity is based on possible yield of feedstock that is available according to given assumptions of possible cultivated land and growth of cultivation in Chapter 7.1.1. From 175 ha of cultivated land, it is possible to produce approximately 215 tons/year of biodiesel as Table 14 shows. This is based on the estimation that 1 liter of oil is used to produce 1 liter of

Table 14 - Biomass yield division for oil extraction and biodiesel conversion in ton/year

Biomass divison tons/annually	number of tons/ha	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
seeds	3	525	604	712	855	1069	1282	1513	1740	2001	2301
Straw, stocks	3	525	604	712	855	1069	1282	1513	1740	2001	2301
Total biomass	6	1.050	1.208	1.425	1.710	2.137	2.565	3.026	3.480	4.002	4.603
Oil extraction											
Yield of seeds for oil extraction		525	604	712	855	1.069	1.282	1.513	1.740	2.001	2.301
RSO amount out of 3 ton of seeds	1.230 ton										
RSO production	1,23	215	248	292	351	438	526	620	713	820	944
Biodiesel conversion											
glycerin	0,12	21	24	28	34	43	51	61	70	80	92
biodiesel outcome of 1.230 L/RSO	1.230										
Biodiesel production		215	248	292	351	438	526	620	713	820	944

Source: Made by author.

biodiesel. One hectare of cultivated land gives 1.23 tons of vegetable oil, which means 1.23 tons of biodiesel (Thamsiriroj & Murphy, 2008). In 2013, 215 tons will therefore be produced both of rapeseed oil (RSO) and biodiesel. The production amount will grow according to harvesting growth and availability from the rapeseed cultivation, as Table 12 in subchapter 7.1.1 illustrates. Table 14 is divided into three parts, that is biomass division in tons/annually, RSO production from oil extraction, and biodiesel production from RSO due to biodiesel conversion process. As Table 14 shows, suitable equipment for biodiesel production and oil extraction is needed to fulfill estimated production capacity.

7.2.2 Biodiesel Equipment

Table 15 - Biodiesel equipment cost for 960 ton/year capacity

Cost factors for 480 ton/year	ISK/000	USD/000
Tanks	6.580	53,5
Pumps	510	4,1
Wiring, taps & fittings	500	4,1
Transportation & installation	1.000	8,1
Heat element	1.632	13,3
Sensors & computer equipment	700	5,7
System control installation	600	4,9
Total	11.522	94
Added cost for increased capacity to 960 ton/year		
Cost factors	ISK/000	USD/000
Tanks	6.500	52,8
Pumps	510	4,1
Intallation	500	4,1
Total	7.510	57
Total 480 + add. investment	19.032	151

Source: Adapted from (Kristján Finnur Sæmundsson, 2009) & (Guðbjartur Einarsson, personal interview, November 20, 2010).

Table 16 - Washing- and methanol recovery equipment cost

Washing equipment		
Cost factors	ISK/000	USD/000
Model EZDW-12a	706	5,7
amount of units	2	2
Transportation	100	0,8
Total	1.512	12
Methanol recovery equipment		
Cost factors	ISK/000	USD/000
MR-50 methanol recovery system	430	3,5
Transportation cost	100	0,8
Total	530	4
Total washing + methanol	2.042	17

Source: Adapted from (Home Biodiesel Kits, e.d), (Hannes Strange, personal interview, December 3, 2010) & (EZBiodiesel, e.d)

The investment cost for the biodiesel plant is based on a study describing biodiesel production in Iceland. A biodiesel plant with a total capacity of 480 tons/year has an estimated cost of 94,000 USD. Table 15 illustrates the most important cost factors. Almost more than half of the costs are due to the tanks, which are made of stainless steel. These numbers do not include the cost of producing RSO, only for the equipment of the biodiesel plant (Kristján Finnur Sæmundsson, 2009). In addition, the added cost in 2017 to increase the biodiesel capacity up to 960 tons/year is 57,000 USD. In total, it is estimated that the investment cost for a 960 ton/year biodiesel plant capacity is 151,000 USD, as can be seen in Table 15. The cost of other equipment is estimated in Table 16. The cost for washing equipment is 12,000 USD. The washing equipment that is used with the water washing system is called the dry washing system. The dry washing system saves time in washing the biodiesel and dries it again. The dry washing system does not make any changes to the biodiesel, it is only passed through the dry wash resin tower (after separation of glycerin). As it passes through the tower, the resin will clean the biodiesel via an "ion exchange" process, similar to the way a water softener works. Nothing is added to the fuel in this process (Sabudak & Yildiz, 2010). Another important piece of equipment is the methanol recovery equipment (Home Biodiesel Kits, e.d). Table 16 shows the costs for the methanol recovery system. The cost is 4,000 USD, but in total, the cost for the washing- and methanol equipment is about 17,000 USD, where transportation cost is 800 USD for each equipment (Hannes Strange, personal interview, December 3, 2010).

7.2.3 Oil Press

The estimated cost of oil extraction equipment is based on equipment from China, as Table 17 shows. An electric heat roller roaster is an oilseed heating and drying process for oil press. The hot process capacity is 200 – 1000 kg/hour (see appendix 7). Table 17 illustrates the cost for the heat roller roaster. Although it is heated with electricity, it is possible to use hot water instead by easily converting to a special heating element (Guðbjartur Einarsson, personal interview, November 24, 2010). The double-screw oil press is suited to many kinds of oil crops, such as camelina and rapeseed. It has both cold press and hot press abilities, with a capacity of 500 – 550 kg/hour and 600 – 650 kg/hour for the hot press. One unit can produce up to 2 tons/day of vegetable oil. This means about 480 tons/year of produced biodiesel with a 5-day operation per week, 10 hours per day, according to a 500 kg/hour capacity. Therefore, 2 units are needed, with a total cost of 11,300 USD for the oil press. The transportation cost is 2,400 thousand USD (see appendix 8) and the installation cost is 8,100 USD (Guðbjartur Einarsson, personal interview December 2, 2010). The total cost for oil extraction equipment, transportation and installation is 26,000 USD, as Table 17 shows.

Table 17 – Cost of oil extraction equipment

Cost factors	ISK/000	USD/000
Double screw oil press 6YL-150D	**696**	**5,7**
amount of oil press units	**2**	**2**
Electric heat roller roaster	**476**	**3,9**
Transportation cost	**292**	**2,4**
Installation cost	**1.000**	**8,1**
Total	**3.160**	**26**

Source: Adapted from (see appendix 7) & (appendix 8).

7.2.4 Unforeseen Cost

To estimate other unforeseen costs, 30% of the total investment cost is used due to the Icelandic Maritime Administration (IMA) experiment in biodiesel production which was done in collaboration with Veltak ltd. (Guðbjartur Einarsson, personal interview, November 24, 2010). A 30% unforeseen cost of the total investment is 33,000 USD in 2012 and 26,000 USD in 2017. The total unforeseen cost is therefore 59,100 USD.

7.2.5 Results and Summary

The total investment cost for the biodiesel plant in the Skagafjörður area is therefore 31.5 million ISK or about 268,000 USD. This investment cost is divided in two parts, as Table 18 shows. Due to an increased yield of harvesting more investment is needed to fulfill required capacity.

Table 18 - Total investment cost

	2012	2013	2014	2015	2016	2017	2018	Total
Investment:	KUSD							
Buildings	0	0	0	0	0	0	0	0
Equipment	156	0	0	0	0	112	0	**268**
Other	0	0	0	0	0	0	0	0
Total	**156**	**0**	**0**	**0**	**0**	**112**	**0**	**268**

Source: Made by author.

Table 19 summarizes the main investment costs and the main sources. The numbers along the left side of the table illustrate the table numbers and in some cases the corresponding chapter numbers (those that contain three figures).

Table 19 - Summary of investment cost

no	Investment:	value	unit	sources
7.2.1	Plant capacity 2013-2017	480	ton/year	Author
7.2.1	Plant capacity 2017-2022	960	ton/year	Author
15	Bio equipment cost 2013	94	USD/000	(Kristján Finnur Sæmundsson, 2009)
15	Bio equipment cost 2017	57	USD/000	(Guðbjartur Einarsson, personal interview, November 20, 2010)
16	Washing equipment 2017	12	USD/000	(Home Biodiesel Kits, e.d)
16	Methanol recovery 2013	4	USD/000	(EZBiodiesel, e.d)
17	Oil press 2013	13	USD/000	(Appendix 7 & 8)
17	Oil press 2017	13	USD/000	(Appendix 7 & 8)
7.2.3	Unforeseen cost 2012	33	USD/000	(Guðbjartur Einarsson, personal interview, November 20, 2010)
7.2.3	Unforeseen cost 2017	26	USD/000	(Guðbjartur Einarsson, personal interview, November 20, 2010)

Source: Made by author.

7.3 Financial Cost

The following subchapters illustrate the main assumptions of financial cost. The last subchapter contains a summary table of those assumptions.

7.3.1 Currency Rate

All cost and revenues in the NPV model are in USD. The estimated currency rate is the one-year average rate from November 23, 2009 to November 23, 2010. The average rate for USD is 123 ISK, for EUR it is 165 ISK and for GBP it is 191 ISK (Landsbankinn, e.d).

7.3.2 Minimum Attractive Rate of Return

In this thesis, the minimum attractive rate of return (MARR) by owners on equity is 15%. That number is based on uncertainty in the international financial market. Especially in Europe, where the euro has been experiencing the longest losing sequence any single currency has experienced since 1999, just after its inception. To illustrate this, it has been noted that the European currency fell more than 7% in May 2010 (Rodrigues, 2010). Also, EU countries like Ireland, Portugal, and Spain are in a difficult situation because of their debt. As such, the outlook of the international financing environment is not very positive for the next 1 – 2 years. Finally, the reasoning for the 15% MARR was made by looking at other similar projects abroad. For example, a 15% MARR is assumed in a 30 and 60 million gallon (equal to approximately 120 - 240 thousand tons) plant in the US (Paulson & Ginder, 2007).

7.3.3 Loan Interest, Working Capital, and Leverage

The interest rate is based on a company in a similar sector as the estimated plant. According to the interim account from N1, which is one of the largest retail and service companies in Iceland with high share of imported fuel, their loan interest is 9% on long-term loans (N1, 2010). The loan repayment is 10 years with 2% management fees. The straight line (SL) method is used to compute the annual depreciation allowances and the resulting book values. With the SL method, a constant proportion of the initial investment is depreciated each year less salvage value (Kimmel, Weygandt, & Kieso, 2007). The leverage for this project is 30% equity and 70% loans, as Table 20 shows. Corporate tax is 18% and the model assumes 30% of profit dividend paid.

7.3.4 Results and Summary

As Table 20 shows, working capital is 90,000 USD in 2010 and 2013 but 80,000 USD in 2014 and 10,000 USD in 2017. In the working capital, it is important to keep the cash count above zero in the first years when sales quantity is not very high. Thus, total financing is 538,000 USD.

Table 20 - Working capital, total financing, leverage, loan repayment and loan interest

	2012	2013	2014	2015	2016	2017	2018	Total
Investment:	KUSD							
Buildings	0	0	0	0	0	0	0	0
Equipment (Biodiesel pla	156	0	0	0	0	112	0	**268**
Other	0	0	0	0	0	0	0	0
Total	**156**	**0**	**0**	**0**	**0**	**112**	**0**	**268**
Financing:								
Working Capital	90	90	80	0	0	10	0	270
Total Financing	**246**	**90**	**80**	**0**	**0**	**122**	**0**	**538**
Equity	30%							
Loan Repayments	10	years						
Loan Interest	9,0%							

Source: Made by author.

Table 21 summarizes the main assumptions for financing with corresponding subchapter numbers provided along the left side.

Table 21 - Summary of main assumptions for financing

no	Financing:	value	unit	source
7.2.1	Currency USD	123	USD	(Landsbankinn, e.d).
7.2.1	Currency Euro	165	Euro	(Landsbankinn, e.d).
7.2.1	Currency Pound	191	Pound	(Landsbankinn, e.d).
7.2.2	MARR	15	%	(Paulson & Ginder, 2007)
7.2.3	Working capital	270	USD/000	Author
7.2.3	Leverage (loans)	70	%	Author
7.2.3	Loan payment	10	years	(Booth et al., 2005)
7.2.3	Loan interest	9	%	(N1, 2010)
7.2.3	Loan management fees	2	%	Author
7.2.3	Corporate tax	18	%	Author
7.2.3	Dividend	30	%	Author

Source: Made by author.

7.4 Operation Cost

In the following subchapters, operation cost, variable cost and fixed cost, are illustrated. Due to different methods in RSO production (oil extraction) and biodiesel production (biodiesel process), two numbers of variable cost are used. The oil extraction method produces RSO, which is feedstock for the biodiesel process. In other words, RSO conversion in this thesis is biodiesel production. In addition, the oil extraction process produces oil rapeseed meal as a by-product. Also, glycerin is also produced as a by-product in the biodiesel process. Therefore the variable cost of producing rapeseed meal and RSO are not the same as for producing biodiesel and glycerin, due to different methods of structure of feedstock and different processes.

7.4.1 Variable Cost of Oil Extraction

To estimate variable cost of oil extraction, information from the EFE project is used and illustrated in Table 22. Table 23 is for comparison later in this text. In the EFE project, it is estimated that the farmer who is harvesting is a grain farmer. This

Table 22 - Harvesting cost of rapeseed/ha in EFE project

Cost factor	ISK/ha	USD/ha
soil preparation, sowning and fertilisation	30.000	244
fertilizer, 800 kg (total)	70.000	569
seed, 7 - 10 kg	8.800	72
threshing	20.000	163
other cost (cleaning and drying)	20.000	163
credit due to subsidy	-10.000	-81
Total	138.800	1.128

Source: Adapted from (Jón Bernódusson, 2010) & (Intellecta, 2009).

means that he/she is already in possession of all the equipment (i.e. tractor, threshing equipment, etc.) and land that is needed for corn and, therefore, rapeseed harvesting. All fuel costs are included, as well. Table 22 shows the average cost for the year 2008, 2009, and 2010 (Jón Bernódusson, 2010). As Table 22 shows, fertilizer is the largest single factor in total cost for rapeseed harvesting or almost half of the total cost. Due to cultivation grants in Chapter 6.3, credit is included, which is about 81 USD/ha. The total cost is therefore 1,128 USD/ha. Chapter 3.4 illustrates that from 1 ha the harvesting amount is about 6 tons, which is divided in 3 ton of rapeseed seeds and 3 ton of straw. In comparison, Table 23 shows a feasibility cost analysis of grain farming in five different scenarios (Intellecta, 2009). When variable cost for cultivation of rapeseed is estimated in this project, the cost/ha is divided by the total biomass, which is about 6 tons. By dividing 1,228 USD by 6 tons the outcome is 0.19 USD/kg (23.1 ISK/kg). However, the price of straw that the farmer could have needs to be taken into account; this lowers his/her harvesting cost of rapeseed. As mentioned in Chapter 7.1.2, an experimental project is taking place in Vallhólmi, involving the use of straw from grain farmers in nearby areas for use as bedding for horses. According to the project manager, the price he pays for straw is about 0.11 USD/kg, as Table 24 shows. This experimental project can use 4-5 tons/day (1,200 tons/year) of straw (of that, 20-25% is waste paper), according to 8 hour workday (see appendix 9). In this thesis, it is estimated that 1,069 tons of straw will be used in 2017 and 2,301 tons in the year 2022. Table 23 contains the cost of straw for grain farmers where cultivated land is 2-10 ha. The cost of collecting the straw is 0.04 USD/kg, including the cost of oil and transportation. In this thesis the estimated cost of straw is 0.06 USD/kg instead of 0.04 USD/kg due to the estimated efficiency of straw is not

Table 23 - Cost analysis of grain farming on 2 – 10 ha of cultivated land

Cost factor	ISK/ha	USD/ha	ISK/kg	USD/kg
cultivation	88.823	722	22,2	0,18
harvesting	15.742	128	3,9	0,03
storage	5.519	45	1,4	0,01
drying	33.837	275	8,4	0,07
straw	20.974	171	5,2	0,04
Total	164.895	1.341	41	0,33

Source: (Intellecta, 2009).

Table 24 - Final cost of harvesting due to price of straw

Cost factor	ISK/kg	USD/kg
price of straw (to farmer)	**14**	**0,11**
cost of straw harvesting (for farmer)	**7**	**0,06**
cost of biomass harvesting	**23**	**0,19**
Final cost of harvesting	**16**	**0,13**

Source: Adapted from (appendix 9), (Intellecta, 2009) & (Jón Bernódusson, 2010).

always being 100%. Some straw that is collected from the field may contain a high proportion of moisture and is therefore not as valuable a product (Björn Hansen, personal interview, December 3, 2010). Therefore, 0.06 USD/kg decreases the cost of cultivation from 0.19 USD/kg to 0.13 USD/kg, as Table 24 illustrates. The cost of seeds for oil extraction is therefore estimated to be 0.13 USD/kg (16 ISK/kg). Table 25 shows the main cost factors of the oil extraction process. To produce 1 L of RSO, 3 kg of seed are required. Therefore, the cost of RSO is 0.4 USD/L. Other costs include the preparation/drying which is 0.02 USD/kg (Jónatan Hermannson, 2009). The cost increases with higher solid matter in the seed. According to Table 4 in Chapter 3, the average solid matter is 74% in the EFE project, thus 0.02 USD/kg (1.9 ISK/kg) is used as cost for preparation and drying. The cost of drying decreases because of a higher proportion of solid matter (Jónatan Hermannson, 2009). Other costs include electricity, which Booth et al. (2005) estimates to be 80 kWh/ton for oil extraction. The total variable cost of oil extraction is 0.42 USD/L.

Table 25 - Variable cost of oil extraction

Cost factors	ISK/kg	requirement kg/L	ISK/L	USD/L
Feedstock	16	3	49	0,40
other			ISK/kg	ISK/kg
preparation/drying			1,9	0,02
	ISK/kWh	reqiure kWh/kg	ISK/kWh	USD/L
Electricity	12	0,08	1	0,01
Total			52	0,42

Source: Adapted from (Booth et al., 2005), (Jónatan Hermannson, 2009) & (Jón Bernódusson, 2010).

7.4.2 Variable Cost for Biodiesel Production

Table 26 illustrates the cost for the catalyst methanol and sodium hydroxide (NaOH). The cost of methanol is 345 ISK/L and the cost of NaOH is 471 ISK/kg (Aron Baldursson, personal interview, November 7, 2010). The requirements for catalysts are 0.09 kg of methanol and 0.01 kg of NaOH for each liter of rapeseed oil, as Table 26 shows. The cost for NaOH is 0.04 USD/kg but for methanol it is 0.06 USD/kg. The methanol recovery system is able to reclaim 99.8 % of the methanol from glycerin by-product (Home Biodiesel Kits, e.d). Due to the purity of the glycerin, it is estimated that 75% of methanol will be recovered in this project (Guðbjartur Einarsson, personal interview, November 24,

Table 26 - Variable cost for biodiesel production

Cost factors	ISK/kg/L	requirement kg/L	ISK/L	USD/L
Methanol	345	0,09	31	0,06
NaOH	471	0,01	5	0,04
other	ISK/kWh	require kWh/L	ISK/L	USD/L
Electricity	12	0,04	0,5	0,004
Total			13	0,11

Source: Adapted from (Booth et al., 2005), (Aron Baldursson, personal interview, November 7, 2010) & (Home Biodiesel Kits, e.d).

2010). Therefore, the cost is 0.25 USD/L (31 ISK/L) for the first product, but due to recovery factor, the cost is lowered to 0.06 USD/L for the second time and throughout the remainder of the operation. Table 26 shows the variable cost of conversion from rapeseed oil (RSO) in rapeseed methyl ester (RME). A conversion cost of 0.11 USD/L is similar to the cost in Europe, according to Chapter 2. The conversion cost of vegetable oil in the US is 0.16 USD/L but in Europe it is 0.08 USD/L (National biodiesel board, 1994). The total variable cost from oil extraction to biodiesel production is 0.42 USD/L plus 0.11 USD/L, as Table 25 and 26 illustrated. Therefore, the total variable cost is 0.53 USD/L. For comparison is cost of RSO in Demirbas study (2010) 0.39 USD/L and the total cost of producing 1/L biodiesel is 0.66 USD/L (Demirbas, 2010).

7.4.3 Fixed Cost

Table 27 illustrates fixed costs, which include the rent for the building, maintenance, hot water and insurance. The largest fixed cost is the cost of renting a facility. A typical cost of rent of a building for an industrial process in the Skagafjörður area is about 100,000 ISK for each 100 m^2 (Ágúst Gunnarsson, personal interview, November 17, 2010).

Table 27 - Fixed cost for renting, maintenance, hot water and insurance

Cost factors	ISK/month	ISK/year	month amount	USD/1000
house renting	**400.000**	**4.800.000**	**12**	**39**
	percentage	ISK/year		USD/1000
maintenance	**2,5%**	**825.427**		**7**
	ISK/cubic meter	Cost/year	month amount	USD/1000
Hot water	**121**	**131.112**	**1.080**	**1**
		Cost pr/year		USD/1000
insurance		**500.000**		**4**
Total		**5.756.539**		**51**
management	**10%**	**625.654**		**5**
TOTAL + management		**6.382.192**		**56**

Source: Adapted from (Skagafjarðarveitur, 2010), (Ágúst Gunnarsson, personal interview, November 17, 2010), (Booth et al., 2005) & (Árni Egilsson, personal interview, December 6, 2010).

As Chapter 7.1.2 illustrates, the use of 400 square meters is estimated for this project. Therefore, the renting cost is 400,000 ISK/year, or 39,000 USD/year. Maintenance is based on a 390 ton/year capacity seed crushing plant in Scotland (Booth et al., 2005), where 2.5% of total capital cost is estimated. To estimate the amount of hot water that is needed, a specialist in heating utilities in Skagafjörður was consulted and said that a typical workshop in the Skagafjörður area uses 360 cubic meters of hot water per year (Árni Egilsson, personal interview, December 6, 2010). According to this information, it is estimated that the biodiesel plant will use threefold the amount of hot water, or about 1080 cubic meters/year. The price for one cubic meter is 121.4 ISK (Skagafjarðarveitur, 2010), which means the total price for hot water is 1000 USD/year. The total price for fixed costs is 51,000 USD. In the end, the management cost added to fixed cost is 10% of the total fixed cost (Booth et al., 2005), and therefore the total fixed cost is 56,000 USD. Table 28 shows the labor salaries for each worker. The labor salaries are based on figures from Statistics Iceland, where the average salary for a technical worker is 463,000 ISK/month in 2009, which is 45,000 USD/year. The same applies for worker 2 and worker 3, which is based on the average salary for laborers in 2009 (Statistics Iceland, e.d). The estimation for the number of workers that need to be hired, as Table 29 shows, is based on an seed crushing plant in Scotland with a total capacity of 390 tons/year, and employs one worker. It is also based on a seed crushing and biodiesel plant in Scotland with a total capacity of 4,700 tons/year of biodiesel, where there are four workers in addition to a secretary and manager (Booth et al., 2005). For comparison, Orkey (biodiesel plant in Akureyri) has three workers (Kristinn Finnur Sigurharðarson, personal interview, October 10, 2010). Therefore, for this project, three workers are estimated to be hired from 2013 – 2016, as Table 29 shows in thousand USD/annually.

Table 28 - Labors salaries

Labour	ISK/year	USD/000
technical worker 1 oil extraction	5.556.000	45
technical worker 1 biodiesel production	5.556.000	45
worker 2 oil extraction	3.840.000	31
worker 2 biodiesel production	3.840.000	31
worker 3 biodiesel production	3.840.000	31

Source: Adapted from (Statistics Iceland, e.d)

Table 29 - Number of laborers and total labor cost annually in thousand USD

Labour pr/year	2013	2015	2016	2017	2018	2019	2020	2021	2022
technical worker 1 oil extraction	45	45	45	45	45	45	45	45	45
worker 2 oil extraction				31	31	31	31	31	31
Total	45	45	45	76	76	76	76	76	76
technical worker 1 biodiesel production	45	45	45	45	45	45	45	45	45
worker 2 biodiesel production	31	31	31	31	31	31	31	31	31
worker 3 biodiesel production				31	31	31	31	31	31
Total	76	76	76	76	76	76	76	76	76
Total oil extraction & biodiesel production	122	122	122	153	153	153	153	153	153

Source: Adapted from (Statistics Iceland, e.d), (Booth et al., 2005) & (Kristinn Finnur Sigurharðarson, personal interview, October 10, 2010).

In 2017, due to an increased production and investment, worker 2 will be hired for oil extraction and worker 3 for biodiesel production. Five workers will therefore be working in the biodiesel plant in 2017. It is estimated that one of the technical workers will also be the manager of the plant. Therefore will the labor cost increase from 122,000 USD in 2013 – 2016 to 153,000 USD in 2017 – 2022.

The total fixed cost for each year is illustrated in Table 30, and is 56,000 USD in 2012 because of no production. In 2013, 122,000 USD is added to 56,000 USD. In 2017 the fixed cost will increase to 209,000 USD because of increased staff demand and labor cost of 153,000 USD due to increased plant capacity.

Table 30 - Total fixed cost

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Fixed Cost	56	178	178	178	178	209	209	209	209	209	209

Source: Made by author.

Table 31 contains the main assumptions for operation costs. On the left side of the table the numbers of each table are provided in addition with subchapters (those that contain three figures).

Table 31 - Summerize of main assumptions for operation

no	Operation:	value	unit	source
22	Harvesting cost	1.128	USD/ha	(Jón Bernódusson, 2010) & (Intellecta, 2009)
24	Final cost of harvesting	0,13	USD/kg	(Appendix 9), (Inntellecta, 2009) & (Jón Bernódusson, 2010)
25	Variable cost of oil extraction	0,42	USD/L	(Booth et al., 2005), (Jónatan Hermannsson, 2009) & (Jón Bernódusson, 2010)
26	Variable cost for bio product.	0,11	USD/L	(Booth et al., 2005), (Aron Baldursson, personal interview, November 7, 2010) & (Home Biodiesel Kits, e.d).
7.3.2	Total variable cost	0,53	USD/L	Sum no 25 & 26
27	Fixed cost without labour cost	56	USD/000	(Skagafjarðarveitur, 2010), (Ágúst Gunnarsson, personal interview, November 17, 2010), (Booth et al., 2005) & (Árni Egilsson, personal interview, December 6, 2010).
28	Labour salaries	45/31	USD/000/year	(Statistic Iceland, e.d)
29	Number of labourers (2013 - 2017)	3 - 5	worker	(Statistics Iceland, e.d), (Booth et al., 2005) & (Kristinn Finnur Sigurharðarson, personal interview, October 10, 2010).

Source: Made by author.

7.5 Revenue

Assumptions for revenues can be divided into three parts. First are the revenues for biodiesel production, where estimated revenues for biodiesel are based on information from FISK Seafood's technical manager. Second, the by-product price for rapeseed meal is estimated from information from Bústólpi Ltd in Akureyri (see appendix 11), which is a producer of animal meal for livestock, layerand poultry in particular. Third are the revenues for glycerin, another by-product, which are based on information from the Demirbas (2009) study about political, economic, and environmental impacts of biofuels. It is estimated that revenues for straw will not be included directly in this project. Straw is a by-product that farmers will benefit from by using as a fertilizer and/or by selling it to the experimental project in Vallhólmi which is mentioned in Chapter 7.1.2. The basic idea is to establish a biodiesel plant with a total output of 175 tons of biodiesel within the first year. This assumption is based on the land availability in the Skagafjörður area in Chapter 7.1.1. For comparison, it is estimated that the Orkey biodiesel plant in Akureyri will produce 300 tons within the first year. To produce 175 tons of biodiesel, 565 tons of rapeseed seed are needed for oil extraction. Roughly, each ha of cultivated land gives an average of about 6 tons of biomass which is divided into approximately 3 tons of straw and 3 tons of rapeseed seed. Those 3 tons of seeds are pressed with an outcome of 1.23 tons of biodiesel. The rest is 2 tons of rapeseed meal and about 120 kg of glycerin.

7.5.1 Biodiesel

One of the most important factors to estimate is the price of biodiesel. In 2008 and 2009, the average purchase price for FISK was 70 ISK/L, not including oil tax and VAT (see appendix 12). The average price of oil was 90 ISK/L in 2009 for marine engines (not VAT included) (Jón Ingi Sigurðsson, personal interview, January 20, 2010). Today the list price of marine gas oil (MGO) is 97 ISK/L (see appendix 6). Due to high consumption of MGO, FISK gets a discount according to list price. This project will estimate a 10% lower price than 70 ISK/L, which is 63.5 ISK/L including oil tax. That price is according to Jón Ingi, technical manager of FISK, who says that the price of biodiesel needs to be 10 - 20% lower than marine oil (Jón Ingi Sigurðsson, personal interview, January 20, 2010). Otherwise, the company sees no benefits in converting the oil consumption of its ships. Therefore, VAT is added to 63.5 ISK/L in the model with a price of 79.1 ISK/L or about 0.643 USD/L.

7.5.2 Animal Meal

Rapeseed meal, a valuable by-product, comes from oil extraction and can be used as material for animal meal due to its high content of protein. The price of animal meal has been increasing both domestically and abroad due to increase of grain prices around the world. According to Bústólpi Ltd. the price of rapeseed meal is around 60 ISK/kg (see appendix 11), or about 0.48 USD/kg.

7.5.3 Glycerin

In a study by Demirbas (2009), it is stated that there is an oversupply of glycerin on the world market and it is sold for little value. The new biodiesel plant in Akureyri, Orkey, is estimated to make an environmental friendly antifreeze employing glycerol as an ingredient, but the price of it is unknown (Kristinn Finnur Sigurharðarsson, personal interview, October 10, 2010). The price for glycerin is 14.7 ISK/kg or about 0.12 USD/kg.

7.6 Net Present Value and Internal Rate of Return

The profitability assessment estimates the NPV of the project and equity is discounted with estimated MARR. According to given assumptions in previous chapters, the results of the NPV calculations are as follows: Assuming 15% MARR, a 9% interest rate and 10 years of operation, the project delivers a NPV of minus 30,000 USD and minus 24,000 USD of equity in the year 2022, as can been seen in Table 32. Equity is for the investment from investors while project is both for equity and loans. The IRR of the project is 14% and the IRR of equity is also 14%. According to this result of NPV calculations, the project is not profitable to investors with a MARR of 15% because the NPV is not above zero and the IRR is below 15%. All other results for investment, operation, cash flow, balance and profitability can be seen in the next subchapters and appendix 10.

Table 32 - Result of NPV and IRR

	Project	Equity
NPV of Cash Flow	-30	-24
Internal Rate of return	14%	14%

Source: Made by author.

7.6.1 Other Results

Figure 16 shows how the total cash flow & capital and net cash flow & equity increase between years. In 2015 and 2016, total cash flow & capitals is positive by approximately 7,000 and 14,000 USD and net cash flow & equity is, on the other hand, negative until 2017. In 2017 more investment in equipment is needed due to demand of the increased capacity of the biodiesel plant. Then the total cash flow & capital becomes negative, approximately 84,000 USD. Then, from 2018 until 2022, both total cash flow & capital and net cash flow & equity are positive. Figure 17 illustrates the accumulated NPV of total cash flow and the NPV of net cash flow. The left vertical axis represents negative thousand USD for the accumulated NPV for total cash flow and net cash flow. As seen in Figure 16, some change in NPV total cash flow is in regards to increased investment in 2017. The NPV total cash flow is then negative by 360,000 USD. On the other

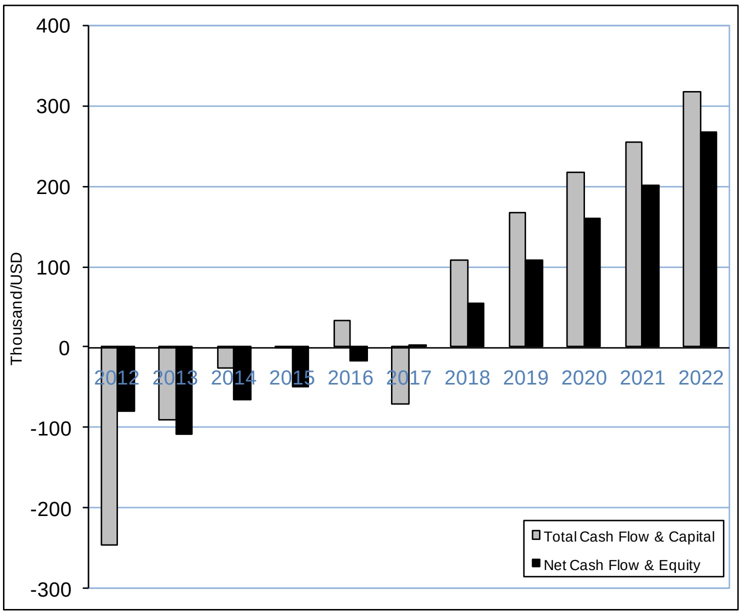


Figure 16 – Total cash flow & capital and net cash flow & equity. Source: Made by author.

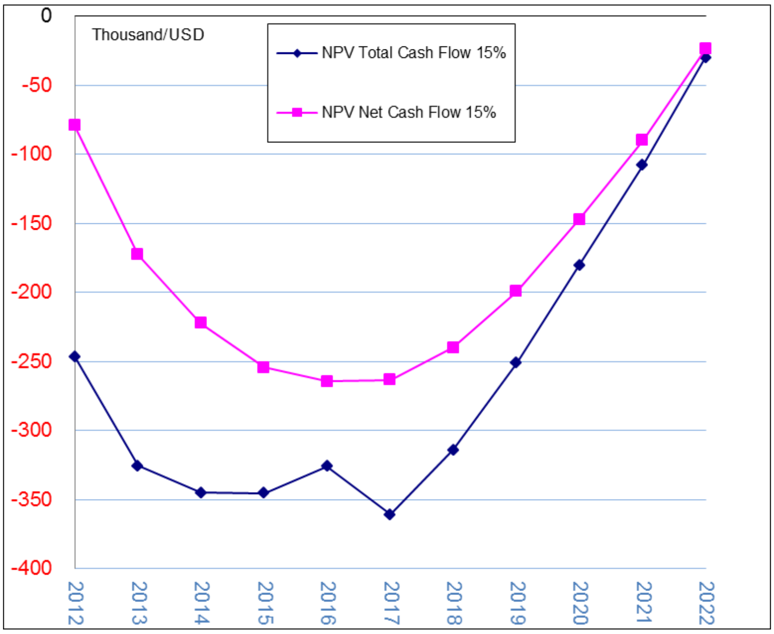


Figure 17 - Accumulated NPV of total and net cash flow. Source: Made by author.

hand, it does not have as much of an effect on the NPV of net cash flow because of leverage, where loans are 70% against 30% for equity.

7.7 Sensitivity Analysis and Discussions

Sensitivity analysis is used to explore and to better understand the effects of uncertainties in varied assumptions, both those that effect cost and revenues. In Chapter 7.7.1, an impact analysis which deals with one uncertain item at a time and estimates the effect of the changes of that particular factor on the IRR of equity will be done. Chapter 7.7.2 discusses the result of the scenario analysis which deals with simultaneous changes in more than one uncertain item on the IRR of equity.

Those chapters illustrate cost and revenue factors that have the most impact on the total outcome of the project. A further illustration of the factors, where they can be viewed separately or comparatively, can be viewed in appendix 13.

7.7.1 Impact Analysis

The impact analysis shows where the impact factor decreases or increases by 10% in the range from -50% to 50%. The revenue factors that are chosen are changes in price and quantity of biodiesel, rapeseed meal, and glycerin. The cost factors are investment-, variable, and fixed cost, loan interest and the currency exchange rate of USD. For a better understanding it is important to reaffirm from Chapter 7.3 the variable cost which is divided into two parts, namely, the variable cost of oil extraction and the variable cost of biodiesel conversion when RSO is used as feedstock for the biodiesel production. Figure 18 contains revenues and cost factors and is a visual picture of which factor is most sensitive to change. Those factors are marked on the right side in the figure as follows: Price of biodiesel (p/bio), price of rapeseed meal (p/meal), variable cost of oil extraction (variable cost oil), currency rate of USD, quantity of biodiesel (Q/bio), quantity of rapeseed meal (Q/meal), quantity of glycerin (Q/glyc), investment cost (equipment cost), fixed cost is unchanged and variable cost of biodiesel conversion (variable cost bio). On the revenue side (the right side of Figure 18) the price of rapeseed meal and price of biodiesel have significant influence on the total outcome of IRR. The increased vertical position of the line means an increased effect on the total outcome of the IRR of equity. On the left side, in Figure 18, changes in fixed cost have significant impact on the IRR of equity as variable cost of oil extraction as well.

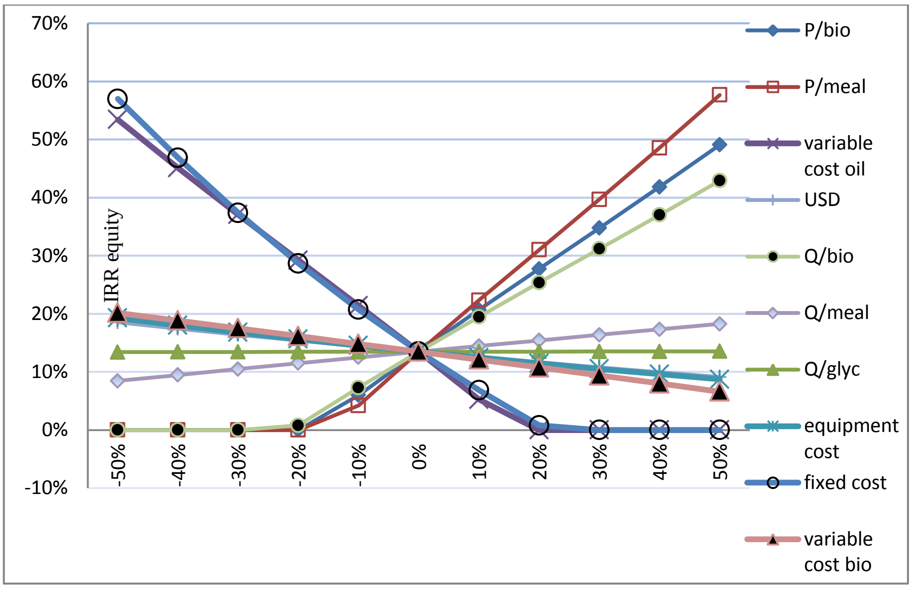


Figure 18 - Impact analysis on IRR of equity with changes in factors ranging from -50% to 50% on x-axis, IRR of equity on y-axis. Source: Made by author.

Table 33 illustrates the same method as Figure 18 in another way and in more detail. The revenue factors are quantity and price for biodiesel, meal and glycerin, labeled as Q/meal, Q/bio, Q/glyc, P/meal, P/bio and P/glyc. The different cost factors are listed on the right side of the table.

Table 33 - Impact analysis on IRR of equity with changes in factors ranging from -50% to 50%

	Revenue factors						Cost factors					
	P/meal	P/bio	Q/bio	Q/meal	P/glyc	Q/glyc	loan interest	USD	equipment cost	variable cost bio	variable cost oil	fixed cost
	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
-50%	0%	0%	0%	9%	13%	14%	14%	19%	20%	21%	54%	58%
-40%	0%	0%	0%	10%	13%	14%	14%	18%	19%	19%	45%	48%
-30%	0%	0%	0%	11%	14%	14%	14%	17%	17%	18%	37%	38%
-20%	0%	0%	1%	12%	14%	14%	14%	16%	16%	17%	30%	29%
-10%	5%	7%	8%	13%	14%	14%	14%	15%	15%	15%	22%	21%
0%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
10%	23%	21%	20%	15%	14%	14%	14%	13%	13%	13%	6%	7%
20%	32%	28%	26%	16%	14%	14%	14%	12%	12%	11%	0%	1%
30%	40%	35%	32%	17%	14%	14%	14%	11%	11%	10%	0%	0%
40%	49%	42%	38%	18%	15%	14%	14%	10%	10%	9%	0%	0%
50%	58%	50%	43%	19%	15%	14%	14%	10%	9%	7%	0%	0%

Source: Made by author.

The factors which have the most significant influence on IRR of equity are the ones that are farthest to right and to left on Table 33, versus those that are in the middle which have less impact, such as loan interest, price and quantity for glycerin. A 10% increase in the price of rapeseed meal would mean a 23% IRR of equity instead of 14%. On the other hand, if fixed cost increased by 10%, then the IRR of equity would be 7% instead of 14%.

7.7.2 Scenario Analysis

For the scenario analysis, scenarios of pessimistic, most likely and optimistic scenarios are set up with changes in more than one impact factor. Two scenarios are set up, the first one asks what would happen to the IRR and NPV on equity if the price of products would go either up or down by 10%. The second scenario shows the most likely outcome. The results can be seen in Table 34. The prices of biodiesel and rapeseed meal are a big factor on total outcome of the project. The price of glycerin does not have as much effect due to relatively little quantity comparing to biodiesel and rapeseed meal. A 10% higher price for those products would mean a 29% IRR and a positive NPV by 233,000 USD

Table 15 - Illustrates the change in NPV and IRR of equity with changes in prices of biodiesel, rapeseed meal and glycerin

Scenario Summary	Current Values:	Pessimistic	Most likely	Optimistic
Changing Cells:				
Price biodiesel	100%	90%	100%	110%
Price rapeseed mea	100%	90%	100%	110%
Price glycerin	100%	90%	100%	110%
Result Cells:				
NPV equity	-24	-290	-24	233
IRR equity	14%	0%	14%	29%

Source: Made by author.

Different cost factors greatly affect the total outcome of this project. With the optimistic scenario of 10% lower cost for variable of oil extraction, the variable cost of biodiesel conversion and fixed cost as Table 35 illustrates, the IRR increases from 14 to 30%. The pessimistic scenario with 10% increasing cost means that the IRR decreases to 0% with a negative NPV of equity of 290,000 USD.

Table 35 - Change in NPV and IRR of equity with changes in variable cost for oil extraction, biodiesel conversion and for fixed cost

Scenario Summary		Current Values:	Pessimistic	Most likely	Optimistic
Changing Cells:					
	Variable cost oil	100%	110%	100%	90%
	Variable cost bio	100%	110%	100%	90%
	Fixed cost	100%	110%	100%	90%
Result Cells:					
	NPV equity	-24	-290	-24	230
	IRR equity	14%	0%	14%	30%

Source: Made by author.

7.8 Additional Thoughts on Profitability

There are many other factors that affect the total outcome of the profitability calculations. The following subchapters will mention those factors and illustrate them further. The factors that have an impact on the sensitivity analysis include different method and feedstock, change in fuel cost and carbon credit.

7.8.1 Different Methods and Feedstock

This report has investigated the feasibility of converting rapeseed into biodiesel in order to use it as fuel on a fishing vessels. The main source for the feedstock is the grain farmer. Figure 19 shows two possibilities of how farmers can use the oil, either for (a) biodiesel production or (b) for vegetable oil production. By searching for sources, interviews, and meeting with specialists in this field, both in cultivation, engineering and fishing industry, this thesis finds that there are other implementations and feedstock sources that are worth investigating further.

I) According to the manager of FISK, it is estimated that there are about 800 tons/year of waste slime from two of the freezer trawlers owned by FISK (Jón Eðvald Jónsson, personal interview, October 20, 2010). It is possible to convert this amount of slime to 80 – 160 tons of fish oil or 79 – 158 tons of biodiesel. Biodiesel production from fish oil can be illustrated in a

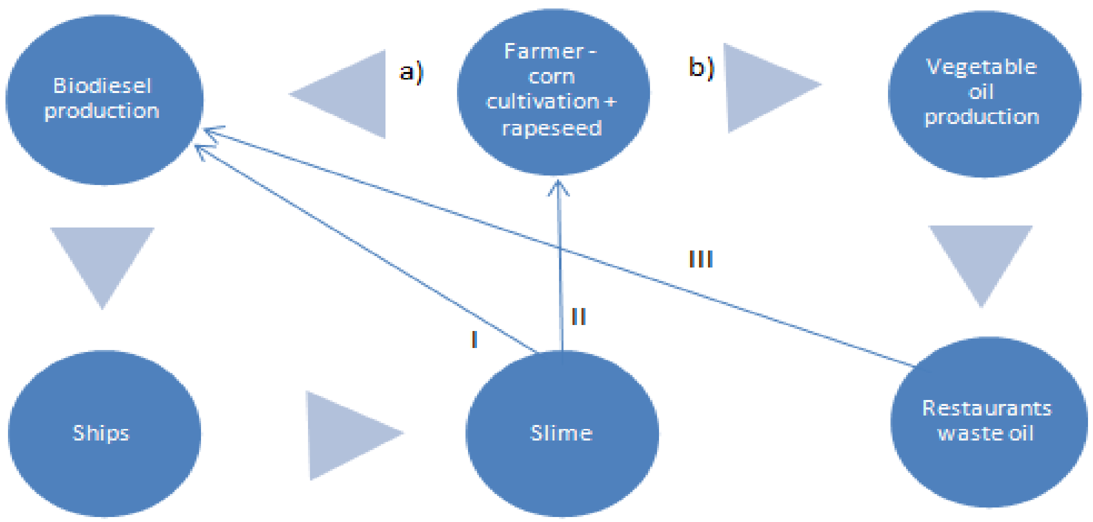


Figure 19 - Shows the flow of different feedstocks and different methods. Source: Made by author.

few steps. The first step is to add acids with the liquefaction of the mass provoked by the action of enzymes from the fish. This is a common way to convert fish waste into a product for oil and animal feed. The second step is the settling of the silage, where the silage is heated up to 90 ˚C, pumped to settling tanks and left to settle. During the settlement the suspension is divided by gravitation into three fractions. Oil, being the lightest, rises to the top, the water fraction, being the densest, sinks to the bottom. In between these layers is the protein fraction that can be utilized as an animal feed ingredient or meal. The third step is the dewatering and filtering of the oil. Due to the high content of FFA in fish oil (5 – 30%) there is a pretreatment process needed (see appendix 15). The downside of this procedure is the little space available onboard the ships to collect the slime. But it is possible to collect the slime in special containers where the slime is prepared for further biodiesel process. The cost for that kind of equipment onboard is unknown.

II) Slime can also be used as fertilizer for rapeseed cultivation. As the cost analysis in Chapter 7.3.1, Table 22 shows, fertilizer accounts for almost half of the total cost for rapeseed cultivation.

III) As previously mentioned, it is possible to produce valuable vegetable oil from rapeseed oil. The price per liter for vegetable oil is probably higher than for biodiesel but the cost of packing, distributing and so on is unknown. Even so, it is clear that competition with the vegetable oil sector is tough for biodiesel production. One solution could be that the farmer sells vegetable oil made from rapeseed to restaurants. An agreement can be made between the farmer, biodiesel plant, and restaurant that waste oil from the restaurant will be sold to the biodiesel plant at a similar price as it costs the restaurant to dispose it. According to Orkey ltd., the price for waste oil is zero and they only have to pay for the transportation cost. But in the long-term, the price of waste oil could increase due to competition on the biodiesel production market. There are also several factors that need to be studied further in this way, such as the reducing of the oil, the cost of waste oil and the process of agreement between the farmer, restaurant and biodiesel plant.

7.8.2 Fuel Saving and Carbon Credit

It is interesting to look at how much savings in fuel FISK is able to manage by using biodiesel on one of its trawlers, Málmey SK-1. Table 36 contains some numbers which show how much FISK could save in fuel consumption every year. The assumptions are the same for the biodiesel price as mentioned in Chapter 7.5.1, the price for biodiesel is 10% lower than fossil diesel which is 87 ISK/L. Málmey SK-1 has used on average 2,600 tons/year of fossil fuel for the last 5 years (see appendix 12). According to those assumptions, fuel cost is 226,200 thousand ISK/year. Table 36 shows the biodiesel amount per year according to growth and harvesting of rapeseed plants. In 2013, fuel used on Málmey SK-1 is blended with 8% biodiesel (B8). Due to 10 % lower cost, for 8 % of the total fuel, the total fuel cost decreased by 1722 thousand ISK or 14,000 USD. This number increases through the years due to a higher proportion of biodiesel. In the year 2022 B35 is used with a total savings of 7549 thousand ISK or 61,000 USD

Table 36 - Possible fuel savings and carbon credit in the future

	Used ton/year	ISK/L Marine gas oil	Fuel cost ISK/000	ISK/L biodiesel	Price difference	Carbon equivalent (kg)	Carbon price Euro/ton				
Málmey SK-1	2.600	87	226.200	79	10%	3,11	14,24				
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	
biodiesel	215	248	292	351	438	526	620	713	820	944	ton/year
fossil diesel	2.385	2.352	2.308	2.249	2.162	2.074	1.980	1.887	1.780	1.656	ton/year
biodiesel proportion	8%	10%	11%	13%	17%	20%	24%	27%	32%	36%	%
biodiesel cost	17.005	19.555	23.075	27.691	34.613	41.536	49.012	56.364	64.819	74.542	000/ISK
fossil oil cost	207.473	204.664	200.788	195.705	188.082	180.458	172.224	164.128	154.817	144.110	000/ISK
fuel saving ISK	1.722	1.980	2.337	2.804	3.505	4.206	4.963	5.708	6.564	7.549	000/ISK
fuel saving USD	14	16	19	23	28	34	40	46	53	61	000/USD
Carbon credit	669	770	908	1.090	1.363	1.635	1.929	2.219	2.552	2.934	ton/year
EUR value	9,5	11,0	12,9	15,5	19,4	23,3	27,5	31,6	36,3	41,8	000/Euro
ISK value	1.573	1.809	2.134	2.561	3.202	3.842	4.533	5.214	5.996	6.895	000/ISK
USD value	13	15	17	21	26	31	37	42	49	56	000/USD
Total saving ISK	3.295	3.789	4.471	5.365	6.707	8.048	9.497	10.921	12.559	14.443	000/ISK
Total saving USD	27	31	36	44	55	65	77	89	102	117	000/USD

Source: Made by author.

In addition to these savings, it might be possible to estimate the value of carbon credit. According to Chapter 5.7, each kilogram of fossil diesel not used is equivalent to 3.11 kg of CO_2. This means that in the year 2013, the credit for biodiesel used will be 669 tons/year as can be seen in Table 36 for year 2013. According to the auctioning of emission allowances in Germany in November 2010, which is part of the EU ETS in Chapter 6.5, the price for the year 2010 is about 14.24 euro/ton (Weis, 2010). In 2013, the value of the carbon credit is estimated to be 1573 thousand ISK. According to Chapter 6.5 it is estimated that the fishing industry will be included in the EU legislation before 2020. When the aluminum industry in Iceland distributed carbon credit, the year 1991 was used as a reference year. It is difficult to say if carbon credit will be included in the account or not, so the value that is obtained according to EU ETS is not able to provide an answer on who exactly will benefit from the credit, but the companies will surely benefit by demand for emission allowances (See appendix 14). Nevertheless, it is possible to estimate a profit of 2561 thousand ISK due to estimated carbon credit in the year 2016 when it is predicted that the fishing industry will possible be included in EU ETS. In 2016, the total value with fuel savings included is 5365 thousand ISK and up to 14,443 thousand ISK in the year 2022, as Table 36 shows. The question concerns the future and to whom there will be value added, or in which way it will be divided between the government or companies.

8 Discussions

After collecting data, researching, and interviewing many individuals and parties that are linked to grain cultivation and biodiesel production, it is clear that there are many technical methods available both in feedstock and production. Although the result of this thesis does not provide a positive NPV and IRR, according to given assumptions, there are several interesting aspects which are worth discussing further. To make biodiesel production by rapeseed cultivation feasible it is important that all parties involved cooperate. The first step of successful rapeseed cultivation might be with oil extraction. The idea of cultivating rapeseed for vegetable oil production is interesting and needs further investigation. It is important to study the market for domestically produced vegetable oil by researching the market size, price and cost of packing and distribution, as well as the idea of producing vegetable oil for restaurants or lunchrooms in companies or schools whereby the waste oil can be re-used for biodiesel production. This recycling idea might be more feasible than using the RSO straight for biodiesel production. To make rapeseed cultivation, or other oil crop cultivation, realistic in Iceland, it is important to estimate possible harvesting land scientifically, with soil samples for example. It is not enough to start new cultivation based on aerial photographs. One of the largest factors that affect the profitability assessment of this thesis is land availability. Although, it is estimated that 175 ha will be used in the first year of cultivation and that cultivated land will increase 18% in average annually, there are other factors that can change the amount harvested each year. Crop failure due to weather or plant infection can have an enormous effect on the profitability assessment. Also it is important that weather is suitable while threshing in the autumn.

The main parties in this thesis are farmers and fishing operators. These are the two important industries in Iceland and many of those who are against joining the EU are farmers or fishing operators. However, subsidies in EU grain farming are higher and focus more on environmental issues than in Iceland. For example, government grants in Ireland are around 20 thousand ISK/ha (166 USD/ha) while they amount to approximately 10 thousand ISK (81 USD/ha) in Iceland. On the other hand, it is questionable whether or not it is beneficial for the Icelandic economy to increase these subsidies at the same level as the EU or to simply join the EU. Joining the EU is not the subject of this thesis, but the reason for increased government support can be rationalized in some way. However, first it is important to identify the real motivations for the Icelandic fishing industry to convert its fuel consumption from fossil diesel to biodiesel. It is clear that FISK is paying a considerably lower price for fuel on their ships according to the given list price for MGO. One of the main assumptions in this thesis is the price of biodiesel which is 10% lower than FISK is paying for the fuel on their ships. FISK is one of the largest fishing companies in Iceland and it is very likely that other similar sized fishing companies have similar discounts as FISK. Therefore it is questionable as to whether the Icelandic fishing companies have enough motivation for converting the fuel on their ships from fossil oil to renewable fuels. As explained in Chapter 7.5.1, the average price of oil was 121 ISK/L (0.98 USD/L) in 2009 with VAT included. Due to discounts, FISK only had to pay 87 ISK/L (0.71 USD/L) on average during the year 2009 with VAT included. That is a 40% average lower price than the given list price. Therefore it is not surprising that the motivation of the fishing industries is not that great in terms of converting their fuel consumption to more environmentally friendly choices. This is a very important factor which the government, institutes, and companies have to take into account when discussing whether the conversion from fossil fuel to renewable fuel is a feasible choice. Finally, there is the rationale of why it could be beneficial for the Icelandic economy to increase government grants in the biodiesel supply chain. With increased domestic environmental fuel production, the demand for imported fossil fuel would decrease, which would result in savings related to currency exchange, more domestic working opportunities, increased energy security, and carbon credits. The carbon credits alone can be valuable to the Icelandic economy due to EU ETS in the future.

9 Conclusions

The main goal of this thesis is to examine the potential of adding value to biodiesel production in a specific area in Iceland called Skagafjörður. Available grain-farming land in Skagafjörður is 550 hectare (ha) with a potential for a 500 ha addition. In the first year the model assumes that 175 ha will be cultivated for rapeseed harvesting. The idea is that cultivating rapeseed in Skagafjörður with the aim of converting rapeseed into biodiesel for use on a fishing fleet. The conclusion is on the border of being feasible, with a minus 24,000 USD Net Present Value (NPV) of equity and a 14% Internal Rate and Return (IRR) of equity. Despite a negative NPV and an IRR of equity under Minimum Attractive Rate of Return (MARR), which is 15%, the sensitivity analysis finds that only a 10% higher price for the by-product of rapeseed meal will result in 22% IRR of equity instead of 14%. Due to increased demand for animal meal both domestically and abroad, it is very likely that the price of animal meal will increase in the coming years. The price of biodiesel is also a significant factor that can change the final outcome of the model outlined in this thesis. Raising the price by 10% results in a 21% higher IRR of equity. The likelihood of a higher price in coming years for biodiesel is rather high according to the market conditions. The price of fossil fuel has never been as high in Iceland as it is today, and the price for marine engines follows. The price of biodiesel is very much linked to changes in the price of fossil fuel as well. Icelandic fishing industries have not escaped higher prices for marine gas oil (MGO). Due to the importance of the fishing industry to the Icelandic economy, it is important to develop environmentally friendly fuel for the future. The conclusion of this thesis is based on the collaborative project between the Icelandic Maritime Administration (IMA), Agriculture University of Iceland (AUI) and several farmers that began in June 2008. This project is called the "Environmentally Friendly Energizer" (EFE). The main idea of the EFE project is to test different locations around the country for feasible rapeseed cultivation with the final goal of producing biodiesel for use on a fishing fleet. The cost of cultivation, and therefore of rapeseed oil (RSO) feedstock in this thesis is based on the EFE project. The cost of RSO is 0.42 USD/L which corresponds to the Demirbas (2009) study, where the RSO cost is 0.39 USD/L. The variable cost is divided into two parts: variable cost for oil extraction and variable cost for biodiesel production. According to a sensitivity analysis, a 10% lower cost in variable cost of oil extraction would lead to a 21% IRR of equity instead of 14%. Due to the importance of applying the right method in the cultivation process, where it has become clear that even a 10% decrease in the cultivation process can have a significant effect, is important to increase Research and Development (R&D) in rapeseed and other oil crop cultivation. Although, RSO can also be used as vegetable oil and the aim of this thesis is to study the potential of using RSO in the biodiesel process with the aim of driving marine engines, there is a potential to recycle waste cook oil in the biodiesel process later on. There are at least two ways of exploiting rapeseed cultivation, either by straight use in the biodiesel process or with recycling in cooperation with restaurants. In this way, and with good cooperation, farmers and operators in fishing industry can link those two industries together with a feasible outcome for the whole economy.

Decreasing fuel cost in the Icelandic fishing industry has been one of the main goals of fishing operators in the past years. Sending the fishing fleet to distant locations has raised some questions related to trade-offs, often with the conclusion that it is not feasible to go fishing at certain distances due to fuel costs. In addition, the issue of greenhouse gas (GHG) emission in recent years has affected fishing industries more and more as in other industries. The establishment of the auction market for carbon credit, called the European Union Emission Trading Scheme (EU ETS), should be motivation for converting from fossil fuel to biodiesel in the Icelandic fishing industry. Motivation from the government is also important with clearer and perhaps better-structured regulations related to the environment, as those which apply to grain farming in the EU. Biodiesel production in Iceland is not different than in other countries where it is not yet feasible without government subsidies.

Although the conclusion of this thesis does not come up with a positive NPV of equity, it is clear that this does not mean that biodiesel production from rapeseed cultivation is not feasible. Due to many important sensitivity factors such as cost of cultivation, prices of rapeseed meal and biodiesel and land availability, more research is needed. For rural development could rapeseed cultivation have positive effect on area like Skagarfjörður. In this thesis are estimated 5 jobs in biodiesel production and that does not include derivative jobs that forms due to operation of biodiesel production.

10 Appendixies

Appendix 1

Jón I. Sigurðsson [joningi@fisk.is]
Sent: 5. nóvember 2010 11:47
Viðtakandi:Sævar Birgisson
Sæll Sævar

Klakkur veiðir ca 4000 tonn af bolfiski á ári, mest þorsk.
Á Klakk er öll lifur úr þorski hirt. Lifur er um 5% af þyngdarhlutfalli óslægð fisks.
Slæingarhlutfall er 13% af þyngdarhlutfalli óslægð fisks.
Þannig að reikna má með að ca 8 - 9% af heildarmagni af bolfiski sé slor.

Kær kveðja / Best regards,
Jón Ingi Sigurðsson
Tæknistjóri / Technical Manager
Sími/tel: +354 455 4417
Fax: +354 455 4401
Vefsíða/website: http://www.fisk.is/

-----Original Message-----
From: Sævar Birgisson [mailto:saevarb09@ru.is]
Sent: 5. nóvember 2010 07:42
To: Jón I. Sigurðsson
Subject: biodiesel verkefni

Sæll Jón

Sævar heiti ég og er að vinna að lokaverkefniu mínu um bíódísel framleiðslu. Ég var í sambandi við þig fyrr á þessu ári og fékk upplýsingar hjá þér varðandi eldnsneytisnotkun skipa ykkar.

Getur þú sagt mér hversu mikið ískfisktogarinn Klakkur er að henda umþb miklu magni af slori í sjóinn á ári?

kv
Sævar Birgisson
nemi í orkuvísindum
REYST

Appendix 2

Biodiesel production countries in Europe (million/ton) 2002-2009								
	2002	2003	2004	2005	2006	2007	2008	2009
Germany	450	715	1035	1669	2662	2890	2819	2539
France	366	357	348	492	743	872	1815	1959
Italy	210	273	320	396	447	363	595	737
Spain			13	73	99	168	207	859
Austria	25	32	57	85	123	267	213	310
Denmark	10	30	70	71	80	85	231	233
United Kingdom	3	9	9	51	192	150	192	137
Sweden	1	1	1	1	13	63	231	233
Czech Republic			60	133	107	61	104	164
Poland				100	116	80	275	332
Slovakia			15	78	82	46	146	101
Lithuania			5	7	10	26	66	98
Slovenia				8	11	11	9	9
Estonia				7	1	0	0	24
Latvia				5	7	9	30	44
Greece				3	42	100	107	77
Malta				2	2	1	1	1
Belgium				1	25	166	277	416
Cyprus				1	1	1	9	9
Portugal				1	91	175	268	250
Netherlands					18	85	101	323
Romania					10	36	65	29
Bulgaria					4	9	11	25
Ireland					4	3	24	17
Finland						39	85	220
Hungary						7	105	133
Total	1065	1417	1933	3184	4890	5713	7986	9279

	2002	2003	2004	2005	2006	2007	2008	2009
Germany	450	715	1035	1669	2662	2890	2819	2539
France	366	357	348	492	743	872	1815	1959
Italy	210	273	320	396	447	363	595	737
Spain			13	73	99	168	207	859
Other EU countries	39	72	217	554	939	1420	2550	3185
Total	1065	1417	1933	3184	4890	5713	7986	9279

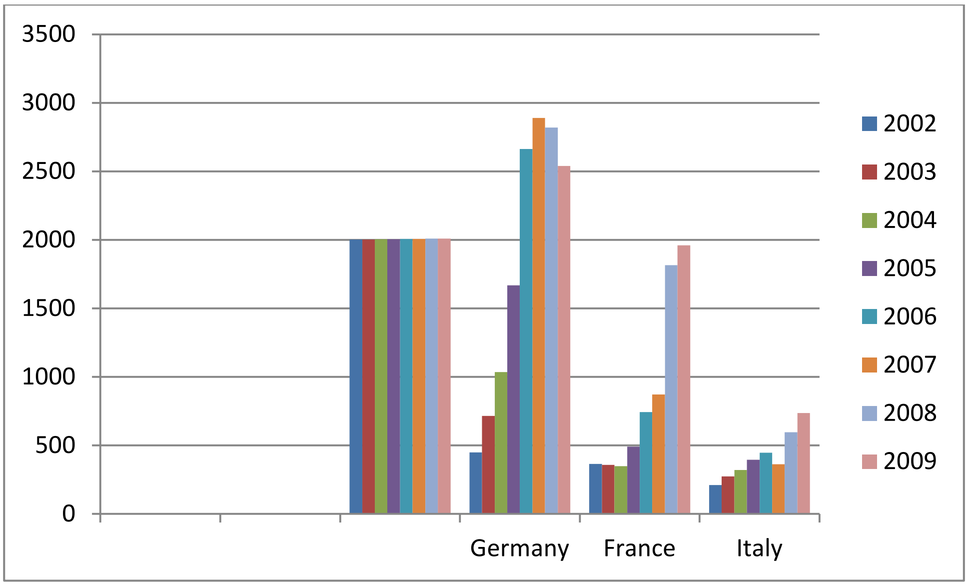
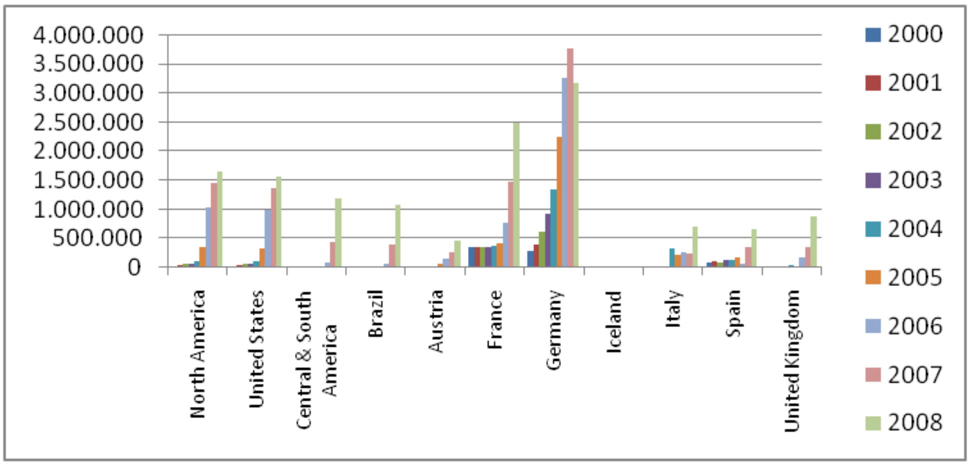


Table: Biodiesel Consumption (Million liters per year)	2000	2001	2002	2003	2004	2005	2006	2007	2008
North America	0	41	64	52	99	354	1034	1458	1667
United States	0	41	64	52	99	343	988	1360	1562
Central & South America	6	12	12	12	12	25	93	447	1197
Brazil	0	0	0	0	0	4	69	406	1079
Europe	808	939	1176	1489	2251	3234	5162	7705	10479
Austria	0	0	0	0	0	59	153	276	459
France	349	352	367	346	376	414	783	1490	2494
Germany	285	395	627	918	1336	2248	3271	3771	3172
Iceland	0	0	0	0	0	0	0	0	0
Italy	0	0	0	0	325	227	256	232	715
Spain	93	93	87	116	128	186	70	343	665
United Kingdom	0	0	3	17	23	35	168	349	883
World	813	997	1258	1573	2392	3821	6825	10409	14542

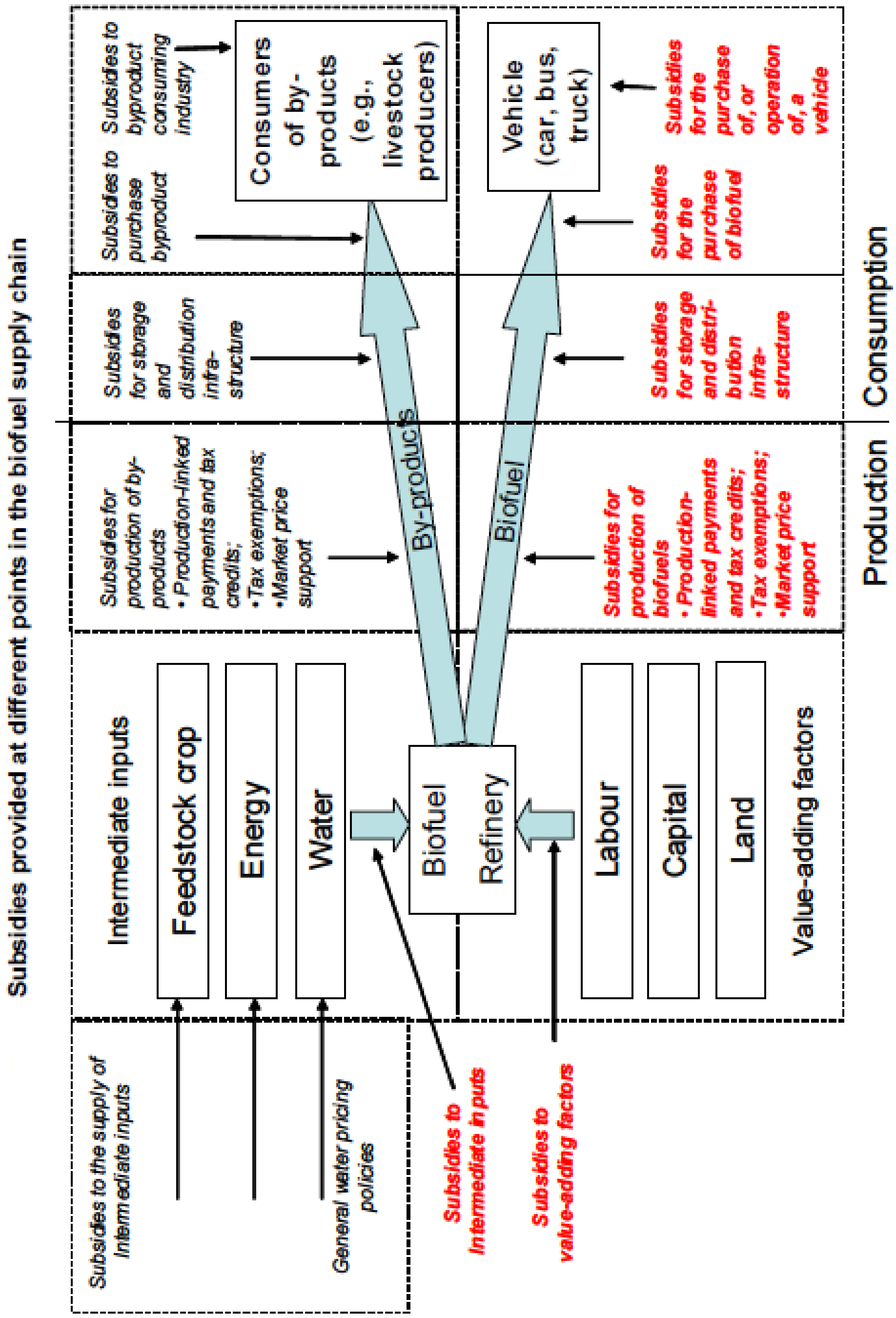


Appendix 3

Specification for diesel & biodiesel fuels in EU

Criteria	Derv (EN590)	Biodiesel (DIN51606)	Biodiesel (EN14214)
Density @ 15°C (g/cm³)	0.82-0.86	0.875-0.9	0.86-0.9
Viscosity @ 40°C (mm²/s)	2.0-4.5	3.5-5.0	3.5-5.0
Flashpoint(°C)	>55	>110	>101
Sulphur (% mass)	0.20	<0.01	<0.01
Sulphated Ash (% mass)	0.01	<0.03	0.02
Water (mg/kg)	200	<300	<500
Carbon Residue (% weight)	0.30	<0.03	<0.03
Total Contamination (mg/kg)	Unknown	<20	<24
Copper Corrosion 3h/50°C	Class 1	Class 1	Class 1
Cetane Number	>45	>49	>51
Methanol (% mass)	Unknown	<0.3	<0.2
Ester Content (% mass)	Unknown	>96.5	>96.5
Monoglycides (% mass)	Unknown	<0.8	<0.8
Diglyceride (% mass)	Unknown	<0.4	<0.2
Tridlycende (% mass)	Unknown	<0.4	<0.4
Free Glycerol (% mass)	Unknown	<0.02	<0.02
Total Glycerol (% mass)	Unknown	<0.25	<0.25
Lodine Number	Unknown	<115	120
Phosphor (mg/kg)	Unknown	<10	<10
Alcaline Metals Na. K (mg/kg)	Unknown	<5	<5

Appendix 4


Subsidies provided at different points in the biofuel supply chain
Intermediate inputs
Feedstock crop
Energy
Water
Biofuel Refinery
Labour
Capital
Land
Value-adding factors
Subsidies to the supply of intermediate inputs
General water pricing policies
Subsidies to intermediate inputs
Subsidies to value-adding factors
Subsidies for production of by-products
• Production-linked payments and tax credits;
• Tax exemptions;
• Market price support
Subsidies for production of biofuels
• Production-linked payments and tax credits;
• Tax exemptions;
• Market price support
By-products
Biofuel
Subsidies for storage and distribution infra-structure
Subsidies for storage and distri-bution infra-structure
Subsidies to purchase byproduct
Subsidies to byproduct consuming industry
Consumers of by-products (e.g., livestock producers)
Subsidies for the purchase of biofuel
Subsidies for the purchase of, or operation of, a vehicle
Vehicle (car, bus, truck)
Production
Consumption

Appendix 5

Ágúst Andrésson [agust.andresson@ks.is]

Notandi svaraði 18.11.2010 16:38.

Sent: 17. nóvember 2010 15:17
Viðtakandi: Sævar Birgisson
Viðhengi:

Sæll Sævar
Skemman er 1400 m2
Verksmiðjan 360 m2
Aðstöðu hús 177m2

Kveðja / With regards
Ágúst Andrésson
Forstöðumaður/Manager

Kjötafurðastöð KS
Eyrarvegur 20 - IS 550 Sauðárkrókur - Iceland
Sími / Tel.: (+354) 455 4582, (+354) 825 4582
Fax:(+354) 455 4581

RE: Vallhólmur

Ágúst Andrésson [agust.andresson@ks.is]

Sent: 17. nóvember 2010 07:59
Viðtakandi: Sævar Birgisson

Sæll Sævar
Afsakaðu seint svar frá mér
En ég er að reyna að finna út varðandi allar stærðir og fæ vonandi upplýsingar í dag um það
En varðandi aðrar spurningar sjá svör:

Hversu stórt er húsnæðið? Kemur síðar
Er einhver starfsemi í gangi þar í dag? Já það er þurkað korn fyrir kornbændur á haustinn og einnig er það geymt fyrir þá í stórsekkjum í skemmunni. Einnig erum við að fást við það að framleiða undirburð undir hross með því að þurrka hálm og köggla hann í bland við úrgangs pappa. Þessi starfsemi er þó enn á tilraunastígi og einn starfsmaður er skráður árið um kring til að líta eftir þessu, hann fær svo aðstoð þegar einhver framleiðsla er í gangi.
Hverjir eru eigendur húsnæðisins og eru einhverskonar tæki og tól til staðar í húsnæðinu sem gætu nýst til fóðumjöls framleiðslu eða lífdísilframleiðslu eins og ryðfríir tankar? KS á húsnæðið og í húsnæðinu er graskögglaverksmiðja með öllum tilheyrandi búnaði sem er staðsettur í vestur hluta hússins, í austurhluta er kornþurrkunin en var áður fóðurblönduverksmiðja, þar eru slatti af sílóum.
Er heitt vatn til staðar'? það er heitt neysluvatn til staðar en alls ekki mikið rennsli. Það er verið að skoða möguleika á því að leggja alvöru lögn um 2-2,5 km leið úr 98°C borholu sem mundi gjörbreyta aðstæðum í Vallhólmi fyrir hverskonar uppbyggingu á starfsemi

Þetta er svona það sem mér dettur fyrst í hug......og kannski hvort að hægt sé að nálgast myndir eða teikningar af húsnæðinu? Það væri best fyrir þig að kíkja í heimsókn í Vallhólm, það má vel vera að staðarhaldarinn eigi teikningar sem þú gætir látið afrita

Kv ágúst

með kærri kveðju
Sævar B.

Appendix 6

Almennt verð frá N1

Jón I. Sigurðsson [joningi@fisk.is]

Sent: 30. nóvember 2010 16:53

Viðtakandi:Sævar Birgisson

Viðhengi: VBRN1-52. 2010.pdf (31 KB)[Opna sem vefsíðu];

Kær kveðja / Best regards,
Jón Ingi Sigurðsson
Tæknistjóri / Technical Manager
Sími/tel: +354 455 4417
Fax: +354 455 4401
Vefsíða/website: http://www.fisk.is/

Tilkynning um verðbreytingar á fljótandi vörum

Nr. 52

Frá og með 30.11.2010 gilda eftirtalin verð:

Bensín	Gildir frá: 30.11.2010	kr.ltr m.vsk	kr.ltr án.vsk		Breyting
	95 oktan	207,70	165,50	Hækkun	3,10
	* 98 oktan	211,70	168,69	Hækkun	3,10

*Sama verð í þjónustu og sjálfsafgreiðslu

Dísil	Gildir frá: 30.11.2010	kr.ltr m.vsk	kr.ltr án.vsk		Breyting
	Dísil	207,70	165,50	Hækkun	3,10
	Bíodísel	210,20	167,49	Hækkun	3,10
	Lituð dísil	142,20	113,31	Hækkun	3,10
Gasolía	**Gildir frá: 30.11.2010**				
	Frá bifreið	202,70	161,51	Hækkun	3,10
	Frá bifreið, Bíodísel	205,20	163,51	Hækkun	3,10
	Frá bifreið, litið gasolía	138,20	110,12	Hækkun	3,10
	Frá bifreið, litað bíodísel	143,20	114,10	Hækkun	3,10
	Húskynding (7% vsk) lituð	117,83	110,12	Hækkun	2,64

Flotaolía	Gildir frá: 30.11.2010	kr.ltr m.vsk	kr.ltr án.vsk		Breyting
	Flotaolía	130,30	103,82	Hækkun	3,00
	Flotaolía lituð	131,30	104,62	Hækkun	3,10
	Húskynding (7% vsk)	111,95	104,62	Hækkun	2,64

MDO	Gildir frá: 30.11.2010	kr.ltr m.vsk	kr.ltr án.vsk		Breyting
	Almennt verð	129,10	102,87	Hækkun	3,10

Steinolía	Gildir frá: 30.11.2010	kr.ltr m.vsk	kr.ltr án.vsk		Breyting
	Frá söludælu	143,80	114,58	Hækkun	3,10

Svartolía	Gildir frá: 30.11.2010	kr.tonn með vsk	kr.tonn án.vsk	kr.ltr með vsk	kr.ltr. án vsk		Breyting
	Frá leiðslu	135,535	107,996	125,37	99,90	Hækkun	3,10
	Frá bifreið	137,049	109,202	126,77	101,01	Hækkun	3,10
	Húskynding 7%						
	Frá leiðslu	115,556	107,996	106,89	99,90	Hækkun	2,64
	Frá bifreið	116,846	109,202	108,08	101,01	Hækkun	2,64

Svartolíuverðlisti

30.11.2010	kr.tonn með vsk	kr. tonn án vsk	kr. ltr.með vsk	kr. ltr. án vsk.		Breyting
IFO 30	135,535	107,996	125,37	99,90	Hækkun	3,10
IFO 180	116,685	92,976	110,85	88,33	Hækkun	2,74
IFO 380	107,056	85,304	102,77	81,89	Hækkun	2,54

N1 Dalvegi 10 - 14 IS 201 Kópavogur Sími 440 1000/MÁ

Appendix 7

Re: SV: SV: cold oilpress RH-6YL-180-B

Carter Yu [hsheng08@gmail.com]

Sent: 1. desember 2010 13:01

Viðtakandi:Sævar Birgisson

Viðhengi: oil press quotation 广州.xls (430 KB)[Opna sem vefsíðu]

Dear,

About your questions we will reply in a EXCEL sheet to answer.

pls kindly find out the attachments wiht my thanks!

anyhow,we will get you feedback at soon, as there is later of the year ,

if you need confirmed the P/O pls let me knowing,we can before to arrange

the production times/.

for more needs negotiable talk we will wecome and expect.

thanks!

yours sincerely,

Mr Carter---

Thanks & best regards,
Global Service and Sales Dept.

http://rhglass.en.alibaba.com/

Zhengzhou Ruihui Information Technology Co., Ltd.

☎+86-371-63575811 Skype: yuheng0910

+86-371-63575822 Q Q: 759713551
TradeManager: yuheng0910 MSN: yuheng0910@hotmail.com

Please consider the environment before printing this e-mail.

发件人：Sævar Birgisson

发送时间：2010-12-01 19:41:18

收件人：Carter Yu

抄送：

主题：SV: SV: cold oilpress RH-6YL-180-B

thanks

What I need from you now. is the size and weight of following equipment from you:

2. LQ-150A/BCX ELECTRIC HEATING ROLLER WOK (ROLLER ROASTER)......1 unit

and....3. 6yl-150D double screws muiltifunction oil press ....also 1 unit.

I need those information to estimate the transporting cost from China to Europe. Also, I need to know from what harbour in China they will be shipped?

best regards

Sævar Birgisson

Frá: Carter Yu [hsheng08@gmail.com]

Sent: 1. desember 2010 11:12

Viðtakandi: Sævar Birgisson

Efni: Re: SV: cold oilpress RH-6YL-180-B

Dear,

it's same thanks on you prompt reply!

as your concerning we can ensure that the quotation charges are usually in USD with for eign trade business.

so pls noted and reply us that your ideas or negotiable advises for continue our business talks.

this quota just based on 1 sets ,if for more or you still like to purchase the others machin e as electric heat roller roaster

for preheat the oil seeds or directly eat the oil seeds like sunflower, peanut, cashew,etc nuts.

we will according your orders quantity make a new quotation which will little discounts.

any requires will welcome if you needs.

yours,

Mr Carter---

Thanks & best regards,

Global Service and Sales Dept.

 http://rhglass.en.alibaba.com/

Zhengzhou Ruihui Information Technology Co., Ltd.

•+86-371-63575811 Skype: yuheng0910

6+86-371-63575822 Q Q: 759713551

•TradeManager: yuheng0910 MSN: yuheng0910@hotmail.com<mailto:yuheng0910@hotmail.com>

P Please consider the environment before printing this e-mail.

发件人：Sævar Birgisson

发送时间：2010-12-01 18:49:10

收件人：Carter Yu

抄送：

主题：SV: cold oilpress RH-6YL-180-B

Thank you very much for your reply

Is the price in US$ or is it Chinese yuan?

Frá: Carter Yu [hsheng08@gmail.com]

Sent: 1. desember 2010 02:19

Viðtakandi: Sævar Birgisson

Efni: Re: cold oilpress RH-6YL-180-B

Dear Mr Saevar birgisson ,

thanks for you inquiry and we are greeting to meet your questions wiht the 6YL180autom atic oil press machines.

we will reply to you step by step sincerely,pls attention on my blue answers under your q uestion is:

thanks to reply immediately, any requires be welcome!

Can you give me some more information about your oil press?

yes,you are welcome! for this we have make a enclose TXT , pls kindly check out the att achment with my thanks.

its tha details parameters instruction, for more could feedback to me in mails or chart onl ines.

How many kg/hour of seed (rapeseed) is the press able to extract?

100-250kg/h production volume on rapeseeds in cold or hot ways.

Is there Seed warmer included?

It has multiple functions, including screw oil press ,electrical element for heating chambe r ,vacuum filter for clearing oil .

Only one machine the user could get the pure edible oil.

what kind of filter is included...if there is some?

our machine match the more popular and cheap de Vacuum oil filter system, you can see the two oil tank before the press,

6YL-
180 type used in 60L tank container , the marterial is stainless steel and Chrome plating.

[cid:__0@Foxmail.net]

I would need a oil press that can produce up to 800 ton/year. How much would such pres s cost from you?

you are surely a big manufactory on cooking oil that which wined more profits from it.

I congratulate your business is thriving, win in the future.

so perhaps you need the more than 1 set oil press, this cost needs to check out form the carriers.

i suggest you could clearly known the oil press then we will talk the ship costs,

We'll try our best to reduce the cost, in order to reduce your spending , isn't it?

yours,

Mr Carter--

Thanks & best regards,

Global Service and Sales Dept.

http://rhglass.en.alibaba.com/

Zhengzhou Ruihui Information Technology Co., Ltd.

•+86-371-63575811 Skype: yuheng0910

6+86-371-63575822 Q Q: 759713551

•TradeManager: yuheng0910 MSN: yuheng0910@hotmail.com<mailto:yuheng0910@hotmail.com>

P Please consider the environment before printing this e-mail.

发件人：feedback@service.alibaba.com

发送时间：2010-11-30 19:54:04

收件人：hsheng08@gmail.com

抄送：

主题：[saevarb09@ru.is]Inquiry from oil press/soybean oil press/ cold oilpress RH-6YL-180-B

[http://img.alibaba.com/images/eng/style/logo/logo_email.gif]<http://www.alibaba.com/>

Search Products<http://www.alibaba.com/Products> | Trade Shows<http://tradeshow.alibaba.com/> | Community<http://resources.alibaba.com/> | My Alibaba<http://us.my.alibaba.com>

[http://img.alibaba.com/images/eng/others/email/top_corner.gif]

You have an inquiry!

Dear Carter yu,

You have received an inquiry from a free member on Alibaba. com. This is the first inquiry from this sender.

Mr Saevar birgisson is interested in these products:

[http://img.vip.alibaba.com/img/product/36/70/34/98/367034989.summ.jpg?12911179 10605] <http://rhglass.en.alibaba.com/product/210536885/367034989/oil_press_soybe an_oil_press_cold_oil_press_RH_6YL_180_B.html>

oil press/soybean oil press/ cold oil press RH-6YL-180-B

Buyer's Message

Subject: Inquiry from oil press/soybean oil press/ cold oil press RH-6YL-180-B

Hello!

Can you give me some more information about your oil press? How many kg/hour of see d (rapeseed) is the press able to extract? Is there Seed warmer included? what kind of fil ter is included...if there is some?

I would need a oil press that can produce up to 800 ton/year. How much would such pres s cost from you?

with best regards

Saevar Birgisson

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Contact Name: Mr Saevar birgisson

Company: FISK

Address:

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Business Email: saevarb09@ru.is

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Alibaba.com Hong Kong Limited,

2403-05 Jubilee Centre, 18 Fenwick Street, Wanchai, Hong Kong

1. 6YL180B multifunction automatic oil press

Details as below:

The integrated oil expeller includes screw oil press, electrical rings for heating chamber, vacuum filter for cleaning oil. After pressing and filtering, we can get pure oil from materials. The multi-function of integrated oil expeller can save labor power and simplify the processing step. Only one machine, you can get better edible oil. Our main in Cooking oil press, olive oil, sprial oil press, roller wok, peanut sheller ,hydraulic press machine, oil seeds elevator,automatic oil filling machine.

China's national patent certified products.

6YL-series automatic multifunction oil presser

1. multifunction : can press such as olives , cashew ,camellia , walnut ,almonds , sesame , peanut , soybean , rape seed and pumpkin seeds etc.
2. advantages :easy to maintenance and operation. Only start or off by CIP controler.
3. saving-labor: only one or two people can production in an area of 10-20 square meters .
4. pure oil quality :the oil filter machine used to remove the residues as to ensure the pure oil quality.
5. Stainless steel is used on the oil press machines.ensure the oil can meet the standard of health guarantee.
6. match with material elevator, can increase production, save electricity.
7. the press cooking oil had meet the Europe CE, GMP,

Technical specification

Item		6YL-180B
Screwdiameter Ø （mm）		80
Spiral axes rotate speed(r/min)		80
Main electromotor power (kw)	motor	5.5/7.5
	vacuum filter	0.55
Temperature power (kw)		3
Capacity (kg/h)	Cold press	100-200
	Hot press	150-250
Net Weight(kg)		950
Size(mm)L-W-H		1750*1100*1650

Raw Material		Output Rate (%)	Cake Residual (%)
Rape Seeds	Hot Pressing	35-38	3-4

6YL-180-B oil press match material elevtor

6YL−180 生熟两用榨油机＋提升机

	Cold Pressing	35-40	
Peanut	Hot Pressing	45-50	3-4
	Cold Pressing	42-48	
Sesame	Hot Pressing	45-52	4-5
	Cold Pressing	45-48	
Olive seeds	Cold Pressing	15-18	4-5
sunflower	Cold Pressing	48-54	4-5
soybean	Cold pressing	18-20%	5-6
Pumpkin seeds	cold	17-20%	4-5

Quotation details

Type model	6YL-180 cold and hot pressing machine
Product details	3 phase power Lower temp start work only 50 degrees, TIME-SAME automatic oil filter refine, keep the virgin oil quality.
Price/FOB prot	**3200$ tianjin**
MOQ	1
Packaging options	wooden case packaged
Payment options	By T/T, @ union pay, west union,paypal, credit card, payment escrow.
Delivery time	5days after 30% depoist,
Product certifications	CCC, ISO9001
Choice match	Material elevator ----save labor, rise productivty. Only add 200$

2. LQ-150A/BCX ELECTRIC HEATING ROLLER WOK (ROLLER ROASTER)


2010' style electric roller wok heater roaster

1. oilseeds heating and drying process for oil press.

2. hot process Capacity: 200-1000 kg/h

3. heating power: 12-60 kw

4. Smokeless, safety, health, environmental protection

5. Constant temperature technology, insulation protection heat loss, improve thermal efficiency

sepecification size design & packaged approved to customed

advantage at following:

1.China's national patent certified products.

2.it could preheated variety of oil crops before oil extraction.

3.Electricity instead of the limited energy (coal, wood, etc.), urban and rural areas can use at any time, without energy constraints.

4.the Government support, Protecting the environment

5. can use it in the houseroom.

Item	Packing/mm	power/kw	Capacity/kg	Deal.kg/h	remark
LQ-30H	1250X650X1100	12KW	30	100-150	B-for alarm device X-for stainless steel materials
LQ-50H	**1250X800X1100**	**18KW**	**50**	**150-200**	
LQ-80H	1800X600X1200	24KW	80	200-300	
LQ-100A/100BC	2500X800X1000	24-36KW	100	350-500	
LQ-150A/150BX	2500X800X1000	24-36KW	150	600-750	
LQ-200A/200BC	2500X800X1100	36-45KW	200	800-850	
LQ-250A/250BC	3000X600X1000	24-45KW	250	900-1000	
LQ-300A/300BC	3000X800X1000	24-45KW	300	1000	
LQ-500A-500BH	4000X800X1100	36-60KW	500	1500	

Quotation details

Type model	LQ-50H electric heating roller roaster (stainless steel materials)
Product details	3 phase power 12kw, automatic temp control in 1-300 degrees , Constant temperature technology, Smokeless, safety, environmental protection
Price/FOB prot	**1750$ tianjin**
MOQ	1
Packaging options	wooden case packaged
Payment options	By T/T, @ union pay, west union,paypal, credit card, payment escrow.
Delivery time	7days after 30% depoist,
Product certifications	CCC, ISO9004,
Choice match	

We are professional manufacturer of oil press machinery, the main products include various type screw press machine, combination oil press, oil filter machine, New style of roller electric heating wok , sheller and other equipment. which is made in advanced technology, reliable quality, good service. We welcome all friends to our company on-the-spot investigation. No matter purchase quantity size, all of us will take customers as god, patience and meticulous ground service, once business, lifelong friends. Products where, our service is there.

3. 6yl-150D double screws muiltifunction oil press

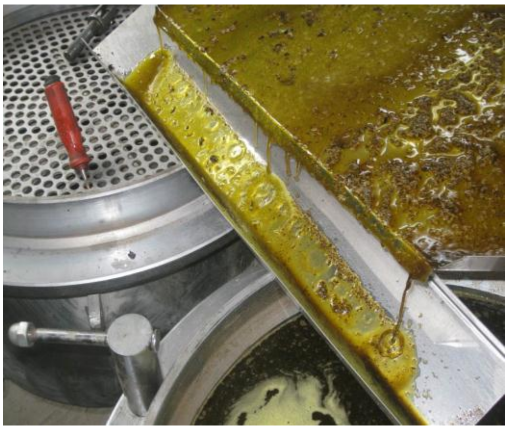
Automatic spiral oil press had meet in CE,ISO9001,CCC,IMS.

National patent technology--Unique double helix oil press .

Two spiral work in same times, raise 2 times the yield, only a power consumption.

China's national patent certified products.

6YL series automatic oil presser



Description

1. Stainless steel is used on the surface to reach the standard of food hygiene.

2. The oil can meet the standard of health guarantee.

4. it can save labour and save cost : only one or two people can meet the production.

5. it can press many kinds of oil crops , such as soybean, sunflower seeds, sesame , rapeseeds, flax , camellia, cashew , palm and walnuts and all the oil content crops.

6. it has multifunctions , including the screw oil press, leetrical element for heating chamber , and the vacuume filter can be for clearing the crude oil.

Technical parameters

Technical parameters:

Model	6YL-150
Spiral diameter	φ 80*2mm
Spiral speed	40-80r/min

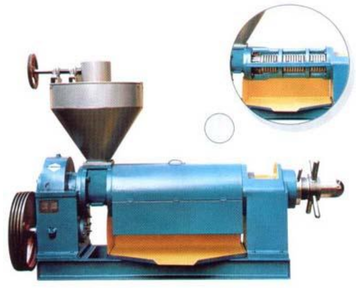
Power	11KW(Y132M-4)
Pump power	0.75KW(Y802-4)
Heater power	4KW
Cold press	500-550Kg/h
Hot press	600-650kg/h
Weight	1800Kg
Dimensions (mm)	2100×1300×1600

Production capacity as bellows:

Raw Material	Oil Extraction Rate(%)	Thickness of Cake(mm)	Residue Oil in the cake(%)
Sesame	46-52	1.0-1.5	<=5
Peanut	40-50	0.8-2.0	<=5
Rapeseed	30-42	1.0-1.5	<=6
Sunflower seed	30-38	1.2-1.5	<=6
Soybean	10-16	0.8-1.5	<=6
Flax seed	33-40	1.0-1.3	<=6

Type model	6YL-150 double svrews oil machine
Product details	3 phase power 7.5kw, capactiy500-550kg/h, lower temp start work only 50 degrees, TIME-SAME automatic oil filter refine, keep the virgin oil quality.
Price/FOB prot	**5000$ tianjin**
MOQ	1
Packaging options	wooden case packaged
Payment options	By T/T, @ union pay, west union,paypal, credit card, payment escrow.
Delivery time	15days after 30% depoist,
Product certifications	CCC, ISO9002
Choice match	Material elevator ----save labor, rise productivty. Only add 200$

3. we recommander the 6YJ series simple oil press machine to you for referens.



6YJ-120 6YJ-100
6YJ-130

400-500KG/H 350-450KG/H 550-
650KG/H

1750X1200X1300 1600X1100X1300
1800X1300X1450

2100$ FOB shenzhen 1400$ FOB shenzhen 2300$ FOB shenzhen

4. hydraulic oil press machine 6YY-190

Technical parameter as below:

1	Type	6YY-190
2	Size(L×W×H)	870×780×1350mm
3	Weight	850KG
4	KN Pressure	1900KN
5	Max Work Pressure	55Mpa
6	Heating Ring Power	2KW
7	Heating Ring Control Temperature	70°C-100°C
8	Sesame Feeding / Time	7-8KG
9	Motor Power	Y901-4 2.5KW

Main technical specification:

Oil plant	Working hour per time	Weight/time	Capacity/10hrs	Output oil rate
Sesame	8-12 minutes	7kg	350-500kg	42%-52%
Peanut kernel	8-12 minutes	7kg	350-450kg	36%-42%
Walnut kernel	8-12 minutes	5-6kg	250-300kg	50%-60%

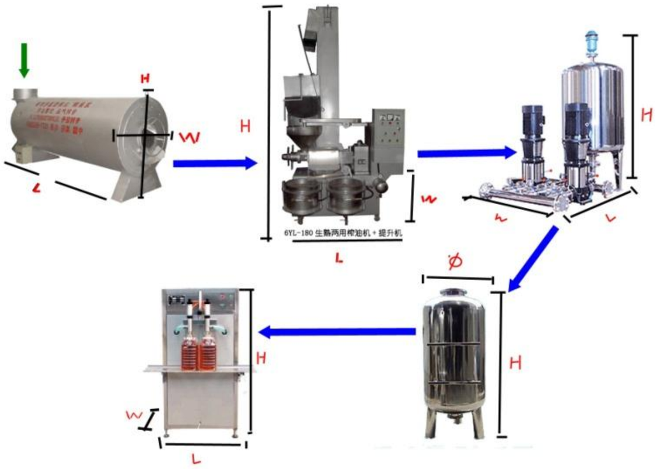
Pine nut kernel	8-12 minutes	5-7kg	300-600kg	45%-60%

Introduction of hydraulic oil press for sesame:

Automatic hydraulic oil press for sesame is the most advanced equipment and it is a best choice to instead of hand-operated worker currently.Auto hydraulic oil press for sesame is the easiest to operate, having the highest oil yield, the least to replace wearing parts among all the range of machines.

Type model	6YY-190 hydraulic oil press machine
Price/FOB prot	**3900$ tianjin**
MOQ	1
Packaging options	wooden case packaged
Payment options	By T/T, @ union pay, west union,paypal, credit card, payment escrow.
Delivery time	15days after 30% depoist,
Product certifications	CCC, ISO9001-2004

5. small oil press refine production lines



LQ-L01 SAMLL OIL REFINE PRESS LINES **refine systems type L02**

The small cooking oil refine press lines include as :

1.electric heating roller wok in 30kg(net capacity) automatic constant temperature electric control.

2. 6YL-180A automatic cold and hot oil presser in 100-150kg/h and
Equipped with automatic constant temperature vacuum oil filter machine.

3.oil refine system in 1-2 tons per days used in type L02

(Fine filtration of pure oils after sterilization by ultraviolet flows into the stainless steel airfield)

4.300L oil tank (stainless steel made) in four outlet valve

5. automatic liquid filler machine match Electron weighing apparatus

6. Matching automatic feeder and ultraviolet radiation sterilization tube.

This equipment can be designed to automatic assembly lines too, But can save part costs , production of edible oil can reach national grade 1 edible oil standards and China GMP standards.

Type model	LQ-L01 small cooking oil refine preoduction lines
Price/FOB prot	**10990$ tianjin**
MOQ	1
Packaging options	wooden case packaged
Payment options	By T/T, @ union pay, west union,paypal, credit card, payment escrow.
Delivery time	15days after 30% depoist,
Product certifications	CCC, ISO9001-2004

Appendix 8

Flutningur frá Kína

Hannes Strange - HSR [hannes@eimskip.is]

Sent: 2. desember 2010 15:25

Viðtakandi:Sævar Birgisson

Viðhengi: 524730 - Sævar Birgisson.PDF (34 KB)[Opna sem vefsíðu];

Sæll Sævar,

Hér meðfylgjandi er verð fyrir flutning frá Kína til Reykjavíkur. Flutningurinn miðast við 8,179m3 og 2760kg.
Það má búast við að flutningstími sé u.þ.b 8 vikur.

Mbk
Hannes

Offer

Eimskip Ísland ehf. Korngörðum 2, 104 Reykjavík, Iceland Sími 525 7000 Fax 525 7009 Kennitala 421104-3520 VSK.nr. 101633

Customer	Customer No./IDNo.	Date
Various Foreign Customers	**1008966**	02.12.2010
Contact Person	**E-Mail**	**Fax-No.**
	import@eimskip.is	4257524
Employee	**Employee Email.**	**Ref-No.**
Hannes Strange	hannes@eimskip.is	524730

Shipping Details:

Place of receipt	Port of loading	Port of discharge	Place of delivery	Valid from	Valid to
	NL RTM	IS REY		02.12.2010	02.03.2011

Commodity Description:

Description	Cont size/ cont type	Wt./Volume	Inco Terms
LCL/LCL		2,8TON 8,2M3	FOB / Guangzhou CH

Service Items	Qty.	Base	Rate	Curr.	Amount	Ex.Rate.	Amount	Ind
Ocean Freight Less than a cont.l	8,180	M3	63,00	EUR	515,28	155,73855	80.249	
BAF Surcharge (Vol)	8,180	M3	14,00	USD	114,51	118,74842	13.598	
Terminal Handling Charge LCL IN	8,180	M3	1.852	ISK	15.148	1,00000	15.148	
Security Charge(Min)	8,180	M3	1,31	EUR	10,71	155,73855	1.668	
Service charge	1,000	PC	1.658	ISK	1.658	1,00000	1.658	
Foreign Costs							169.546	
Total value					**ISK**		**281.867**	

Vöru-og farmverndargjöld á Íslandi eru reiknuð samkvæmt gjaldskrá viðkomandi hafnar

Olíuálag (BAF) er breytilegur kostnaður sem tekur mið af heimsmarkaðsverði á olíu og uppreiknast á mánaða fresti Ofangreind verð innifela ekki efni til sjóbúnings.

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Best Regards, Date______________________________

______________________________ ______________________________

Eimskip Ísland ehf **Various Foreign Customers**

Hannes Strange

Email: hannes@eimskip.is

Appendix 9

Re: hálmur-kostnaður-repja
bborg [bborg@simnet.is]
Sent: 14. desember 2010 17:57
Viðtakandi:Sævar Birgisson
Sæll Sævar.
Við skulum gefa okkur að rúllan sé 280 kg, og við borgum fyrir hana 4000 kr komna í Vallhólma, þá kostar 1 kg 14,29 kr það er það sem við notum. Ef rúllurnar eru undir 280 kg að meðaltali frá bónda, nota ég 14,29 kr pr /kg verð á þær.
Eins og staðan er í dag getum við unið c/a 4 - 5000 kg af hálmi og pappa (pappi c/a 20-25 %) á 8 tíma vinnudegi. Ég vona að þetta geti hjálpað þér.

Kv Bjössi Hansen.

----- Original Message -----
From: "Sævar Birgisson" <saevarb09@ru.is>
To: <bborg@simnet.is>
Sent: Monday, December 13, 2010 11:12 AM
Subject: hálmur-kostnaður-repja

Sæll Bjössi

Í framhaldi af samtali okkar þá ætla ég að senda þér spurningar sem gott væri að fá svör við. Sumum spurningum hefur þú þegar svarað, en það er betra að hafa þessar tölur í póstinum. Ég geri mér grein fyrir því að sumum spurningum er ekki auðvelt að svara beint út......en einhverskonar nálgun er alltaf betri en ekki neitt.

Hvert er verðið á hálm-rúllunni inn til þín, og hversu þung er hún?
Hversu miklu magni af hálmi getur verksmiðjan hjá þér unnið úr daglega......eða árlega?

kv
Sævar Birgisson=

Appendix 10

Assumptions and Results

		2012	2013	2014	2015	2016	2017	2018	Total
Investment:		KUSD							
Buildings		0	0	0	0	0	0	0	**0**
Equipment	**100%**	156	0	0	0	0	112	0	**268**
Other		0	0	0	0	0	0	0	**0**
Total		**156**	**0**	**0**	**0**	**0**	**112**	**0**	**268**
Financing:									
Working Capital		90	90	80	0	0	10	0	**270**
Total Financing		**246**	**90**	**80**	**0**	**0**	**122**	**0**	**538**
Equity	**100%**	**30%**							
Loan Repayments	**100%**	**10**	years						
Loan Interest	**100%**	**9,0%**							

MARR	**15%**	
Planning Horizon		years
	Projec	Equity
NPV of Cash Flow	-30	-24
Internal Rate of ret	14%	14%
Capital/Equity		
after 10 years		
Min Cash Account	15	

Operations:		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	
Sales Quantity biodies	**100%**	0,2	0,2	0,3	0,4	0,4	0,5	0,6	0,7	0,8	0,9	Kton/year
Sales Quantity rapeme	**100%**	0,3	0,4	0,5	0,6	0,7	0,9	1,0	1,2	1,3	1,5	Kton/year
Sales Quantity glycerir	**100%**	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,1	Kton/year
Total Quantity sales		**0,6**	**0,7**	**0,8**	**1,0**	**1,2**	**1,4**	**1,7**	**1,9**	**2,2**	**2,6**	Kton/year
Sales Price biodiesel	**100%**	643	643	643	643	643	643	643	643	643	643	USD/ton
Sales Price rapemeal	**100%**	488	488	488	488	488	488	488	488	488	488	USD/ton
Sales Price glycerin	**100%**	120	120	120	120	120	120	120	120	120	120	USD/ton
Revenues biodiesel		**138**	**159**	**188**	**225**	**282**	**338**	**399**	**459**	**527**	**606**	USD/ton
Revenues rapemeal		**171**	**196**	**231**	**278**	**347**	**417**	**492**	**565**	**650**	**748**	USD/ton
Revenues straw/stocks		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	USD/ton
Revenues glycerin		**3**	**3**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	**11**	USD/ton
Total revenues		311	358	423	507	634	761	898	1032	1187	1365	USD/ton

Investment

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Investment and Financing			1	2	3	4	5	6	7	8	9	10	11
Investment:													
Buildings		0	0	0	0	0	0	0	0	0	0	0	0
Equipment 2012		156	133	109	86	63	39	16	16	16	16	16	16
Equipment 2017		0	0	0	0	0	112	95	78	62	45	28	11
Other		0	0	0	0	0	0	0	0	0	0	0	0
Booked Value		**156**	**133**	**109**	**86**	**63**	**151**	**111**	**94**	**77**	**60**	**44**	**27**
Depreciation:													
Depreciation Buildir	4%		0	0	0	0	0	0	0	0	0	0	0
Depreciation Equip	15%		23	23	23	23	23	23	0	0	0	0	0
Depreciation Equip	15%		0	0	0	0	0	17	17	17	17	17	17
Depreciation Other	20%		0	0	0	0	0	0	0	0	0	0	0
Total Depreciation			**23**	**23**	**23**	**23**	**23**	**40**	**17**	**17**	**17**	**17**	**17**
Financing:		**246**	**90**	**80**	**0**	**0**	**122**						
Equity	30%	74	27	24	0		37						
Loans	70%	172	63	56	0		85						
Repayment 2012	10		**0**	17	17	17	17	17	17	17	17	17	17
Principal		172	172	155	138	121	103	86	69	52	34	17	0
Interest	9%		16	16	14	12	11	9	8	6	5	3	2
Loan Managem. Fe	2%	3											
Repayment 2013	10			**0**	6	6	6	6	6	6	6	6	6
Principal			63	63	57	50	44	38	32	25	19	13	6
Interest	9%			6	6	5	5	4	3	3	2	2	1
Loan Managem. Fe	2%		1										
Repayment 2014	10				**0**	6	6	6	6	6	6	6	6
Principal				56	56	50	45	39	34	28	22	17	11
Interest	9%				5	5	5	4	4	3	3	2	2
Loan Managem. Fe	2%			1									
Repayment 2017	10		0	0	0	0	**0**	0	9	9	9	9	9
Principal		0	0	0	0	0	85	85	77	68	60	51	43
Interest	9%		0	0	0	0	0	8	8	7	6	5	5
Loan Managem. Fe	2%						1,7						

Operations

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Operations Statement												
Sales Quantity biodiesel			0,22	0,25	0,29	0,35	0,44	0,53	0,62	0,71	0,82	0,94
Sales Quantity rapemeal			0,35	0,40	0,47	0,57	0,71	0,85	1,01	1,16	1,33	1,53
Sales Quantity straw/stocks			0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Sales Quantity glycerin			0,02	0,02	0,03	0,03	0,04	0,05	0,06	0,07	0,08	0,09
Sales Price biodiesel			643	643	643	643	643	643	643	643	643	643
Sales Price rapemeal			488	488	488	488	488	488	488	488	488	488
Sales Price straw/stocks			0	0	0	0	0	0	0	0	0	0
Sales Price glycerin			120	120	120	120	120	120	120	120	120	120
Revenues biodiesel			138	159	188	225	282	338	399	459	527	606
Revenues rapemeal			171	196	231	278	347	417	492	565	650	748
Revenues straw/stocks			0	0	0	0	0	0	0	0	0	0
Revenues glycerin			3	3	3	4	5	6	7	8	10	11
Total revenues			311	358	423	507	634	761	898	1032	1187	1365
Variable Cost RSO			148	170	201	241	301	362	427	491	565	649
Variable Cost catalyst+other			25	29	34	41	51	61	72	83	95	109
Total variable Cost			173	199	235	282	352	423	499	573	659	758
Net Profit Contribution			138	159,2	187,8	225,4	281,8	338,1	399	458,8	527,6	606,79
Fixed Cost			178	178	178	178	209	209	209	209	209	209
Diverse Taxes												
Operating Surplus (EBITDA)			-39	-18,33	10,33	47,89	73,03	129,4	190,2	250,1	318,9	398,05
Inventory Movement			0									
Depreciation			23	23	23	23	23	40	17	17	17	17
Operating Gain/Loss			-63	-42	-13	24	50	89	173	233	302	381
Financial Costs (Interest & LMF)		5,2	16,8	22,3	24,7	22,6	19,9	25,0	22,4	19,0	15,6	12,2
Profit before Tax		-5,2	-79,3	-64,1	-37,8	1,9	29,6	64,1	151,1	214,3	286,5	369,0
Loss Transfer	0	-5	-84	-149	-186	-185	-155	-91	0	0	0	0
Taxable Profit		0	0	0	0	0	0	0	60	214	287	369
Income Tax	18%	0	0	0	0	0	0	0	11	39	52	66
Profit after Tax		-5	-79	-64	-38	2	30	64	140	176	235	303
Dividend	**30%**	0,0	0,0	0,0	0,0	0,6	8,9	19,2	42,1	52,7	70,5	90,8
Net Profit/Loss		-5	-79	-64	-38	1	21	45	98	123	164	212

Cash Flow

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cash Flow											
Operating Surplus (EBITDA)	**0**	**-39,1**	**-18,3**	**10,3**	**47,9**	**73**	**129**	**190**	**250**	**319**	**398**
Debtor Changes		78	12	16	21	32	32	34	34	39	45
Creditor Changes		26	4	5	7	11	11	11	11	13	15
Cash Flow before Tax	**0**	**-91**	**-26**	**-0,42**	**34**	**52**	**108**	**167**	**228**	**293**	**368**
Paid Taxes		0	0	0	0	0	0	0	11	39	52
Cash Flow after Tax	**0**	**-91**	**-26**	**0**	**34**	**52**	**108**	**167**	**217**	**255**	**317**
Financial Costs (Interest+LMF)	5	17	22	25	23	20	25	22	19	16	12
Repayment	0	0	17	24	29	29	29	38	38	38	38
Free Cash Flow	**-5**	**-108**	**-66**	**-49**	**-18**	**3**	**54**	**107**	**160**	**201**	**267**
Paid Dividend		0	0	0	0	1	9	19	42	53	70
Financing - Expenditure (Wcap)	90	90	80	0	0	10	0				
Cash Movement	**85**	**-18**	**14**	**-49**	**-18**	**12**	**45**	**88**	**118**	**149**	**196**

Source and Allocation of Funds

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Source of Funds											
Profit before Tax	-5	-79	-64	-38	2	30	64	151	214	287	369
Depreciation	0	23	23	23	23	23	40	17	17	17	17
Funds from Operations	-5	-56	-41	-14	25	53	104	168	231	303	386
Loan Drawdown	172	63	56	0	0	85					
Equity Drawdown	74	27	24	0	0	37					
Funds for allocation	**241**	**34**	**39**	**-14**	**25**	**175**	**104**	**168**	**231**	**303**	**386**
Alloction of Funds											
Investment	156					112					
Repayment	0	0	17	24	29	29	29	38	38	38	38
Paid Taxes	0	0	0	0	0	0	0	0	11	39	52
Paid Dividend	0	0	0	0	0	1	9	19	42	53	70
Total allocation	**156**	**0**	**17**	**24**	**29**	**142**	**38**	**57**	**91**	**129**	**160**
Changes Net Curr. Assets	**85**	**34**	**22**	**-38**	**-4**	**33**	**66**	**111**	**140**	**174**	**226**
Analysis of Changes											
Current Assets											
Cash at start of year	0	85	67	81	33	15	27	72	160	278	427
Cash at end of year	85	67	81	33	15	27	72	160	278	427	623
Changes in Cash	**85**	**-18**	**14**	**-49**	**-18**	**12**	**45**	**88**	**118**	**149**	**196**
Debtor changes	0	78	12	16	21	32	32	34	34	39	45
Stock Movements	0	0	0	0	0	0	0	0	0	0	0
Changes in Current Assets	**85**	**60**	**26**	**-33**	**3**	**44**	**77**	**122**	**152**	**187**	**241**
Liabilities											
Creditor changes	0	26	4	5	7	11	11	11	11	13	15
Changes Net Curr. Assets	**85**	**34**	**22**	**-38**	**-4**	**33**	**66**	**111**	**140**	**174**	**226**
Check line	0	0	0	0	0	0	0	0	0	0	0

Balance

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Balance Sheet												
Assets												
Cash Account	0	85	67	81	33	15	27	72	160	278	427	623
Debtors (Acc Rec)	25%	0	78	90	106	127	158	190	224	258	297	341
Inventory	0	0	0	0	0	0	0	0	0	0	0	0
Current Assets		**85**	**145**	**171**	**138**	**142**	**186**	**262**	**385**	**537**	**724**	**965**
Fixed Assets		156	133	109	86	63	151	111	94	77	60	44
Total Assets		**241**	**278**	**280**	**224**	**204**	**337**	**373**	**479**	**614**	**784**	**1008**
Debts												
Dividend Payable		0	0	0	0	1	9	19	42	53	70	91
Taxes Payable		0	0	0	0	0	0	0	11	39	52	66
Creditors (Acc Pay)	15%	0	26	30	35	42	53	63	75	86	99	114
Next Year Repayment		0	17	24	29	29	29	38	38	38	38	38
Current Liabilities		**0**	**43**	**53**	**64**	**72**	**91**	**120**	**165**	**215**	**259**	**309**
Long Term Loans		172	218	251	222	192	249	211	173	136	98	60
Total Debt		**172**	**261**	**304**	**286**	**264**	**340**	**331**	**339**	**351**	**357**	**369**
Equity	0	74	101	125	125	125	162	162	162	162	162	162
Profit & Loss Balanc	0	-5	-84	-149	-186	-185	-164	-119	-21	102	266	478
Total Capital		**69**	**16**	**-24**	**-61**	**-60**	**-3**	**42**	**140**	**263**	**428**	**639**
Debts and Capital		**241**	**278**	**280**	**224**	**204**	**337**	**373**	**479**	**614**	**784**	**1008**
Check Line		0	0	0	0	0	0	0	0	0	0	0

Profitability

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Profitability Measurements												
NPV and IRR of Total Cash Flow												
Cash Flow after Taxes		**0**	**-91**	**-26**	**0**	**34**	**52**	**108**	**167**	**217**	**255**	**317**
Loans Drawdown		-172					-85					
Equity Drawdown		-74					-37					
Total Cash Flow & Capital		**-246**	**-91**	**-26**	**0**	**34**	**-70**	**108**	**167**	**217**	**255**	**317**
NPV Total Cash Flow	15%	-246	-326	-345	-346	-326	-361	-314	-251	-180	-108	-30
IRR Total Cash Flow		0%	0%	0%	0%	0%	0%	0%	0%	3%	9%	14%
NPV and IRR of Net Cash Flow												
Free Cash Flow		-5	-108	-66	-49	-18	3	54	107	160	201	267
Equity		-74										
Net Cash Flow & Equity		**-79**	**-108**	**-66**	**-49**	**-18**	**3**	**54**	**107**	**160**	**201**	**267**
NPV Net Cash Flow	15%	-79	-173	-222	-254	-265	-263	-240	-200	-147	-90	-24
IRR Net Cash Flow		0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	13%
Financial Ratios												
ROI (Profit+Interest/Debt+Capital)			-26%	-15%	-5%	11%	24%	26%	46%	49%	49%	49%
ROE (Profit/Shareh. Capital)			-115%	-390%	160%	-3%	-49%	-2287%	333%	125%	89%	71%
TR (Revenue/Debt+Capital)			129%	129%	151%	226%	310%	226%	240%	216%	193%	174%
Capital/Debt+Capital			6%	-8%	-27%	-29%	-1%	11%	29%	43%	55%	63%
Net Current Ratio			3,4	3,2	2,2	2,0	2,0	2,2	2,3	2,5	2,8	3,1
Liquid Current Ratio			3,4	3,2	2,2	2,0	2,0	2,2	2,3	2,5	2,8	3,1
Market Value (Total Capital/Equity)			0,2	-0,2	-0,5	-0,5	0,0	0,3	0,9	1,6	2,6	4,0
Debt Service Coverage			-5,4	-0,7	0,0	0,7	1,1	2,0	2,8	3,8	2,1	6,3
Acceptable minimum			1,5	1,5	1,5	1,5	1,5	1,5	2,5	3,5	4,5	5,5
Loan Life Cover Ratio:												
Future Cash Flow			146	272	343	395	415	418	356	217	438	678
Principal of Loans			172	155	138	121	103	86	69	52	34	17
LLCR			**0,8**	**1,8**	**2,5**	**3,3**	**4,0**	**4,8**	**5,2**	**4,2**	**12,7**	**39,3**

Appendix 11

RE: repjumjöl
Hólmgeir Karlsson [holmgeir@bustolpi.is]
Sent: 14. október 2010 10:43
Viðtakandi: Sævar Birgisson

Sæll Sævar

Geri ráð fyrir að þú sért að tala um mjöl sem unnið er úr repjuhratinu eftir að olían hvefur verið pressuð úr.
Við notum slíkt sem hráefni við fóðurgerð og er það þá venjulega kögglað.
Sem slíkt er þetta með kostnaðarverð inní fóðurgerð hjá okkur nú 54-55 kr pr kg. Þetta rokkar nokkuð eftir heimsmarkaði og gengi, en líklegt verð yfir lengra tímabil er frá 45 kr/kg og upp undir 60 kr pr kg.

Bestu kveðjur

Hólmgeir Karlsson,
framkvæmdastjóri
Bústólpi ehf.

-----Original Message-----
From: Sævar Birgisson [mailto:saevarb09@ru.is]
Sent: 13. október 2010 14:54
To: Hólmgeir Karlsson
Subject: repjumjöl

Góðan daginn Hólmgeir

Sævar heiti ég og er nemandi við HR í orkuvísindum. Ég er að vinna að verkefni sem tengist repjumjöli. Getur þú frætt mig um það hver hráefniskostnaðurinn er ca. fyrir kílóið af repjumjöli í dag? Og hefur það verð haldist nokkuð óbreytt eða er það mikið að breytast?

með fyrirfram þökk

Sævar Birgisson
meistaranemi í Orkuvísindum

Appendix 12

RE: olíunotkun (repjan)
Jón I. Sigurðsson [joningi@fisk.is]
Sent: 30. nóvember 2010 16:52
Viðtakandi:Sævar Birgisson
Sæll

Meðalverðið til okkar án vask síðustu 3 ár er 70 kr/líter.
Ég skal líka senda þér skjal frá N1 sem mér barst í dag um almennt verð á olíu.

Kær kveðja / Best regards,
Jón Ingi Sigurðsson
Tæknistjóri / Technical Manager
Sími/tel: +354 455 4417
Fax: +354 455 4401
Vefsíða/website: http://www.fisk.is/

-----Original Message-----
From: Sævar Birgisson [mailto:saevarb09@ru.is]
Sent: 30. nóvember 2010 14:49
To: Jón I. Sigurðsson
Subject: SV: olíunotkun (repjan)

Sæll aftur

Í ágúst fékk ég þær upplýsingar hjá N1 að svartolía og flotaolía á skip væru undanþegin vsk, aðeins væri olíugjaldi bætt við sem er 2,9 kr/liter. Þannig að þær upplýsingar eru greinilega rangar eða ég hef misskilið þá svona herfilega.

En gætirðu þá kannski sagt mér hvert meðalverð ykkar hefur verið síðustu 2 - 3 árin án vsk?

kv
Sævar B.

Frá: Jón I. Sigurðsson [joningi@fisk.is]
Sent: 30. nóvember 2010 13:27
Viðtakandi: Sævar Birgisson
Efni: RE: olíunotkun (repjan)

Sæll Sævar

121 kr/líter Þetta verð er líklega fullt verð vaski.
60 kr/liter meðalverð síðustu 5 ára er verð án vasks.
Olíuverð hefur hækkað töluvert mikið síðustu 3 ár en árin 2 þar á undan var verð mikið lægra.
Olíuverð til okkar útgerðar er töluvert lægra en uppgefið fullt verð frá N1.
Fullt verð frá N1 í dag með vaski er 125 kr/liter.

Kær kveðja / Best regards,
Jón Ingi Sigurðsson
Tæknistjóri / Technical Manager
Sími/tel: +354 455 4417
Fax: +354 455 4401
Vefsíða/website: http://www.fisk.is/

-----Original Message-----
From: Sævar Birgisson [mailto:saevarb09@ru.is]
Sent: 30. nóvember 2010 11:56
To: Jón I. Sigurðsson
Subject: SV: olíunotkun (repjan)

En getur verið að meðalverð fyrir 2009 sé 121 kr/liter? allavega fékk ég þær upplýsingar hjá þér snemma þessa árs. Semsagt olíverð hefur þá hækkað mikið milli ára?

kv
Sævar B.

Frá: Jón I. Sigurðsson [joningi@fisk.is]
Sent: 30. nóvember 2010 11:54
Viðtakandi: Sævar Birgisson
Efni: RE: olíunotkun (repjan)

Sæll Sævar

Meðalverð á olíu síðustu 5 ár er 60 kr/líter.

Kær kveðja / Best regards,
Jón Ingi Sigurðsson
Tæknistjóri / Technical Manager
Sími/tel: +354 455 4417
Fax: +354 455 4401
Vefsíða/website: http://www.fisk.is/

-----Original Message-----
From: Sævar Birgisson [mailto:saevarb09@ru.is]
Sent: 30. nóvember 2010 09:37
To: Jón I. Sigurðsson
Subject: SV: olíunotkun (repjan)

Sæll aftur

En hvað er meðalverðið á líter á þessum 5 árum?

kv
Sævar B.

Frá: Jón I. Sigurðsson [joningi@fisk.is]
Sent: 25. nóvember 2010 09:40
Viðtakandi: Sævar Birgisson
Efni: RE: olíunotkun (repjan)

Sæll Sævar

Meðal olíueyðsla á Málmey síðustu 5 ár er 2.600.000 ltr á ári

Kær kveðja / Best regards,
Jón Ingi Sigurðsson
Tæknistjóri / Technical Manager
Sími/tel: +354 455 4417
Fax: +354 455 4401
Vefsíða/website: http://www.fisk.is/

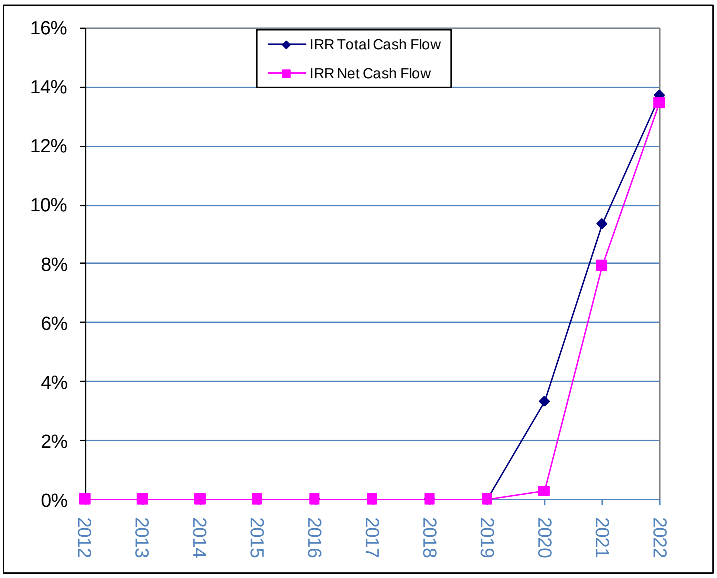
-----Original Message-----
From: Sævar Birgisson [mailto:saevarb09@ru.is]
Sent: 24. nóvember 2010 11:43
To: Jón I. Sigurðsson
Subject: olíunotkun (repjan)

Sæll Jón

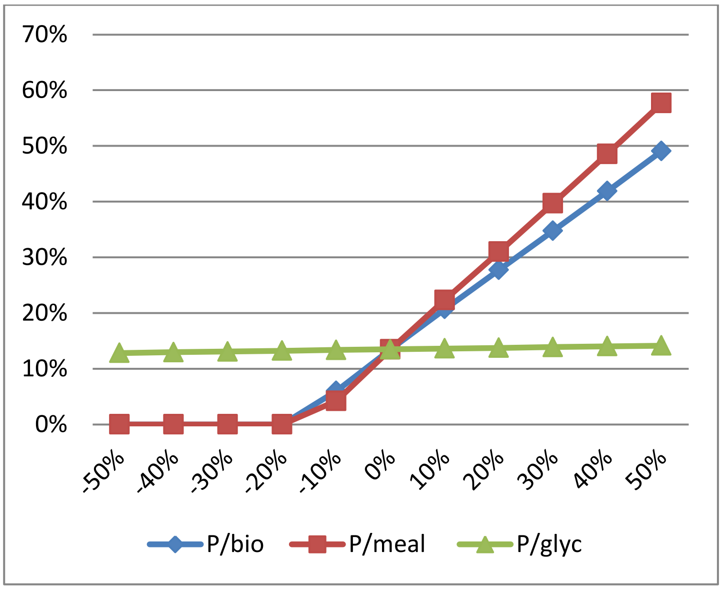
Sævar hér, sá sem er að vinna að repjuverkefninu. Getur þú gefið mér upplýsingar hvað Málmey eða eitthvað annað skip hjá ykkur hefur notað mikla olíu á ári að meðaltali síðustu árin....kannski fimm eða tíu árin?

kv
Sævar B.

Appendix 13



16%
14%
12%
10%
8%
6%
4%
2%
0%
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
IRR Total Cash Flow
IRR Net Cash Flow



70%
60%
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40%
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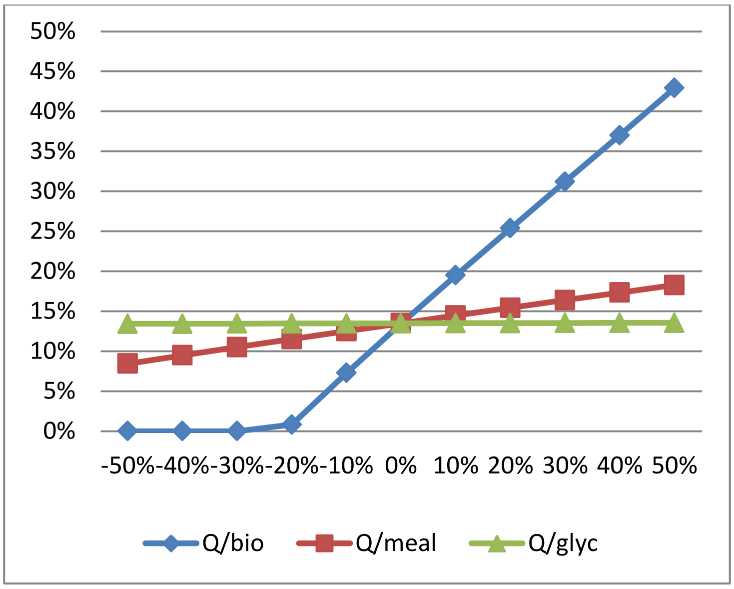
P/bio
P/meal
P/glyc


50%
45%
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15%
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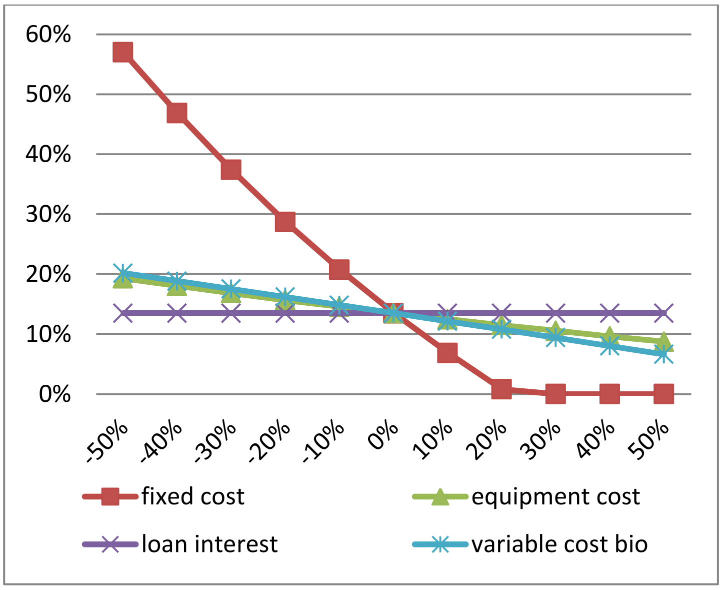
-50% -40% -30% -20% -10% 0% 10% 20% 30% 40% 50%
Q/bio
Q/meal
Q/glyc


60%
50%
40%
30%
20%
10%
0%
-50% -40% -30% -20% -10% 0% 10% 20% 30% 40% 50%
fixed cost
equipment cost
loan interest
variable cost bio

Appendix 14

RE: SV: SV: kolefniskvóti
Eyrún Guðjónsdóttir [eyrun.gudjonsdottir@kolka.is]
Notandi svaraði 7.12.2010 16:25.
Sent: 6. desember 2010 15:45
Viðtakandi: Sævar Birgisson
Sæll Sævar,

Biðst afsökunar á hvað ég svara seint, pósturinn einfaldlega fór fram hjá mér.

Það er erfitt að svara þessari spurningu þinni á einfaldann hátt með já eða nei...

Varðandi það að útgerðfélögin nýti umhverfisvænni orku og losi þannig minna af CO2 þá hefur ekkert verið fest í alþjóðlegum loftlagssamningum hvað þetta varðar. Það er hins vegar á planinu að útgerðin muni falla undir samninginn í framtíðinni og verði því skuldbundinn og þurfi að hafa tilskyldar heimildir til losunar.

Að því gefnu að útgerðarfélögin muni eins og áætlað er falla undir sáttmálam á næstu 6-10árum þá mun verða sett ákveðið miðviðunarár (og þannig miðað út frá magni losunar á CO2 það ár) hjá útgerðarfélögunum, út frá því ári yrðu svo sett markmið fyrir útgerðina með að draga úr losun(líkt og gert var fyrir iðnfyrirtækin þá var viðmiðunarárið 1991). Það má svo ætla að þau útgerðarfyrirtæki sem væru að nýta umhverfisvænni orkugjafa fengju ívilnun í einhverju formi, einnig væri það þeim til góða að útblástur væri minni þar sem fyrirtækið þarf þá að kaupa sér færri heimildir fyrir sinn rekstur og þar af leiðandi minni kostnaður vegna skuldbindinga sem felast í alþjóðlegum loftlagssamningum.

Erfitt er að segja til um hvort að fyrirtækin fái sérstaklega heimildir sem þau gætu selt eða bókfært hjá sér, en það gæti mögulega fallið undir einvherskonar úrbótarverkefni þegar útgerðarfyrirtækin hafa verið skuldbundin og gæti það þá virkað svipað og þróunarerkefni (CDM) eða samvinnuverkefni (JI)

Hringdu endilega í mig ef frekari spurningar vakna.

Gangi þér vel
Bkv.Eyrún

-----Original Message-----
From: Sævar Birgisson [mailto:saevarb09@ru.is]
Sent: 25. nóvember 2010 16:13
To: eyrun.gudjonsdottir@kolka.is
Subject: SV: SV: SV: kolefniskvóti

Sæl Eyrún aftur

Takk fyrir fundinn um daginn.

Það hafa vaknað nokkrar spurningar í viðbót sem mig langar að senda á þig.

Ég hef reiknað út hversu mikið kolefnislosun minnkar hjá útgerðarfélagi við að nota biodiesel í stað svartolíu á skip sín. Sú minnkun kemur væntanleg inn sem kvóti sem hægt er þá í framtíðinni að selja á markað í Evrópu.
Þarf það magn að vera meira en 100 þúsund tonn? Er einhver hugmynd hvernig framkvæmd að slíkri kvótasölu fer fram....munu útgerðarfélög sem minnka

losunina á þennan hátt geta eignfært slíkan kvóta inn í bókhaldið hjá sér í framtíðinni??

kær kv.
Sævar B.

Appendix 15

To see messages related to this one, group messages by conversation.

11/04/10

[John Venema]

John Venema

john@greenerpro.com

Add to contacts

To Sævar Birgisson

From:**John Venema** (john@greenerpro.com)

Sent: Thu 11/04/10 5:12 PM

To: Sævar Birgisson (saevarbirgisson43@msn.com)

Hotmail Active View

1 attachment (1255.8 KB)

FishOil.pptx

Download(1255.8 KB)

Download as zip

I made a small presentation of how to make biodiesel from fish waste. It is actually quite simple to understand. Basically it is cutting the fish in small parts in an acid environment, cooking and settling to obtain the oil. The biodiesel part is adapted to fish oil. The standard way of making biodiesel would lose the FFA in the form of soap. I think it is better to convert this too (esterification) into biodiesel by means of an acid catalyst. The rest products glycerine and fish meal could be used for animal food or used in a fermenter to produce biogas.

I think Iceland already produces a lot of fish oil?

Fish Oil as an Alternative Feedstock

Fish oil can be an alternative feedstock to produce biodiesel.

Fish oil from byproducts and underutilized fish can be easily converted into usable biodiesel, which is a clean-burning bio-oil and can be used to reduce dependence on imported fuel and improve air quality.

800 ton fish waste could be converted into 80 – 160 ton fish oil or 79 – 158 ton biodiesel

Fish waste contains 10 – 20 % oil which can be converted to Biodiesel

How do you make fish oil?

First step

Preparation of fish silage from filleting fish wastes

Fish silage is a liquid product produced from fish waste, to which acids are added, with the liquefaction of the mass provoked by the action of enzymes from the fish (FAO, 2003).

It is a common way to preserve and transform fish waste into a product for oil and animal feed ingredient production.

How do you make fish oil?

Second step

Settling of the silage

The silage is heated up to 90 °C, pumped to settling tanks and left to settle.

During the settlement the suspension is divided by gravitation into three fractions: oil as lightest phase on top, the water fraction, having the highest density, sinks to the bottom.

In between these layers is the protein fraction, that can be utilized e.g. as an animal feed ingredient or meal.

How do you make fish oil?

Third step

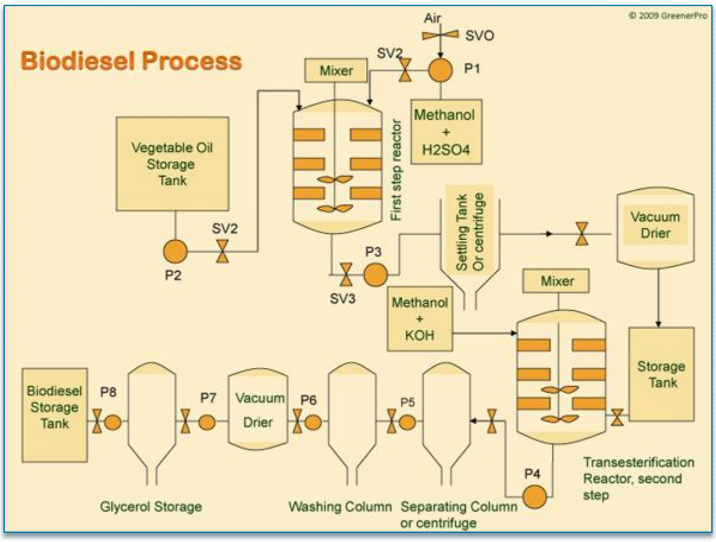
The fish oil needs to be dewatered, filtered and degummed. This is a simple process.

The actual biodiesel process is adapted to high FFA feedstock as fish oil usually is.

Up to 15% FFA we use an acid-base 2 step process.

>15% FFA needs an acid one step process.

All FFA is converted into biodiesel resulting in a high yield



Recommended process for fish oil < 15% FFA aka Acid-Base reaction

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