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PROFITABILITY ANALYSIS OF BIOFUELS AND THE IMPACT OF BIOFUEL POLICIES IN FINLAND

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ABSTRACT

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This study analyses the effects of policy support on the profitability of biofuel production. The focus is on the investment profitability of biofuels and how the penalties, fuel taxes and the possible financial subsidy affect the investment profitability. The theory section consists of literature on biofuel policies and profitability of biofuels. Additionally, the theory examines the biofuel production and policy support in Finland.

The empirical section analyses the biofuel policy effects on net present value of renewable diesel and fossil diesel blend. The fuel components of the blend are analysed separately to obtain more information about the influence of policy support to the net present values. The methods used in this study are net present value, internal rate of return and sensitivity analysis which is used to examine the uncertainty of net present value results. Lastly, the net present values are presented with triangular pay-off distribution based on fuzzy pay-off method to clearly understand the profitability distributions. The study examines the profitability of a renewable diesel and fossil diesel blend from the perspective of five different biofuel policy scenarios. Data has been collected from publicly available sources and cost-related data is based on estimated averages from literature.

The results of the study indicate that Finnish biofuel policy seeks to increase the production of biofuels through penalty payments influencing the investment profitability negatively and with tax reliefs targeted to biofuels. The results received from sensitivity analysis indicate that penalties encourage to decrease the share of fossil fuel from all fuels sold. Furthermore, the results suggest that the production of renewable diesel is not profitable at the current price of diesel in neither biofuel policy scenario. Information of this thesis can be used by policymakers and investors seeking to understand the impact of biofuel policies on profitability.

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Tämän tutkimuksen tavoitteena oli selvittää liikenteen biopolttoaineisiin kohdistuvan lainsäädännön vaikutuksia biopolttoainetuotannon investoinnin kannattavuuteen. Tutkimuksessa keskityttiin siihen, miten sanktiomaksu, polttoainevero ja mahdollinen tuotantotuki vaikuttavat nettonykyarvoon. Tutkimuksen teoreettisessa osuudessa käsiteltiin biopolttoaineiden lainsäädäntöä ja tukimekanismeja sekä paneuduttiin Suomen biopolttoainetuotantoon sekä siihen kohdistuviin käytäntöihin ja lainsäädäntöön.

Empiirisessä osuudessa kartoitettiin biopolitiikan vaikutuksia uusiutuvan dieselin ja fossiilisen diesel -sekoitteen nettonykyarvoon. Tämän lisäksi polttoainetyyppien nettonykyarvot analysoitiin erikseen, jotta saatiin tarkempi kuva sekoitteen sisältämien polttoainekomponenttien kannattavuudesta. Investointikannattavuutta tutkitaan perinteisen nettonykyarvon ja sisäisen korkokannan kautta. Herkkyysanalyysin avulla tutkittiin nettonykyarvoon vaikuttavia epävarmuustekijöitä. Kolmen polttoainetyypin nettonykyarvon yksityiskohtaiseen analysointiin hyödynnettiin kolmiomaista kannattavuusjakaumaa. Tutkimuksessa tarkasteltiin polttoaineiden kannattavuutta viiden erilaisen biopolitiikkaskenaarion näkökulmasta. Empiirisen osuuden aineisto on koottu julkisesti saatavilla olevista lähteistä ja perustuu tuotantokustannusten keskiarvoihin.

Biopolttoaineita koskeva lainsäädäntö ja käytännöt pyrkivät kannustamaan biopolttoaineiden tuotantoa sanktiomaksuilla ja biopolttoaineisiin kohdistuvilla verohelpotuksilla. Herkkyysanalyysin tulokset viittasivat sanktiomaksujen kannustavan vähentämään fossiilisen dieselin osuutta tuotannosta, sillä nettonykyarvo laski fossiilisen dieselin tuotannon lisäämisen seurauksena. Tämän lisäksi tutkimuksessa selvisi oletetusti, että uusiutuvan dieselin tuottaminen ei ole kannattavaa nykyisen dieselin hinnalla tutkimuksen esittelemissä biopolitiikan skenaarioissa. Tämän tutkielman tietoja voivat hyödyntää päättäjät ja sijoittajat, jotka pyrkivät ymmärtämään biopolttoaineisiin kohdistuvan lainsäädännön ja käytäntöjen vaikutuksia kannattavuuteen.

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I still remember the first day after moving to Lappeenranta feeling anxious about this new chapter of my university life starting. I could never have imagined how many good memories this place would offer me. After five years this chapter of my life is closing and a new one is opening. University has taught me a lot and it was a place where I encountered long-term friends with whom I enjoyed the student life.

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Inka Ruponen
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HVO Hydrotreated vegetable oil or renewable diesel

ILUC Indirect land use change

RED Renewable Energy Directive

RED II Renewed Renewable Energy Directive

1 INTRODUCTION

In decarbonization of the transport sector, biofuels have received attention of policymakers in Europe and the quantity of biofuels is estimated to increase in transport sector worldwide. IEA (2020) forecasts that the production of biofuels will increase by 25% from 2019 to 2024. Finnish Government released a plan to increase the share of biofuels in transport to 30 percent by 2029. The biofuel mandate includes strict biocomponent share that fuel providers bust distribute to consumption. Finnish legislation is linked to European Union's renewed Renewable energy directive, including directives ensuring the sustainability criteria for biofuels. Biofuels are helping to substitute the use of fossil fuels in transport sector. However, currently transport sector is dependent on fossil fuels and renewable fuels still represent a small section in transport sector but due to several governments making policy measures to increase the biofuel use. (European Commission 2020a)

Renewable fuels in transport are currently mainly concentrated to ethanol production in key markets globally (IEA 2019a). However advanced biofuels produced from waste and residue especially renewable diesel have received policy makers attention as they can be integrated with current vehicle infrastructure without modification and can reduce emissions. Biofuel policies such as production mandates, tax incentives and financial subsidies provide stimulus to develop renewable fuel options and the consumption of biofuels is dependent on Member States and their National legislative. Finnish Government (2021) released a roadmap towards a fossil free transport sector stating to replace fossil fuels with renewable fuels and electricity. Emphasizing the factor that renewable fuels must be made from sustainable raw materials.

1.1 Background

European Commission released a new plan to achieve climate neutrality by 2050, European Green Deal. The goal will be achieved by enhancing the economy through renewable technology, creating sustainable transport and industry, throughout cutting the pollution. The European Green deal provides a roadmap for key actions in transforming EU's economy sustainable for the future. (European Commission 2021) The directives promoting the use of biofuels are Renewable Energy Directive, Fuel Quality Directive and Directive to reduce indirect land use for biofuels. European directives guide Finnish biofuel policy structure.

1.1.1 Renewable biofuel policy in Europe

Biofuels are in the centre for renewable energy policy framework for road transport. Including blending mandates, financial incentives, support for blending and fuelling infrastructure and incentives for advanced biofuels. Blending mandate being the most common renewable support policy adopted in several countries. Financial incentives are less commonly adopted but have been deployed in the form of subsidies and tax credits. (REN21, pp 63-69)

Financial incentive (Innovation fund)

European Commission (2020b) manages the world's largest funding programme called Innovation Fund for renewable energy projects. It will provide investment support for up to 10 billion euros to projects helping to decarbonize Europe. The funding will take place in 2020-2030. In 2012 European Commission released a similar fund program, NER300 that granted investment support to renewable energy projects. In 2017 European Commission (2017) granted Kaidi Finland an 88,5 million Eur investment subsidy for its second-generation biofuel refinery project in Finland.

Fuel quality directive 2009/30/EY

Fuel quality directive (2009/30/EC) issues blending mandates to European countries, regulating the share of biofuels in fossil fuels. These standards are referred to as European EN fuel standards. EN590 standard allows maximum 7% of biodiesel to be mixed with fossil fuel. Standard creates a blend wall thus some fuels cannot be blended to fossil fuels more than the maximum share or used as such. To achieve higher bio-shares in diesel fuels, hydrotreated vegetable oil or renewable diesel must be used. Fuel is under EN 15940 standard, which is specifically created for renewable diesel. Standard allows to higher bio-share blends in fossil fuels and currently renewable diesel is the only biofuel that has the technical capabilities to be blended over the blend wall limit, allowing up to 100% mixtures possible. (Sipilä et al. 2018)

Renewable Energy Directive

EU Energy and Climate Change package (ECP) promotes renewable energy use in Europe with Renewable Energy Directive (RED). There are renewable energy targets, along with multiple sub-targets. 173 countries set their renewable targets by conducting their own legislation according to EU's renewable directive. One of RED target was that the transport sector achieves a common 10% share of renewable energy and 20% share of renewable energy by 2020. By the end of year 2018 only two member states had achieved the transport sector's target share of 10%, Finland (14,9%) and Sweden (29,7%). The average share of renewable energy in EU used in transport was 8,3%. The new RED II was adopted later, renewing the legislation in renewable energy, and setting new goals for the next ten years. (Eurostat 2019)

Renewable Energy target share to renewable energy has been increased to 32% in the overall consumption of renewable energy sources by 2030. In addition, there is a sub-target that fuel suppliers must provide 14% of renewable alternatives consumed in road and rail transport. Directive must be implemented through member state's national renewable action plans. (ICCT 2018) Directive also defines sustainability and greenhouse gas emission criteria to biofuels that must be filled to receive financial support from the government. Renewable fuels must meet sustainability criteria which include reducing lifecycle carbon emissions, not contributing to deforestation, not competing with agriculture.

According to European Commission (2019a) conventional biofuel production might take place in cropland that can also be used to agriculture, grow food and feedstock. This can lead to indirect land use change (ILUC) when biofuel production causes the expansion of land use, such as forests. Without strong policies, biofuel production could contribute to desertification or to unsustainable farming practices by eliminating the greenhouse gas savings that increasing biofuel production brings. RED II set limits on these biofuels that have a high ILUC-risk in carbon sink areas by limiting the amount of these biofuels that member states include in their national target biofuel shares.

The Renewable energy policy targets will potentially decrease the use of conventional biofuels made from agricultural feedstocks and increase the demand of advanced biofuels that are waste based. Nonfood and waste-based oils might play an important role in the future of Europe’s renewable energy strategy. Limiting the controversy of biofuels competing with food supply. (European Commission 2019)

1.1.2 Key challenges

The cost-related competitiveness of biofuels does not only depend on production costs but also on the price of fossil fuels (Archinas et al. 2019). Transport sector is influenced by low crude oil prices which is why biofuels producers must be protected from the price volatility with long-term policies. Low oil prices bring challenges to the biofuel sector, since with low crude oil prices the production of fossil fuels is profitable. Low oil price environment may cause investment cutbacks and slow the implementation of biofuel production facilities and decrease investments to research and development of advance biofuels. (IEA 2020a)

1.2 Research gaps in biofuel studies

The amount of analysis made especially about biofuel policy impacts on renewable fuel production is at great extent. Studies have been made from multiple perspectives as case studies concentrating on a specific country’s policy effect additionally qualitative analysis and broad overviews covering policy structures. Even though several studies have been carried out, the impacts of current policy revisions should be analysed, especially in Finland.

There are no studies focusing on profitability analysis of Finnish biofuel production used in transport, even though Finland has an advanced biofuel policy structure in place. Finland has been recognised to be a forerunner of sustainable bioeconomy especially in wood-based biofuels. According to REN21 (2020) production of renewable diesel is concentrated in Finland, Netherlands and Singapore. This situation requires more attention to understand the impact that biofuel policies have on profitability of the projects, as this would bring more insights of biofuel policy implications in Finland. Furthermore, research papers focus on analysing the profitability of purely biofuel production, thus the production of fossil fuel and biofuel together should be analysed.

1.3 Research problem and objectives

This study provides information of different biofuel policies and their influence on the profitability of biofuel production. The research analyses the biofuel distribution obligation in Finland and the effect of the policy for the profitability of biofuel production. The objective of this study is to analyze the investment profitability of refineries producing hydrotreated vegetable oil also known as renewable diesel.

The work concentrates on biofuel policies currently in Finland and the value they bring from the investment point of view. Europe’s renewable energy policy will also be covered since it guides the Finnish legislation, additionally this research will conduct an overview of policies worldwide to achieve a comprehensive understanding of different biofuel policies. This research aims to explain the government support, such as penalties, financial support and fuel taxation in Finland and their role in the increasing demand to the production of biofuels. The biofuel policy analysis on investment profitability will be based on analyzing data available in public sources. This study analyses the production of renewable diesel with fossil diesel.

The goal of this thesis is to analyze current support policies of biofuels. By analyzing profitability of different biofuel blends operations under different policies, this research uncovers the incentives different policies provide to investors. The results will show the influence of penalties, taxes and financial support to production of renewable diesel and fossil diesel.

The main research question is:

How does Finnish and other biofuel policies encourage investments to biofuel production?

This thesis aims to answer this question by analyzing the profitability of biofuel and fossil fuel production by concentrating in co-production of both biofuel and fossil fuel, as well as by analyzing the production of both fuels separately. Sub-questions supporting the main research question are:

- What are the main support policies influencing the profitability of biofuel investments in Finland and elsewhere?
- How do different factors influence the profitability of biofuel production under these policies?

Last question aims to provide comprehensive picture of co-production of biofuel and fossil fuel, under the Finnish biofuel distribution obligation.

- Is co-production of renewable diesel and diesel profitable under distribution obligation?

1.4 Data and Method

Data used in the analysis is collected from public articles providing information about investment and material costs. Cost-related information of biorefinery projects is based on literature providing numerical values generated from currently operating plants. Data is mostly collected from Consultants Inc. (2018) and compared with information available in literature. Other numerical data for the analysis is collected from different sources, which provide estimates of renewable diesel production plants in Europe. Values used in this study are based on estimated costs since availability of specific plant projects are not publicly available. The objective of this study is to analyse the effect different biofuel policies have on investment profitability and the results should be interpreted as suggestive.

Net present value is a commonly used method to calculate the investment profitability by providing the value of the project by evaluating the cash flows during the whole plant lifetime. Different policy combinations are compared based on the change in the project net present values. Internal rate of return allows to estimate the annual return of the project. These are conventional metrics used in profitability analysis:

- Net present value method
- Internal rate of return

Furthermore, net present value and internal rate of return regarding their sensitivity is examined with method below:

- Sensitivity analysis

Sensitivity analysis is performed to selected variables used in profitability analysis to determine the key variables in profitability of the project when only one specific variable change. Sensitivity analysis is conducted to achieve information about the most critical variables affecting the profitability. Furthermore, the net present value with different policy scenarios is analysed and illustrated with fuzzy pay-off method.

- Fuzzy pay off method

Overall, the goal in this analysis is to understand the influence of biofuel policies in Finland on profitability of biofuel production.

1.5 Limitations and definitions

1.5.1 Policy types

This thesis concentrates on the profitability of biofuel production and to the financial impact of biofuel policies to the fuel production. The policies analysed in the empirical section are distribution obligation, tax reduction for biofuels, penalties and financial subsidy. Distribution obligation analysed is implemented to Finnish legislative which is why geographical delimitation has been made to Finland. However, literature review will cover biofuel policies worldwide, especially biofuel policies in Europe to understand the scope of biofuel policies implemented globally.

1.5.2 Biofuel types

The number of different biofuels large, limitation is made to advanced biofuels. Furthermore, conventional biofuels are mentioned in literature review since it is crucial to analyse the development of biofuel policies that has started with conventional fuels and later as technology has developed new technologies have emerged. Moreover, empirical section of this thesis concentrates specifically in production of renewable diesel. Other biofuels produced in Finland are briefly presented to understand the current biofuel production in Finland. The following terms are explained, to understand the differences of biofuels:

Liquid biofuels are generally divided into following fuel types: ethanol made from different sugar types, biodiesel and renewable diesel made from different oils. Biofuels can be produced from multiple different materials and they are often divided into three different generations based on the materials they are produced from. (Demirbas 2010)

Conventional biofuels are produced from food-based crop and have raised the issue about the effect on food security that occurs from the global increase in production of conventional fuels (OECD 2006). First generation biofuels and food production utilise the same raw material and it creates a competition between these two industries. Conventional biofuel production increases the prices of food prices because the main feedstock used for production is food crop. This creates competition from resources related to agricultural and natural resources. (Koizumi 2015)

Advanced biofuels were created to overcome the issue of food competition thus these fuels are produced from non-food crops including waste cooking oil and residue streams from forest industry. IEA (2019b) defines these fuels as sustainable fuels that do not compete with feed and food crops of agriculture and does not affect sustainability. Renewable diesel also called hydrotreated vegetable oil is an advanced biofuel that can be blended without any limit to fossil fuel thus offering fuel producers flexibility to blend more biofuel in fossil fuels.

Third generation biofuels can be produced from micro-organisms such as algae (Brennan & Owende 2010). Algae based biofuels have not received investment interest and these biofuels are not yet commercially available (Doshi et al. 2017).

1.5.3 Other limitations

The data used for the analysis are average estimates derived from publicly available sources. Therefore, the results should be interpreted as such. This study will not cover the technical conversion processes used in biofuel production. Additionally, this research is limited to biofuels that are used in transport, not in energy or industrial sector.

1.6 Structure of the thesis

The structure of this thesis is constructed of seven sections, including introduction, literature review, biofuel policy and production in Finland, methodology, results, discussion and conclusions. Second chapter includes analysis of biofuel policies worldwide, profitability analysis of biofuels and research related to Finland concentrating on biofuels. Third chapter presents Finnish biofuel policies and fuel production costs. Methodology used in the analysis of this study is presented in chapter four as the results obtain are introduced in chapter five. Fifth chapter presents the findings made from the data. Final chapters in this thesis includes discussion where the results are analyzed deeply considering limitations as in conclusions the research questions are answered.

2 LITERATURE REVIEW

This literature review presents research that has been already written about biofuel policies and profitability, to find the literature that helps to answer the main objective of this study. Identifying the main notions and patterns in the policy environment worldwide of biofuel production, both conventional and advanced biofuels. Conventional biofuels are also presented in this literature review since it will help to establish the overall perspective of biofuel policies. There are multiple research articles written about biofuel policies and they include several topics in different fields of research. Biofuel is a common name used for many different biofuels including conventional and advanced biofuels, literature concerning multiple biofuels is selected to understand the overall picture of biofuel policies in different countries. In this literature review the focus is on academic articles related to liquid biofuel policies thus allowing to have a clear overview of the topic. Firstly, the focus is to present research articles that have analysed the biofuel policies and walk through the results. Secondly the articles covered will be related directly to profitability analysis of advanced biofuel production. Last section introduces the articles related to Finland to this topic.

2.1 Overview of biofuel policies

The production of biofuels has increased, and this increase can be mostly explained by governmental policies. Several research articles have analysed biofuel policies with a descriptive style analysing different biofuel policies worldwide, hence studying the development of governmental support in multiple countries. For example, Sorda et al. (2010) presents the biofuel policies in the US and in Europe with a descriptive nature, concluding the main drivers to support production and consumption in Europe to have been blending targets, tax exemptions and subsidies. Panoutsou et al. (2013) analyses the development of biofuel policies by concentrating in financing instrument options in Europe and in US for advanced biofuel production, concluding that there is activity in policy development and the policies are developing towards sustainability and resource efficiency. However, Kapustova et al. (2020) addresses the rapid development of conventional biofuels have affected the prices of food crops but revision of renewable energy directive will lower the production of these fuels and encourage the production of advanced biofuels. Furthermore Araújo et al.

(2017) state that biofuel policies have reduced barriers and encouraged the use of sustainable processes, additionally they raise the need for funding the projects.

France and Germany are often raised in Europe related research papers (eg. Kapustova et al. 2020) as exemplar member state of EU, perhaps since they are the biggest producers of biofuels in Europe, especially in producing biodiesel. There are case studies concentrating in these two European countries e.g. Gardebroek et al. (2017) analyse the linkage between raw material prices and the biofuel policies including mandatory blending in Germany and production quotas in France. Europe seems to be a widely researched continent concerning biofuel policies and their effect on increasing biofuels in the transport sector. (e.g. Cansino et al. 2012) Furthermore there are case studies reflecting on a specific national policy in a certain country; Raslavičius et al. (2014) studies the potential of biofuel production and the necessary policies needed in Lithuania, Harnesk et al. (2015) conducts an overview of the government support in Sweden concentrating in liquid biofuels of the transport fuel sector; Zhang et al. (2014) analyze four common subsidy modes for biofuel refining in China: tax, investment, sales and raw material price subsidy. Their results suggest final product and raw material price subsidy increases the profits of both biofuel enterprises and raw material recycler. Descriptive nature of articles related to policies is present in multiple articles. IEA (2018) additionally addresses in their report that multiple countries have imposed penalties for not achieving to meet the biofuel mandate, these countries include Germany, Italy and Sweden. Furthermore, similar penalty for fuel distributors is currently in commission in Finland (446/2007).

Few countries outside Europe have transformed to a successful biofuel economy, mainly by producing ethanol, these countries include US, Brazil, India and more recently Thailand. These countries have created supporting renewable fuel policies that have led to production and use. Chaiyapaa et al. (2018) study three large Oil and gas companies’ renewable energy investments in Thailand and highlight that biofuels are the main investment priority in decarbonisation the transport sector. Chanthawong and Dhakal (2016) concluded that Thailand has established a wide range of policies with national biofuel targets with supporting blending mandates, subsidies and tax reliefs, that has increased the biofuel sector rapidly. Saravanan et al. (2017) overview the National Biofuel policies of India; Colmenares-Quintero et al. (2020) assess biofuel production, by investigating barriers and drivers to biofuel production in Colombia, one driver being policies and governmental regulations. However, Ohimain (2013) studies Nigeria that has its own biofuel policy blending mandates, there still has been little progress in domestic production in four years after the policy release. Concluding that additional financial incentives are needed.

Janda et al. (2012) emphasize that conventional biofuels are not profitable with the absence of fiscal incentives or high oil prices. Food security is also a concern with conventional biofuels, especially in some African and Asian countries in which the use of food crops for fuel is not sustainable in a long term in biofuel production from social perspective (e.g. Mizik & Gyarmati 2021), since edible raw materials of conventional biofuel production compete with food production. Few articles additionally compare and address the need of optimal economic instruments and biofuel regulation, such as mandates, tax reduction and subsidies (e.g., Sorda, G. et al. 2010). Ebadian et al. (2019) conclude that biofuel policies have indeed supported the use of biofuel and their production, especially widely used policies as previously mentioned. They state that supporting policies have been crucial in the production growth of biofuels, but not sufficient in efforts to decarbonize the transport sector since the sector still as of this day relies mostly in fossil fuels.

Blanco et al. (2010) distinguishes four EU level instruments that support the use of biofuels and their production:

(a) Budgetary support including tax reliefs for biofuel producers. (national level)
(b) Mandates, blending and consumption targets. (national level)
(c) Trade measures internationally. (EU level)
(d) Measure for biofuel-chain, by taking actions to stimulate efficiency and productivity (EU level)

Gardebroek et al. (2017) talks about distinguishing two different levels in above mentioned European Union policy instruments. European Union level policies provide guidelines to member states that can be implemented on a national level allowing countries to reach EU targets by country specific measures. Results reflected that EU policies have increased the raw material prices because of higher demand for raw materials used in production of biofuels, furthermore, increasing the production costs. In a scenario analysis of the future effects of biofuel policies, Araujo Enciso et al. (2016) found that biofuel policies: mandates, tax credits, import and export tariffs, seek to bring more stability in biofuel prices in the long run. They also state in their study, that without biofuel policies the global demand for biodiesel would decrease by 32%. On the other hand, Drabik & Venus (2019) address in their article the uncertain nature of biofuel policies, due to government revising and changing directions of policies and the absence of implementation supports. They state that these policy changes require costly modifications to production infrastructure if modification is possible, thus leading to smaller returns of biofuel producers.

To conclude multiple research articles, argue that the biofuel policies concentrated to increase the supply and demand of biofuels tend to increase food prices. This has led to a widely studied theme about food versus feed competition. Raw materials used in conventional biofuel production tend to increase the price of agriculture crops due to high demand. This leads to the before mention topic of competition between two industry of the same product. Competition has occurred for the feedstock because of quick development of biofuel industry and could be conquered with a developed policy structure. Moreover, current biofuel policy structure in the European Union is aiming to decrease the quick increase of conventional biofuels and increase production to advanced biofuels, produced from waste. Renewed European biofuel policy structure is aimed to address the feed and food competition.

2.2 Biofuel production profitability

Papers related to profitability of biofuel production, usually assess the investment profitability form the producer’s perspective. Profitability of different projects is often addressed concentrating on a certain country or region’s possibilities to produce advanced biofuels. In majority of studies related to profitability of biofuel production the policy impact is studied with a quantitative approach but additionally with a descriptive way. The effectiveness of different policies has also been addressed, in some cases to find the most profitable policy for producers and few addressing the cost of the policy for the government. US biofuel policies have received the attention of multiple research articles, that concentrate on analysing the tradable credit, renewable identification number price with other policies supporting the biofuel production.

Chu et al. (2020) claim that policies would have a large impact on project's profitability, additionally projects are sensitive to fuel and feedstock prices. They additionally stated that the renewable identification number attracts investors, which is a financial incentive in US biofuel policy to produce biofuels. Renewable identification number (RIN) is used in the US to track amount of renewable fuels in the market, Renewable fuel standard obligates a certain share of biofuels production per a specific year. RIN is created when producing a certain amount of biofuel and non-biofuel producers must buy them from the markets to achieve the renewable fuel amount required (EPA 2021). Song (2012) brings up that the government should tender investment subsidies to promote the use of waste oils in biofuel production. Naylor et al. (2017) result in their study that without blending mandates the production of biofuels would not increase largely due to oil prices being low and feedstock costs high.

Ghoddusi (2016) uses a real option approach to substitute gasoline when prices are too high and the possibility to increase supply of ethanol at low crude oil prices. Concluding that volatility of both ethanol and oil costs resulted in higher return for the ethanol producer. Furthermore, creating a model to evaluate the value of blending mandate for a biofuel producer. From a different perspective, Miao et al. (2012) considers the real options view whether biofuel mandates affect a risk-neutral investor decision to invest in cellulosic biofuel refineries in early stage or later. The impact that mandates have on investments depends on marginal costs and the price range of biofuels. If marginal costs increase, then both non-waivable and waivable mandate can stimulate investment in an early stage. Additionally, raises a question about tax credit's effect on the development of biofuel industry in the long run. Li et al. (2014) uses real options thinking to determine if decision maker should invest with current biofuel mandates in place or later, proving both to be profitable and later investments being more profitable. Furthermore Markel, E. et al. (2018) view the investor perspective addressing the influence of uncertainty in Renewable Fuels Standard program in the US for entering and exiting the biofuel market. Establishing different diesel price in which entry in the market would occur. Raising the issue policy uncertainty due to annual revisions to biofuel policies that affect the price volatility of Renewable Identification Credits thus decreasing the entrance to biofuel markets. Finding that tax incentives will lower the marginal costs of producers thus encourage the entry for the biofuel producer.

Uncertainty is examined in some papers not by only addressing the issue of uncertainty in biofuel policies but additionally by considering different uncertain parameters in the analysis. Usually uncertain variables are fuel prices, raw material prices and investment and operating costs. Chu et al. (2016) examines the uncertainty of capital cost, price of feedstock, crude oil, gas, electricity, water and oil content of raw materials. Martinovic et al. (2018) only examines the uncertainty of the cost of biodiesel, while in another article of Li et al. (2014) addresses the uncertainty of fuel prices. Cheali et al. (2016) uses Monte Carlo simulation to assess the uncertainty of market prices and for generating possible future scenarios, conducting a comparative analysis between two different raw materials and production technologies. Finding that biorefineries combining different products provide elasticity against market disturbances, such as price changes.

Some research papers analyse project's financial performance by concentrating on market price volatility and uncertainty, due to their largest impact on investment profitability (e.g. Campbell et al. 2018). Festel et al. (2013) also found that raw materials are the costliest factor in the total production, therefor having a significant impact on investment profitability. Furthermore (e.g. Campbell et al. 2018 and Sarkar et al. 2011) have found that production costs for liquid biofuels produced from forest biomass tend to be too high to compete with fossil fuels without policy support. Multiple articles analyse biofuels from techno-economic aspect by concentrating in both technical and economic performance of the process. Finally, product selling price is also seen as a risk since the fuel prices tend to move between a large scale (e.g. Petter & Tyner 2013 and 12 Zhao et al. 2016) Previous articles imply that biofuel industry has multiple uncertain parameters present in financial analysis.

Developing countries are also raised in cost related analysis, as van Eijck et al. (2014) conduct profitability analysis for multiple biofuels in different developing regions. Implying that production of advanced biofuels is cost effective and capital intensive when deployed in a large-scale. They highlight that policies are needed to achieve a cost competitive biofuel production and decrease risk for investors.

Furthermore, articles analyse biorefineries cost environment, by comparing different technology pathways to biofuel production. (e.g. Witcover & Williams 2014) More recent publications usually model the production costs higher in research papers, mainly due to increasing demand of the same raw materials, that increase the raw material price and waste material prices, latter still having a lower price.

2.3 Research in Finland

Publications addressing specifically Finnish biofuel policies in transport are rare, however literature sometimes raises Finnish biofuel policies as a part of EU policy overviews. Mentioning that Finland has an advanced national biofuel policy in place, however, there seems to be little academic papers concentrated in the profitability of biofuel production in Finland. Academic publications analysing specifically Finland concentrates on biorefineries that produce biofuels as a side stream in forest industry. Kangas et al. (2011) study the impacts of different biofuel policies, by setting fixed biofuels production targets and analysing which subsidies or biofuel price levels are needed to achieve the targets. The policies used in the study are subsidy for biofuel production subsidy, input subsidy for each wood-based used in production and investment subsidy. Results found that investments were close to profitable with fair policy support, additionally investment and production subsidy will increase the amount of smaller biorefineries. Furthermore Reini & Törmä (2010) study economic effects of building biorefinery in Center Finland. Additionally, Natarajan et al. (2014) studies the minimization of costs in finding an optimal biodiesel plant location in Finland and providing information about suitable feedstock in operation.

Waste based biofuels are studied from a descriptive point, Pongracz et al. (2015) review the waste-based biofuel production sector in Finland. Their overview of domestic production possibilities stated that Finland could be the forerunner in biofuel production. They stated that Finnish biofuel target of 20% renewable fuels in transport can be achieved solely by domestic production. This brings a strong interest to Finnish biofuel policies, whether the government support to biofuel producers in Finland are creating incentives to achieve the 2030 target of 30% share of biofuels in transport.

3 BIOFUEL POLICY AND PRODUCTION IN FINLAND

Finnish Government proposed a recent bill that the share of biofuels in transport will increase to 30% by 2030. This so-called distribution obligation requires fuel suppliers to increase the share of biocomponent in fuels with a possible penalty for not compliance. This target is in line with the current government program of making Finland carbon neutral in 2035. Energy Minister has stated that the aim of distribution obligation is that companies invest to biorefineries in Finland. The future biofuel projects are mainly concentrated to production of advance biofuels. All Finish producers such as Neste and UPM have planned to increase their biofuel production in Finland or overseas.

3.1 Drivers and policies in Finland

Finland is committed to the long-term goal of EU to achieve carbon-neutrality by 2035 thus making it the first welfare society to do so. Transport is one of the key sectors for Finland's goals towards climate neutrality. Finland has fixed a biofuel policy all the way to 2030 – one of the most progressive biofuel policies. Three key solutions to reduce GHG emissions are energy efficiency of vehicles in transport sector and replacing fossil-based fuels with renewable alternatives. Finland has been continuously moving away from carbon energy and it is a global leader in producing biofuels from wood and waste. (European Commission 2020a, IEA 2020a)

According to Ministry of Transport and Communication (2020) Finland has agreed to decrease 50% (compared to 2005) of domestic GHG emissions produced in transport sector by 2030. This means that there should only be 6,35 million tons of emissions by 2030 to meet this target. Key emission reduction measures in road transport are liquid biofuels and other renewable liquid fuels, natural gas, biogas and other gas fuels and electricity. As there are only a limited amount of waste based raw materials available the Finnish Government aims that the absolute number of biofuels in road transport will not increase after the 2030 target is reached. The production of advance biofuels is promoted by fuel taxation, fuel blending mandates, investment subsidies and quotas.

The distribution obligation of biofuels

Ministry of Transport and Communications (2020) states that the most important control to increase the biofuel share in transport by 2030 is the distribution obligation of biofuels. It requires fuel suppliers to provide 30% of all fuels sold to the market to be biofuels by 2030. The share of biofuels provided by the supplier increases gradually each year. Distribution obligation ensures a minimum volume of biofuels, thus securing the demand in the market creating a regulatory environment for biofuel production capacity. In the case the fuel supplier has not supplied the required volume of biofuels during the year, the Finnish Tax Administration will impose a penalty fee for non-compliance. Currently energy consumption in the transport sector is 46TWh/year and it is estimated to be 42TWh/year by 2030. This means that approximately 12,6TWh are expected to be replaced by biofuels in 2030. Distribution obligation determines by law (2007/446 §5) the percentage of fuels needed to release in consumption. As discussed earlier the percentage will increases gradually to 30% based on the energy content as follow:

Table 1.The distribution obligation percentage of the energy content of all transport fuels sold in consumption (2007/446 §5)

Year	Biofuel share
2020	20%
2021	18%
2022	19,5%
2023	21%
2024	22,5%
2025	24%
2026	25,5%
2027 2028 2029 →	27% 28,5% 30%

Double counting of sustainable biocomponents was removed in 2020, which previously allowed fuel suppliers to count the number of certain renewable fuels produced as double to reach the target share of a specific year. Thus, the real amount of renewable fuels distributed w was not reflected to the biofuel share. Double counting will be removed in 2021 since the Finnish Government did not see a justification to continue to apply the double counting to achieve the target share of biofuels towards a cleaner transport sector. (HE 199/2018)

Therefor the biofuel share will first decrease seen in Table 2. to 18% in 2021 hereafter the biofuel share will increase regularly by 2030. For non-compliance, the fuel supplier will be imposed with a penalty fee established in law (2007/446 §11). The amount of penalty is 0,04 euros per MJ which is based on the energy content of the fuel. The Finnish Parliament (HE 2018/199) states the penalty responds to 1,355 eur per litre as diesel equivalent.

Liquid fuel taxation in Finland

In addition to the previously mentioned penalty, biofuels have lower taxation compared to fossil fuels. Excise tax of liquid fuels consists of the energy, carbon dioxide and security supply level tax. Carbon dioxide tax creates an advantage to biofuels since renewable fuels are not subject to carbon dioxide tax. Diesel fuel taxes can be seen in Table 2. and the difference for renewable fuels to fossil diesel excise taxes are listed in the right column. Overall, the excise tax for biofuels blended with fossil diesel is slightly higher than biofuels sold without blending.

Table 2. Diesel Fuel taxes in Finland 2021 (Finnish Tax Administration 2021)

	Energy tax (c/l)	CO2 tax (c/l)	Security of supply levy (c/l)	Total tax (c/l)	Difference to diesel fuel (c/l)
Fossil diesel fuel	34,57	24,56	0,35	59,48	
Biodiesel (e.g. renewable diesel)	28,65	0,00	0,35	29,00	-30,48
Fossil diesel fuel blends and substitute products	32,65	0,00	0,35	33,00	-26,48

The purpose of fuel taxation is not to promote the use of biofuels, but to tax each fuel based on their energy content and carbon oxide emission. The objective is to support the best fuels for the environment based on their capabilities. In turn it is noticeable that the taxation of fuels in Finland directs in promoting renewable fuels in transport by significantly increasing the final product price of fossil fuels as with renewable fuels the taxation is significantly lower. (HE 2018/191)

Individual subsidy to a Finnish company for a pilot project with biodiesel in 2008

In 2008 European Commission accepted an individual subsidy by the Finnish authorities to Neste. NExBTL-biodiesel was granted tax reduction that decreased the market price of biodiesel compared to fossil diesel. The purpose of this subsidy was to support the entering of second-generation biodiesel into the market. End users were half of the public transport companies in metropolitan area and waste companies. As seen in Table 4. the price of biodiesel was still significantly higher than its fossil option. (European Commission 2008)

Table 3. Individual tax subsidy and additional production costs of biodiesel compared to fossil diesel fuel (European Commission 2008)

Production costs (EUR)/1000 litres NExBTL-biodiesel ccompared to fossil fuel (diesel fuel) costs	
Raw materials	733
Production costs	172
Profit margin (5%)	45
Total	950
Taxes (-VAT)	364
Tax subsidy	319
Biodiesel price	995
Fossil Diesel fuel with the same energy capacity as 1000 litres of NExBTL	548
Difference in price of biodiesel and diesel	**447**

According Nylund et al. (2015) there are multiple uncertainties related to the cost environment of biofuel production, the price of crude oil and the production costs of fossil fuels, the price development of raw materials used in biofuel production thus the cost of biofuels and taxation, additionally the development of electric fuels. The domestic taxation affects crucially the implementation of alternative options in transport sector.

Investment aid and other financial instruments

Ministry of Economic Affairs and Employment (2020) has provided financial support for new energy technology projects from 2019. Total of 40 million euros are available for investment support also in 2020 for projects that are align with Finnish and EU 2030 energy and climate targets. Additionally, European Commission (2020b) offers member countries to apply investment subsidy for innovative low- carbon technologies. Allowing the possibility to achieve subsidy to decrease risks related to capital costs.

3.2 Biofuel markets in Finland

Finnish companies are known to be the pioneers of developing biofuel technologies. Domestic production consists of two types of biofuel: renewable diesel, biodiesel and bioethanol. There are mainly three companies producing biofuels: Neste world's largest producer of renewable diesel, UPM producing renewable diesel from tall oil and St1 producing ethanol. As can be seen in Table 5. domestic biofuel production of biofuels was 535 ktoe and 2300 ktoe abroad in 2018. Neste Oyj production capacity was 78% of domestic biofuels and accounted for 100% of biofuels produced abroad. The second largest domestic producer is UPM that accounted for 19% of biofuel production. Neste produces approximately 385 ktoe of renewable diesel, UPM 100 ktoe of renewable diesel and St1 10 ktoe of bioethanol. (IEA 2019a, Ministry of Transport and Communications 2020) According to Ministry of Transport and Communications (2020) domestic biofuel production is expected to grow by 1000 ktoe and foreign production will increase by 1640 ktoe. Domestic capacity of biofuel production shares is projected to be as follows: Neste 41%, UPM 40%, Kaidi Finland 16% and St1 Oy 3%. Neste would have 94% of the foreign production capacity.

Table 4. Biofuel production in Finland in 2018 and planned capacity in 2025 (Ministry of Transport and Communications (2020) modified)

Company and refineries	Current capacity		*Planned capacity 2025*	
ktoe/a	Domestic	Foreign	*Domestic*	*Foreign*
Neste Oyj	**420**	**2300**	*630*	*3690*
Porvoo	420		*630*	
Rotterdam		1150		*1320*
Singapore		1150		*2370*
St1 Oy	**15**	**<1**	*40*	***250***
Etanolix	10	<1	*10*	*10*
Bianolix	<1		*<1*	
Cellunolix	5		*30*	*30*
Göteborg HVO				*210*
UPM Kymmene Oyj	**100**		*620*	
Lappeenranta	100		*100*	
Kotka			*520*	
Kaidi Finland			*240*	
Kemi			*240*	
Total	**535**	**2300**	*1530*	*3940*

Table 5. Biofuel types produced in Finland (Ministry of Transport and Communications 2020)

Company and refineries	Raw material	Product
Neste Oyj	UCO, animal fats, vegetable oil production residue and waste, palm oil	Renewable diesel
St1 Oy		
Etanolix	Biowaste from the food industry and process residues	85% Bio ethanol
Bianolix	Biowaste	85% Bio ethanol
Cellunolix	Saw dust	Cellulose ethanol
Göteborg HVO	Tall oil	Renewable diesel
UPM Kymmene Oyj		
Lappeenranta	Tall oil	Renewable diesel
Kotka	E.g . algal, vegetable, wood or animal oils and fats, solid and liquid waste streams and solid biomass	Renewable diesel
Kaidi Finland	Wood-based biomass	Renewable diesel and gasoline

In 2020 multiple companies announced investments to renewable diesel factories in Europe. Renewable diesel projects are forecasted to triple in the European Union by 2025 compared to 2020. The required capacity of biofuels produced by 2030 according to distribution obligation in Finland is 1 100 kilo tonne per year. This means that there is a need for a domestic capacity addition of 600 kilo tonne per year. (Ministry of Transport and Communications 2020) In 2018 Finland was more than self-sufficient in producing biofuel since the consumption was 370 ktoe in domestic road transport. However, Neste is dependent of imported raw materials in production as UPM and St1 rely on domestic materials. (IEA 2019)

3.3 Renewable diesel in Finland

IEA (2019) defines liquid biofuels as fuels derived from biomass used as an alternative renewable fuel to fossil fuels in transport. Biofuels can be mixed to gasoline and diesel or used as such. In Finland renewable diesel is produced from tall oil and from multiple waste and residue products, such as used cooking oil, animal and vegetable residue fats (Ministry of Transport and Communications 2020).

The one significant factor affecting the biorefinery profitability is the price of renewable diesel, which is greatly affected by the cost of raw material. Due to lower taxation of waste-based biofuels, these fuels receive a small benefit in the markets as they can be sold a lower price as they would with CO2 tax. The price of renewable diesel is not listed publicly in the markets, because the sales are concentrated to a few suppliers. Renewable diesel is sold to other fuel suppliers thus the prices related to agreements between the fuel suppliers and providers. Sipilä et al. (2018) Finnish Government (HE 199/2018) estimate that advanced biofuels will raise the cost of fuels for consumers. Distribution obligation across Europe will increase the demand of advanced biofuels thus the lack of supply of waste based raw materials will reflect to fuel prices. This exceptional supply constrained market will lead to the prices being determined by fines or imposed tax advantages.

However, the price of fossil diesel influences the amount of profit the fuel producer receives thus it is necessary to analyse the price of diesel in Finland. As previously mentioned, the price for consumers is mostly affected by taxes, which is currently 0,5948 euro per litre and additionally consumers pay value added tax of 24% from fuel. Diesel price without taxes is calculated by first subtracting the value added tax and secondly subtracting the fuel taxes from the fuel consumer prices. The monthly price development of diesel prices can be seen in Figure 1.

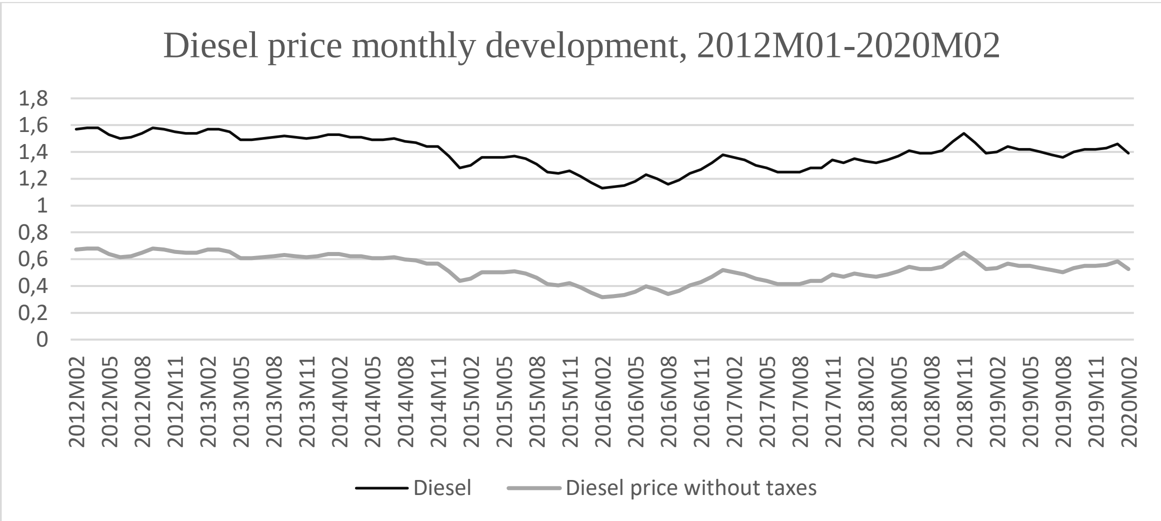

Figure 1. Diesel prices in Finland 2012-2020 (Statistics Finland 2021, Diesel price without taxes are authors own calculations)

Price of diesel was 0,61-0,67 euro per litre in 2012 to 2014, until a decrease in price to the lowest value of 0,34 euro per litre due to low crude oil prices in August 2016, afterwards the price of diesel peeked to 0,65 euro per litre in January 2018. The average price of tax-free diesel during 2012 to 2018 has been 0,53 euro per litre.

Furthermore, it is necessary to analyse the development of crude oil since it used to produce fossil diesel. Figure 2. represents the price variation of crude oil, which is used to produce diesel. Prices are converted from euro per barrels to tons per parrels. The cost of crude oil is the largest factor that affects the diesel production cost, since the price of crude oil has a crucial role in production costs. As can be seen from Figure 2. the price of crude oil was at the highest points in 2012 to June 2014 until the price started to decline. Average price of crude oil in 2012-2020 was 435 euro per ton (59 euros per barrel), however the average price of crude oil in 2015-2020 has been 359 euros per tonne (49 euros per barrel). As can be seen visually from the figure there has been great variation among the prices.

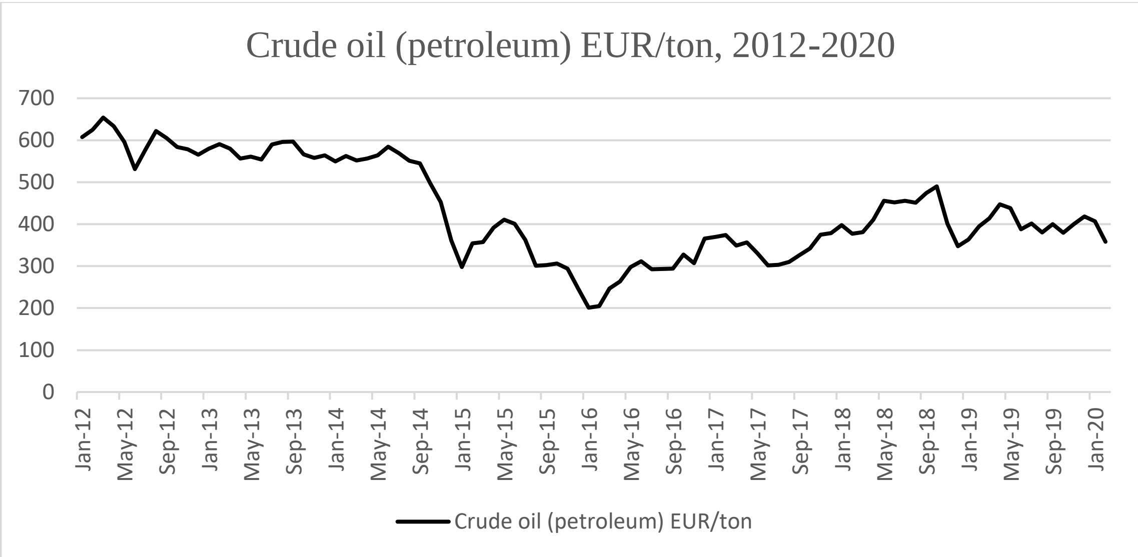

Figure 2. Price development of crude oil 2012-2020 (Indexmundi 2021)

3.4 Production costs of renewable diesel

Hydrogenated vegetable oil or commonly referred renewable diesel is a second-generation biofuel. Renewable diesel is produced from a multiple range of different vegetable oils or animal fats and has technical abilities close to fossil diesel. Food industry waste is utilized to produce renewable diesel. Renewable diesel can be mixed with fossil diesel with high percentage or can be used as such in diesel fuel engines. Hence renewable diesel can be blended by several percentages and meeting the fuel quality standards or used as a 100 % renewable fuel in heavy duty diesel engines (Mikkonen 2008) Currently 100% renewable diesel is sold in gas stations in Finland and has been approved by several car manufacturers. In this chapter the aim is to analyse the literature that has studied the cost environment of renewable diesel production thus finding the justifications for the inputs chosen in the analysis of this thesis.

Capital costs are the overall investment of the project that include installation of the plant and the purchase of the equipment. Precise publicly available cost related information about biorefineries producing renewable diesel is low. UPM invested 179 million euros to a biorefinery producing renewable diesel from tall oil with a current production capacity of 160 million litres (UPM 2021). St1 released a plan to invest 200 million to a new biorefinery, plant would operate in Sweden producing 200 000 tons of renewable diesel and the production would start in 2020 (St1 2019). However, investment cost to renewable diesel production significantly higher, according to Neste Oyj (2009) press release of the investment of 800 million euros with a capacity of 800 000 tons. Kalligeros et al. (2018) estimate the capital cost of a renewable diesel plant can have a range from 500 -1500 Eur per ton of produced fuel. Furthermore, Holmgren et al. (2008) building a biorefinery plant on an existing petroleum refinery infrastructure the capital costs can be minimized thus renewable diesel production would require less capital investment. (S&T)2 Consultants Inc. (2018) estimate that the capital cost of a 500 000-ton biorefinery would be 0,86 euros per litre, concluding to a total investment of 430 million euros. To conclude it is noticeable that the production quantity increases the capital cost since the overall investment is greater due to larger purchases in equipment and installation.

Operating costs include the daily operating expenses which include raw material costs and other daily operation expenses. Kalligeros et al. (2018) analyses production costs for biorefinery producing renewable diesel from waste residues ranges from 0,60 – 1,1 euros per litre. They state that the cost of raw material is 60 – 80% of the total operating costs. The production cost of renewable diesel produced from wood biomass and residue was studied by Patel et al. (2019) concluding renewable diesel production cost to a range of 0,98 – 1,27 dollars per litre (0,81 – 1,04 Eur per litre). To compare the dollar-based estimates with Euros, US dollars are converted to Euros with the average exchange rate in 2010-2020 from OECD (2021). Furthermore, Festel et al. (2013) created a calculation model to generate information about future cost of biofuels, renewable diesel or hydrotreated vegetable oil as stated in their study has production cost of 1,28 euros per litre in 2020, raw material used in this study for calculations was palm oil.

4 ANALYSIS

This study aims to explain the effects of biofuel policies in Finland to the investment profitability of a biorefinery producing renewable diesel and fossil diesel. The analysis concentrates on analysing the profitability of a fuel producer producing renewable diesel and diesel, under Finnish biofuel distribution obligation. Additionally, production types of both only renewable diesel and fossil diesel production are analysed to further understand the impact of biofuel policies to the profitability. Since there is no publicly available data of the cost environment for specific to biorefinery projects in Finland, estimates were made based on plants currently operational in Europe. The aim is to analyse the impact of multiple biofuel policies and their effect on the profitability of a fuel producer under the biofuel share required by Finnish distribution obligation for biofuels. This section explains analysis methods used in this study.

4.1 Net present value method

Net present value (NPV) method is described by Götze et al. (2015) in their study to be the monetary loss or gain from a project over the whole lifetime of the project, by discounting the future cashflows of the project hence the cash flows are discounted the net present value indicates the present value of the investment. Net present value is one of the most common tools used in calculating the profitability of a project or an investment. Cash flows from each year of the project are discounted to present time to generate the profitability of the project. Positive NPV indicates that the project generates value to the investors while negative NPV will result in losses. Key concept of the method is that the project is profitable if the net present value is greater than zero, furthermore method can be used to compare different projects thus allowing to choose the investment with the highest net present value (Beaves 1993). Before introducing the NPV equation, cash flow calculations are conducted with equations 1-4:

$$EBITDA = Revenue - Operating\ costs \tag{1}$$

Revenue is calculated by multiplying the price of fuel with the production quantity and it implies to the total sales of fuel. Operating costs are total costs of both renewable diesel and fossil diesel production, including the costs of refining both fuels, crude oil and raw material costs to produce fuel. Earnings before interest, taxes, depreciation, and amortization are calculated from these according to the equation 1.

$$EBIT = EBITDA - Depreciation \tag{2}$$

Earnings before interest and taxes is calculated by subtracting the depreciation from EBITDA.

$$Net\ income = EBIT - Taxes - Capital\ costs \tag{3}$$

Taxes are deducted to achieve the net income of the specific year. In cash flow models where fuel taxation is analysed, the fuel taxes are subtracted to receive net income. In cash flow models without fuel taxation the only taxes that are deducted is taxes based on the corporate tax rate. Capital costs in cash flow models occurs in year zero when they are subtracted from the net income.

$$Cash\ flow = Net\ income + Depreciation \tag{4}$$

Cash flows used in the net present calculations are derived from net income to which the depreciation is added back to be included in the present value of cash flows.

The net present value method can be described with following equation to assess the investment profitability:

$$NPV = \sum_{i=0}^{n} \frac{CF_i}{(1+r)^i} \tag{5}$$

CF is discounted cash flows for the generated cash flows at time **i;**
i is the time in years or the lifespan of the investment;
r is discount rate and
n is number of times periods.

4.2 Internal rate of return

Internal rate of return (IRR) is a profitability method used with net present value (NPV) to obtain the discount rate for the project when net present value equals zero. This indicates that the future cash flows for the selected project are zero and the project does not generate gain or loss. Thus, it is a common tool used in comparing projects by analysing the internal rate of return of each project and accepting the one with the highest one. This method will result to an annual rate of return an investor should receive from a certain project. Investment is profitable if the internal rate of return is higher than the discount rate used in net present value method. Internal rate of return can be described mathematically with equation below:

$$NPV = \sum_{i=0}^{n} \frac{Cash\ flow_i}{(1+IRR)^i} = 0 \tag{6}$$

IRR is internal rate of return.

4.3 Sensitivity Analysis

Sensitivity analysis is a common tool to analyse the uncertain variables in profitability analysis. The method helps to predict the future outcome of a project with different ranges of selected variables. In sensitivity analysis one variable is changed under selected scenarios when other variables remain the same thus allowing the management to analyse which variables have a large impact on investment's financial performance, in this research the change in net present value. Uncertain variables are chosen based on their effect on project financial performance. Finally resulting to analyse the change in net present value with different scenarios for the variables. (Dayananda et al. 2002)

4.4 Fuzzy pay-off method

The profitability of projects can be examined with fuzzy pay-off method (FPOM) considering the real option value of the investment. The method presents a fuzzy NPV off pay-off distributions, constructed from three scenarios optimistic, pessimistic, and best estimate, of possible NPV values for future project. Three pay-off scenarios create the fuzzy NPV of the project. The real option is derived from the weighted average of the positive values. Pay-off for the project are presented as triangular or trapezoidal pay-off distribution of three or four cash flow scenarios, respectively. Fuzzy NPV is defined with three cash flow scenarios which each are assigned a degree of membership 0, 1 and 0, respectively. (Collan, Fullér & Mezei 2009, Collan Haahtela & Kyläheiko 2016) The case of three NPV scenarios is illustrated as follows:

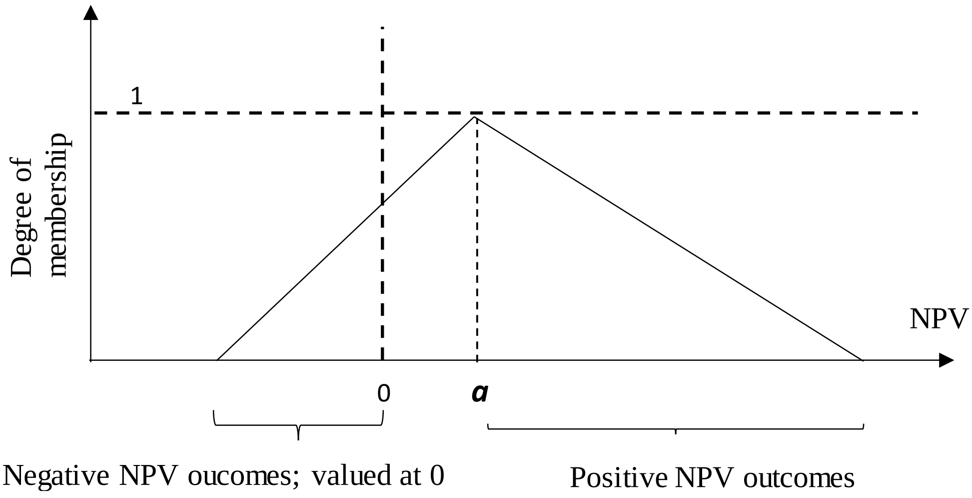

Figure 3. Triangular fuzzy pay-off distribution defined by three points

Real option value can be calculated from three cash flow scenarios as a fuzzy NPV of the project by computing fuzzy mean value of the positive side of the triangular fuzzy pay-off distribution and negative values are valued as zero Equation used to calculate the real option value from the fuzzy NPV in FPOM is presented in equation 7 (Collan, Fullér & Mezei 2009).

$$ROV = \frac{\int_0^\infty A(x)dx}{\int_{-\infty}^\infty A(x)dx} \times E(A_+) \qquad (7)$$

ROV is the real option value;

A is the fuzzy NPV;

$\boldsymbol{E(A_+)}$ is the fuzzy mean value of the positive area of fuzzy NPV;

$\boldsymbol{\int_0^\infty A(x)dx}$ is the area below the fuzzy NPV and

$\int_{0}^{\infty} \boldsymbol{A}(\boldsymbol{x})\boldsymbol{dx}$ is the area below the positive area of fuzzy NPV.

4.5 Model explanation

Model was created in Microsoft Excel to examine the influence of different biofuel policy to net present value of a renewable diesel investment. In total five cash flow models were created to fully understand and analyse the differences in the results for biofuel policies; same input variables were used in following models; cash flow model for no policy support, penalties, and financial benefit. Last two models, including penalties and taxes and only taxes were created with one variable being different, the price of fuel. Models were created to analyse influence of different biofuel policy on the profitability of a fuel producer producing renewable diesel and diesel simultaneously.

There are several numerical assumptions made in the analysis, which are explained precisely in chapter 4.6. Production starts in 2030 thus the biofuel distribution obligation in Finland reaches a 30 % share during that specific year. Policies that are included in the analysis are penalties for not providing biofuels, taxes and financial subsidy which value is calculated by the author. The investment is made overnight to an existing refinery infrastructure to produce renewable diesel along with diesel.

The model was designed to describe the influence of 30 % biofuel share obligation to the profitability of fuel producers in Finland, producing renewable diesel and diesel, furthermore, selling the mixed diesel to consumers. The specific fuel mix has been studied to reduce green-house gas emissions (e.g. Bortel et al. 2019 and Dobrzyńska et al. 2020) thus it reasonable to study the possibility to produce the specific fuel mix with average diesel price in Finland. Thus, it is important to study the economic effect of this specific fuel blend with the distribution obligation of 30 percent share of biofuels according to Finnish legislation.

4.6 Numerical assumptions for the model

In this analysis, operating and capital costs used in the models are based on (S&T)2 Consultants Inc. (2018) unless otherwise mentioned. The operating costs of producing renewable diesel is estimated to be 0,80 euros per litre. Total operating costs per litre for a 500 Million litres plant is 0,80 € per litre, that in line with literature provided by Kalligeros et al. (2018) estimating a range of 0,60 – 1,1 euros per litre for renewable diesel operating costs. Capital cost of the plant is 0,86 € per litre resulting in a total capital cost of 430 Million euros.

The cost of diesel production is derived from crude oil costs and refining costs. IEA (2020b) generated the production cost for diesel to be 0,42-0,46 Usd per litres in United States and 0,51-0,61 Usd per litres in Brazil in 2017. The production cost of diesel varies depending on the crude oil price thus it is crucial to analyse the price development of crude oil and diesel because it is impossible to make profit when crude oil prices are higher than the production costs. Festel et al. (2014) analyze the production costs for fossil fuels and biofuels in Europe. Creating different scenarios of crude oil prices and resulting to a 50 euro per tonne crude oil operating cost for fossil fuel to be 0,3645 euros per liter. Total operating cost of fossil diesel of approximately 0,37 euros per litre calculated by Festel et al. (2014) is used in this study thus the average price of crude oil in 2016-2020 has been 48,71 euros per barrel.

The discount rate used in the analysis is chosen from research articles analysing the profitability of biofuel production profitability. McCarty & Sesmero (2014) and Brown et al. (2013) utilizes in their profitability analysis of second-generation biofuels a discount rate of 10%. To address the inflation in Finland the inflation rate is considered to discount rate described and final rate used in the analysis is 8,91%. Thus, allowing to count the cash flows in real terms.

The economic lifetime of a plant used in studies varies for biorefinery 20-25 years but in most studies, it is assumed to be 20 years. Brown et al. (2013) calculate the NPV an IRR of a second-generation biofuel plant with a lifetime of 20 years, which is also used in the study. Corporate tax rate of 30 % is used in the analysis and fuel tax rates are derived from Finnish Tax authorities (2021) to fossil diesel and for renewable diesel.

In this analysis the profitability is calculated based on the average price of diesel 0,53 euros per litre. The price development of diesel in Finland is described more detailed in previous chapter in Table 7. The price of diesel including the taxes is derived with the same logic and it is calculated to be 1,12 euros per litre. The price of fossil diesel is used in the analysis thus it is assumed that the fuel producer blends the produced renewable diesel to achieve the blending requirements settled in biofuel distribution obligation. Furthermore, the revenue is generated from selling the blended fuel.

Table 6. Parameters for fuel production

Input	*Value*
Plant size renewable diesel	500 million litres per year
Plant size diesel	1166 million litres per year
Operating costs of renewable diesel	0,86 euros per litre
Operating costs of diesel	0,37 euros per litre
Investment cost	430 million euros with a 500 million litres production plant for renewable diesel
Price of fuel	0,53 euros per litre
Price of fuel with taxes	1,12 euros per litre
Discount rate	10 %
Assumed start of operation	year 2030
Lifetime of the investment	20 years

5 RESULTS

This section presents the results of the previously described analysis methods. Net present value was conducted for three different fuel production types with five policy scenarios to analyse the effects of biofuel policies to the profitability. Furthermore, sensitivity analysis is conducted for four policy scenarios. Finally, the results of three policy scenarios are examined with pay-off method. Policy scenarios analysed in this section are referred as following throughout this thesis:

(1) No policy support.
(2) Penalties paid for not providing 30 percent of biofuels to distribution.
(3) Penalties and excise taxes, current Finnish biofuel policy.
(4) Financial benefit subsidy that is received for each litre of renewable diesel produced.
(5) Excise taxes paid for each litre of fuel sold.

Furthermore, sensitivity analysis is conducted to observe the differences in key variables for each policy scenario. Finally, the results are examined with pay-off method.

Each policy scenario is analysed with following production types to analyse the profitability of different fuel blends:

- Fossil diesel production only
- Renewable diesel production only
- 30 % renewable diesel and 70% fossil diesel production

5.1 Net present value

Net present value for the twenty-year renewable diesel expansion project can be seen in Tables below for the different production types and policy supports. In this section the analysis concentrates in three different production modes to examine the variance in net present value for different policy supports. First production mode *Diesel production* listed in the table column signifies a fuel provider that produces only fossil diesel and does not produce renewable diesel, which can be seen in row share of renewable diesel. The second production mode *Renewable Diesel (RD)* presents a fuel provider producing solely renewable diesel and selling it with the average price of diesel at 2012-2019 in Finland. Last production mode in the columns *Renewable diesel and Diesel (D)* attends to the fuel supplier producing the share of biofuels obligated according to Finnish biofuel obligation. Tables 8-12 presents the results obtained from net present value calculations with different policy support and no policy support, the policy type is indicated in the table title.

Table 7. Net present values for policy scenarios

	Diesel production	Renewable diesel production	Co-production of both fuels
Renewable diesel, Million litres per year	0	500	500
Diesel, Million litres per year	1166	0	1166
Share of Renewable diesel	0%	100%	30%
Penalties, Million € (policy scenarios 2 and 3)	-4035	0	0
NPV (1 no policy support), M€	1112	-1180	-67,8
NPV (2 only penalties), M€	-2957	-1180	-67,8
NPV (3 penalties and taxes), M€	-2957	-405	674
NPV (4 financial benefit), M€	1112	-1112	0
NPV (5 only taxes), M€	1078	-405	674

Overall, it is noticeable that renewable diesel production is not profitable without policy support. In Table 7. the NPV for each three production types are generated without **any policy support**. Net present value for fossil diesel production is highly positive and fuel producer has no incentive to produce renewable diesel, due to the net present value being deeply negative. Thus, it is economically profitable to only produce fossil diesel without any policy support. Furthermore, co-production of renewable diesel and fossil diesel is also slightly negative.

Second policy scenario of fuel production with **only penalties** (2) shifts net present value of fossil diesel production deeply negative, due to large number of penalties needed to be paid for not providing biofuels to consumption. Since penalties only affect the net present value of diesel production other net present values for two different production types remain the same as with no policy support scenario. Overall, each production type has a deeply negative net present value, thus none of them is profitable.

Next is a policy scenario considering both **penalties and excise taxes** (3). As with other scenarios when penalties are included diesel production is deeply negative due to the large number of penalties the fuel producer must pay as a sanction payment for not producing or buying biofuels. Net present value of renewable diesel production is negative, but the effect of lower tax rate of biofuels can be noticed since the net the net present value is higher than with other policy scenarios, -405 > -1 180 or -1 112 million euros. Furthermore, the last production type of 30% renewable fuel production becomes profitable thus the fuel producer is not bounded to pay penalties since it produces the required share of biofuels. The value of overall excise taxes paid in one year is 165 million euros for a 500 million liters renewables diesel production, when the fuel is mixed with fossil diesel.

Financial benefit (4) is a financial incentive that is received for each liter of renewable diesel produced. The value is calculated with goal seek method to obtain a zero net present value for production type of 30% renewable diesel and diesel. It indicates that investors receive the required rate of return from the project, thus the project generates no loss neither significant profit. Diesel production is profitable, but renewable diesel is still deeply negative.

Finally, by taking a closer look at the net present value results from only **taxes** (5), fossil diesel production becomes deeply profitable, and the production generates profit. Even though fossil diesel producer must pay a large amount of taxes, the profit margin with current outputs is high thus the production is profitable. The amount of taxes needed to be paid is significantly smaller with renewable diesel than with fossil diesel, but since the production of renewable diesel is not profitable with current fuel price the net present value is as well negative. Final production type with both fuels is positive.

Overall, it is obvious that policy support is needed to offset the production of fossil fuels, since at no policy scenario the fossil diesel producer receives huge profits and will keep producing fossil diesel without policies. Without any policies affecting the fossil diesel producer incentive to produce other fuels than fossil fuels, it is not profitable for the fuel producer to produce renewable diesel mixed to fossil fuel simply from a financial perspective. The price of penalty influences the fuel producer’s net present value making it deeply negative thus. In the observed cases the number of penalties create a higher loss to fuel producer than the loss that renewable diesel production generates. Furthermore, to increase the production of renewable diesel tax reduction slightly decreases the losses the producer generates from producing renewable diesel. The financial benefit allows investment to be profitable based on the level of support received.

5.2 Sensitivity analysis

Production type under Finnish distribution obligation is examined as base case for which the sensitivity of variables is analysed. The production starts in 2030 hence it is the year when the share of biofuels must be 30 % from all fuels sold. The sensitivity is measured to the co-production of both fuels including each policy scenario. It is noticeable that variables have different effects, in previously mentioned policy scenarios, to the profitability of the project what can be observed from the shapes of the figures below.

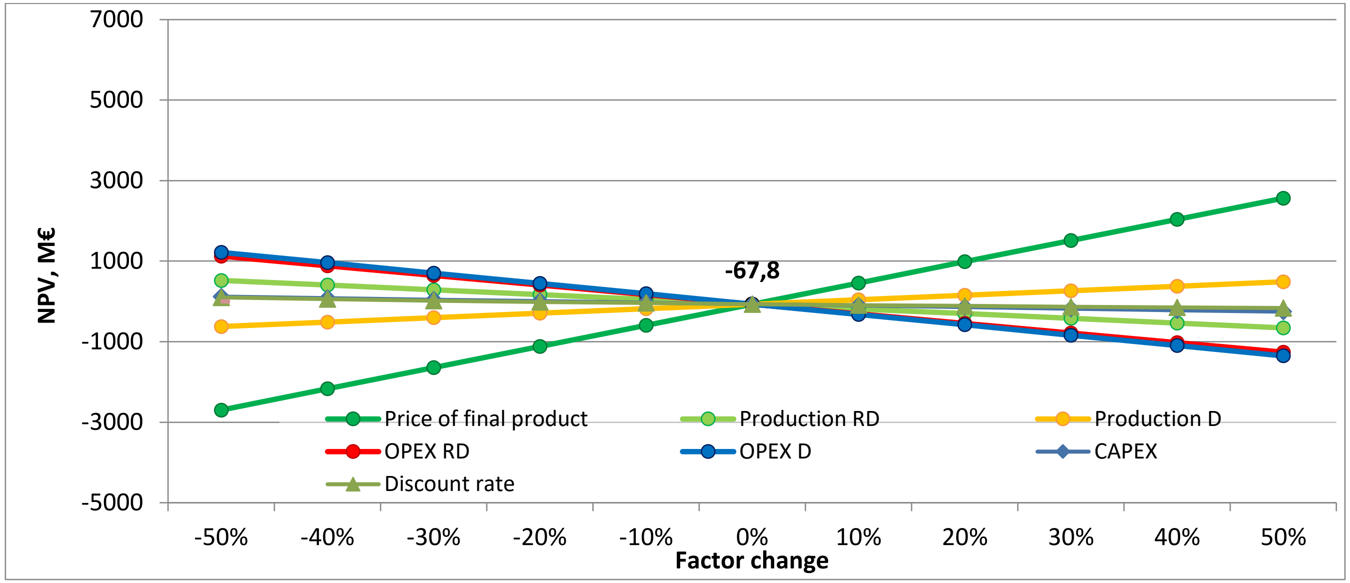

Figure 4. Sensitivity analysis of fuel production with no policy support (1)

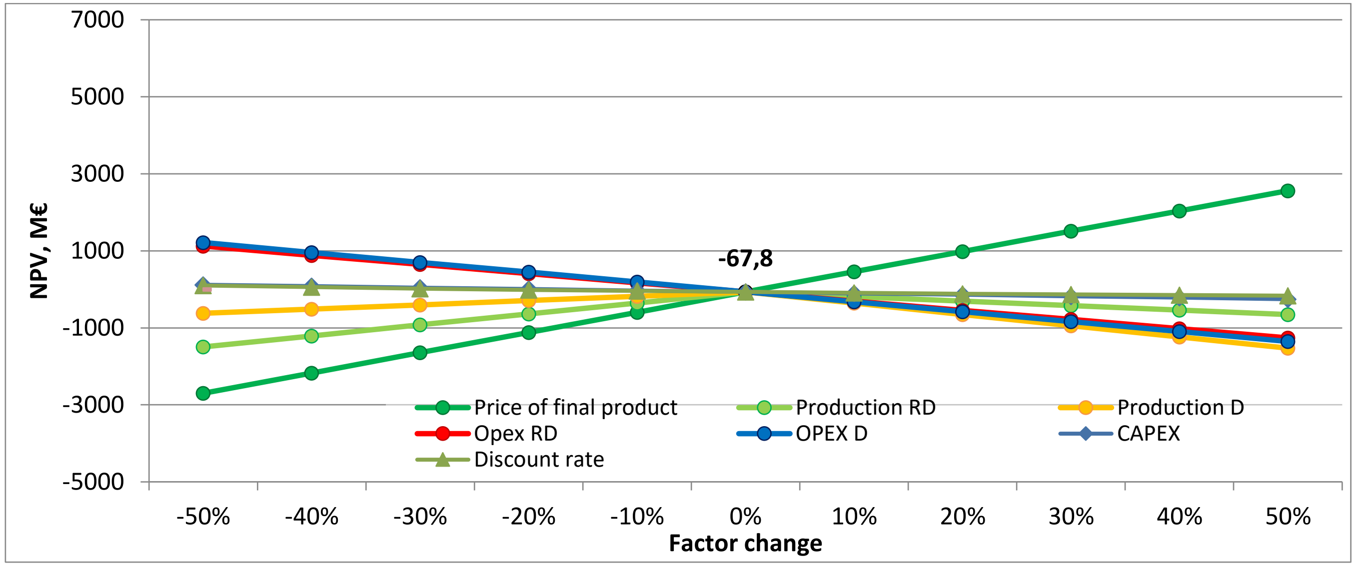

Figure 5. Sensitivity analysis of fuel production with penalties (2)

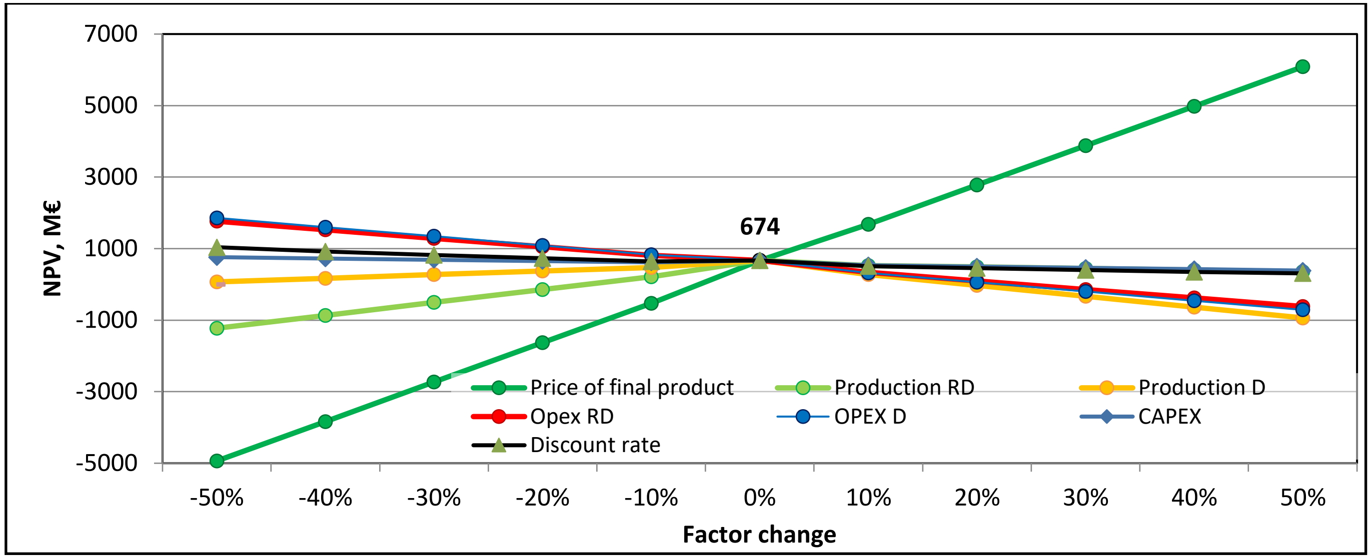

Figure 6. Sensitivity analysis of fuel production with penalties and excise taxes (3)

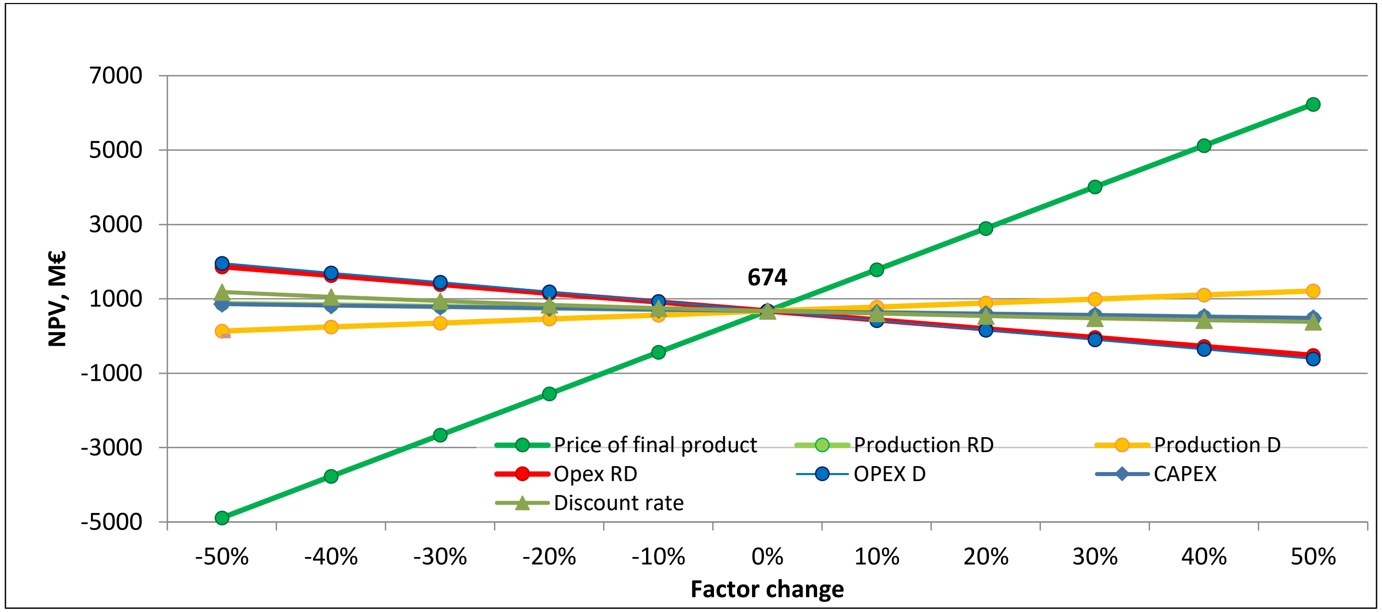

Figure 7. Sensitivity analysis of fuel production with excise taxes (5)

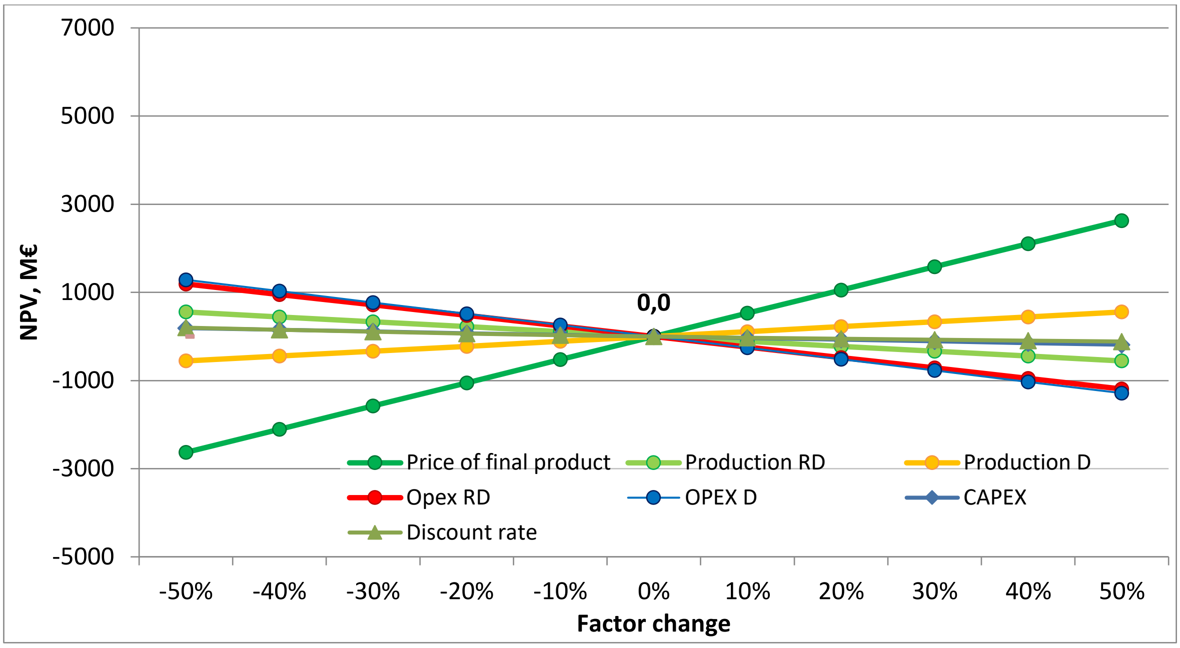

Figure 8. Sensitivity analysis of fuel production with financial benefit (4)

First, by comparing each policy scenario it can be observed that in policy scenario 1, 4 and 5 fuel producers can increase profitability by increasing the production of fossil diesel and by decreasing the production of renewable diesel. As in policy scenarios 2 and 3 the increase of fossil diesel production will result to a negative NPV, due to the penalties needed to be paid for not providing a 30 percent share of renewable fuels in distribution.

As seen in each policy scenario price of the final product has the largest influence on net present value of the project since it has the largest positive scope. The final price of fuel affects the revenues of the fuel producer received from the sold fuels. In policy scenarios 1, 2 and 5 the increase of 10 % in price of final product, makes project significantly profitable. Furthermore, price of final product is the only variable that has a positive impact to the net present value in the positive range in policy scenario 2. Price of final product has the largest negative scope of all the variables examined, thus having a significant negative impact to the project's profitability if the price decreases as expected. Net present value is positive in scenarios 3 and 5, in both scenarios tax deduction for renewable diesel is included. Overall, price of final product has a much higher effect to net present value compared to other variables. Taxes seems to have an impact to the profitability of the project and considering the lower tax rate of renewable diesel the co-production of both fuels, production becomes profitable.

The impact of the penalty for not providing biofuels in distribution can be observed from the production of diesel in policy scenarios 2 and 3. Production of diesel signifies the quantity of diesel produced by the fuel producer and it impacts the profitability negatively both by decreasing and increasing in scenario including the penalties. When the production quantity of diesel increases, fuel producer is obliged to pay penalties for each percentage of no renewable diesel distributed. The quantity of fossil diesel increases thus the share of renewable diesel is smaller than 30 %, hence the penalties for non-compliance of biofuel distribution obligation impact decreases net present value. Alternatively, the decrease of diesel production also leads to a decrease in net present value hence fossil diesel has a higher profit margin than renewable diesel in base scenario. Moreover, by taking a closer look at production of renewable diesel in policy scenarios 2 and 3 it has the same pattern as production of diesel with a larger impact to net present value in the negative scope. The fuel producer is obligated to pay penalties when there is a decrease in production of renewable diesel thus the distribution obligation is not fulfilled. The negative impact to net present value has a steeper angle after the base case than diesel production thus indicating that paying the penalty will result in a significant economic loss. Overall, the production of diesel does not affect net present value as much when taxes are included in the model but affects net present value negatively in the positive scope after a 20 % increase. However, production of renewable diesel has a negative effect on profitability after the production quantity decreases more than -20 %.

Both operating cost of renewable diesel and diesel has a significant impact to net present value while there is an increase in costs, as well when there is a decrease in operating costs. Only a 10% decrease in operating costs results to a positive net present value of the project in scenario 2 where only penalties are penalties included. From each policy scenario it can be observed that operating cost of both renewable diesel and diesel seems to have the largest positive impact on net present value in the negative scope. Operating costs of diesel have a slightly higher impact in profitability, but operating costs of renewable diesel follows parallelly. The change in operating costs increases the profitability the most in the negative scope and decreases the net present value in the positive scope, expect in policy scenario 2 and 3. In scenarios where penalties are included as policy support, the production quantity of diesel has the largest negative influence in net present value in the positive scope.

Capital cost of plant producing renewable diesel and diesel has almost a non-existent impact on net present value of the project with chosen possible range of variation +/- 50% in all policy scenarios. This is explained by the high value of operating cost a renewable diesel plant requires thus the change in capital cost does not have a significant impact in profitability. The annual operating cost of renewable diesel are close to the total investment of the plant. The initial investment is high but compared to the operating cost that are needed to produce renewable diesel and diesel is higher, hence the raw material cost and the crude oil cost are included in operating costs. Purchase of these materials is necessary to produce both renewable diesel and diesel, thus the operating costs are high and the influence on capital costs are not significant.

One significant limitation of sensitivity analysis is that it can only examine the change of single variable at a time while other variables remain the same. In the real world it is rare that only a single variable changes in a financial analysis, and other variables remain the same. However, sensitivity analysis is a great tool to examine the influence of single variables to the projects profitability as previously mentioned.

5.3 Triangular pay-off

This section illustrates the results of policy analysis with the fuzzy pay-off distributions. The triangular distributions are constructed out of three production modes, renewable diesel ( ), co-production of both fuels ( ) and fossil diesel ( ). Such pay-off distributions are constructed for each policy scenarios. The title of every figure specifies the policy scenario. Negative NPV values are highlighted in red and positive NPV in green.

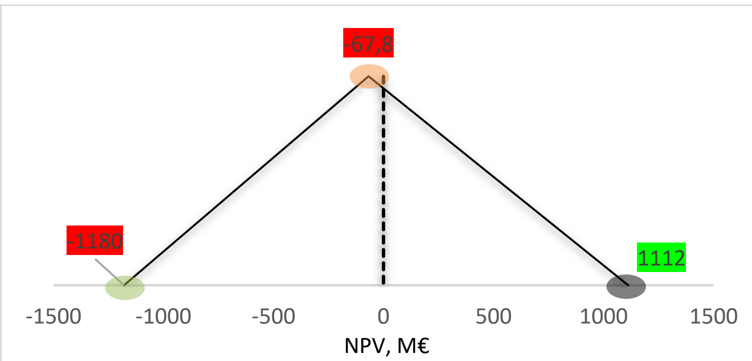

Figure 9. Triangular pay-off distribution with no policy support (1)

Project with no policy support results to pay-offs where only one production type (fossil diesel) is profitable. Other production types of renewable diesel (-1 180) and co-production of both fuels (-67,8) are situated in the negative area of the triangular pay-off.

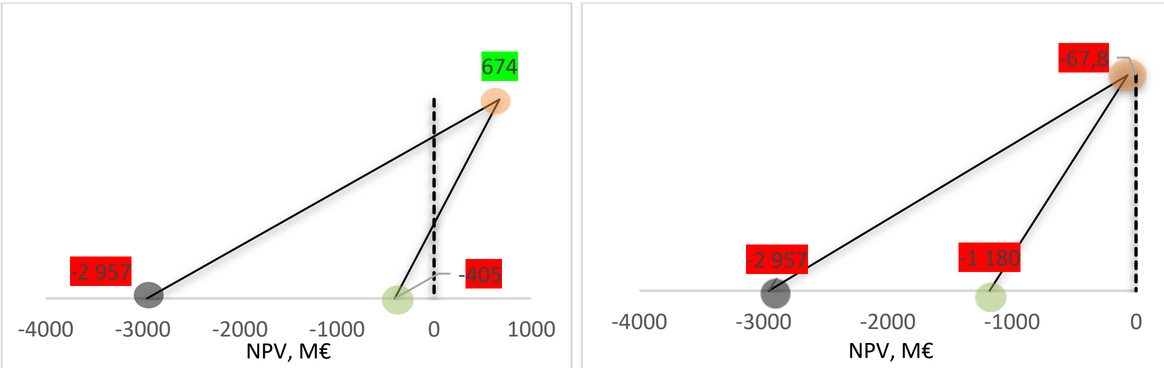

Figure 10. Triangular pay-off distribution with penalties and excise taxes (3) (left) and penalties only (2) (right)

Under penalties and paying excise taxes the co-production (renewable diesel and fossil diesel) is profitable in scenario (3). The NPV for co-production of fuels is higher when including lower tax rates for renewable diesel, compared to policy scenario (1). When including only penalties (2) as policy support each three production modes have a negative net present value. Renewable diesel production only in policy scenario (3) an (2) has a negative net present values indicating that production is not profitable alone with current price of diesel. However, including lower tax rates with penalties as policy support the net present value for renewable diesel production increases.

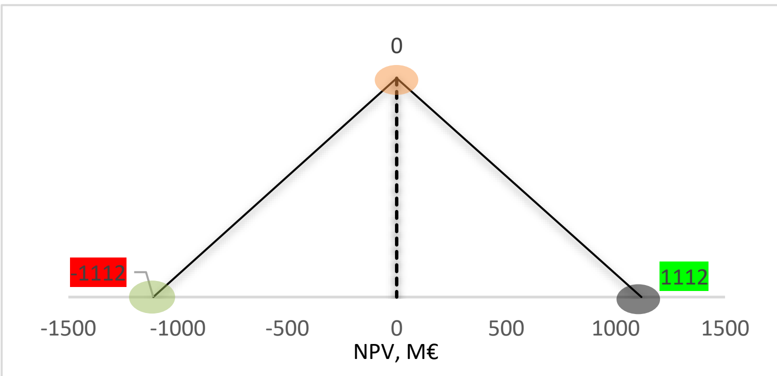

Figure 11. Triangular pay-off distribution with financial subsidy (4)

The financial subsidy level is defined to set the NPV of the co-producing case to zero. However, the production of fossil diesel remains profitable since there are no penalties included that the producer needs to pay and NPV for renewable diesel production remains negative. Additional policies are needed to offset the production of fossil diesel as can be seen with policy scenario (2) and (3), where NPV of fossil diesel production is deeply negative for not providing the required share of biofuels to consumption.

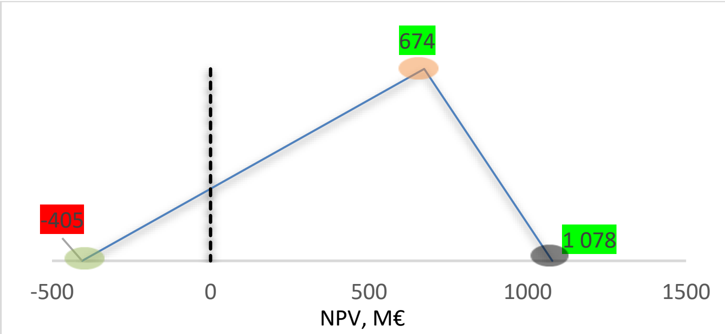

Figure 12. Triangular pay-off distribution with excise taxes (5)

As can be seen in Figure 12. the fossil diesel production has a positive NPV without penalties included as a policy support for biofuel production. Penalties have a significant negative effect on profitability of fuel production if producer does not distribute the required volume of biofuels to consumption.

Real option value calculation based on fuzzy pay-off method was not calculated since the pay-off distribution in this thesis is not based to three possible NPV scenarios of the same project but to compare the production modes. Thus, ROV is not calculated because it would not bring more insights to the analysis of the profitability of the fuel mix. In this thesis the triangular pay off method is used for illustrative reasons to compare the fuel mix to policy scenarios.

Overall renewable diesel production alone is not profitable in any policy scenario with current price of diesel and the production cost of renewable diesel are high. If production costs of fossil diesel remains at the same level as analysed in this thesis the losses generated from renewable diesel production can be reduced in the co-production (renewable diesel and fossil diesel). However, analysing renewable diesel production alone, the production would generate losses for the producer at current price of diesel thus price of diesel is under pressure to increase when 30 percent of renewable diesel is mixed to diesel.

6 DISCUSSION

Finnish government released a mandate to increase the share of biofuels in transport to 30 percent by 2029. Finnish legislative includes lower excise tax rate for certain biofuels and sanction payments (penalties) to producers if they are not able to distribute the required share of biofuels in distribution each year. The goal of this thesis was to find whether Finnish biofuel policies encourage investments to biofuel production in Finland. The required share of biofuels in Finnish distribution obligation was used as one production type to analyse the effect of biofuel policies and whether the production can be profitable with current price of fuel. The best way to analyse policy measures from the profitability perspective was to use net present value method for different policy scenarios and compare the effects of variables in sensitivity analysis. Empirical section analyses biofuel policies currently in Finland including penalties and taxes, additionally a financial benefit was analysed to further compare it with biofuel policy scenario 3. The results indicate that net present value for renewable diesel production alone is not profitable in any policy scenario with the average price of diesel Finland thus the co-production of both fuels is profitable in policy scenario 3. This indicates that renewable diesel must be sold at a higher price for the production to be profitable thus the prices of fuel could increase when renewable diesel is mixed to fossil diesel.

The importance of penalties as a policy can be seen in sensitivity analysis comparing policy scenario (1) with policy scenario (3). In the no policy support case, by increasing the production of fossil diesel the producer can receive higher return thus, having no financial incentive to produce renewable diesel. The strong effect of fuel price can be seen from the sensitivity analysis, only with a 10 % increase the co-production of fuels becomes highly profitable. Especially in policy scenario (3) including taxes and penalties, the price of fuel has the most significant effect to profitability in sensitivity analysis. The price of fuel might have pressure to rise in the long term as the share of biofuels will increase. The results of this thesis indicate that policy measures are needed to discourage the production of fossil diesel as well to increase the production of biofuels. As Araujo Enciso et al. (2016) states that the production of biofuels would decrease without effective biofuel policies, the same conclusion can be found in this thesis by observing the no policy scenario (1). The penalties needed to be paid for neglecting the share of biofuels in Finland offers a sanction incentive to produce or buy the required amount of biofuels. In all policy scenarios the net present value is deeply negative when producer chooses only to produce fossil diesel when penalties are included as a policy. The project would not be proceeded in a case of negative net present value, which encourages companies to find other renewable fuel options to fulfil the Finnish distribution obligation of biofuels requiring a 30 % share. The results suggest that biofuel distribution obligation alone is not enough for the biofuel share to be reached, since without any financial incentive the NPV of co-production is negative. Penalties will create incentive to develop renewable fuels, but penalties alone will not result to a positive net present value of renewable diesel production due to higher operating costs than fossil diesel. The price of fuel will have to increase for renewable diesel production to be profitable as well.

Excise taxes paid of fossil diesel is significantly higher (0,59 euro per litre) compared to the renewable diesel blended to fossil fuel (0,33 euro per litre) and 100 % renewable diesel (0,28 euro per litre). Nevertheless, taxes influence the profitability of fuel mix production at some extent. Net present value of the blended fuel production is profitable when taxes and penalties are included in the model in policy scenario (3). It is profitable to produce the fuel mix, since paying the penalties would result in a significant loss. However, the production of renewable diesel is still unprofitable alone but the production of fossil fuel offsets the loss made from renewable diesel production. Furthermore, financial subsidy was analysed as a production subsidy required for producing one litre of renewable diesel.

6.1 The future of biofuels

Sorda et al. (2010) argue that the main drivers behind the increase of biofuel production have been blending targets, tax exemptions and subsidies. The results of this thesis suggest that blending target provides indeed an incentive to increase the production of biofuels. However further policy support to offset the production of fossil fuel is needed, such as penalties observed in this research. Naylor et al. (2017) suggest that without blending mandates the production of biofuels would not increase, due to high production cost and Araujo Enciso et al. (2016) state that production of biofuels would decrease 32% without any policy support. Similar results are found in this study, as net present value for fossil diesel production alone is profitable without any policy support, indicating that without biofuel policies the fuel providers would likely keep producing the cheaper fossil fuel option. Witcover & Williams

(2014) compare different technological methods that are used to produce biofuels. As results in this study indicate that net present value for renewable diesel production alone is negative in each policy scenario, the future for cost competitive biofuel production could be achieved by technologic development or cheaper raw materials.

6.2 Limitations and further research

Limitation of cost related numerical values should be considered since values used in this thesis are estimated values derived from literature and the results in this thesis must be interpreted as such. Additionally, the results are limited to one renewable transport fuel, renewable diesel, and other biofuels are not considered in this thesis since currently renewable diesel is the only fuel that can be mixed with fossil diesel without a blending limit. Further research should be done to analyse several biofuels to understand more closely the possibility to produce the required share of biofuels thus analysing the biofuel policy effects for a certain fuel producer. Secondly further research should be done to analyse the co-production of both renewable diesel and fossil diesel with exact numerical values and compare the costs of different raw material used to produce renewable diesel. Raw material costs have a large impact on operating costs of fuel production thus the analysis would be reasonable to find the most cost-effective solution.

7 CONCLUSIONS

The goal of this thesis was to analyse whether Finnish biofuel policies encourage investments to biofuels, this was analysed by comparing different policies to current Finnish biofuel policy and their influence to net present value for different fuel production types. Mainly concentrating in the co-production of both renewable diesel and diesel to analyse the distribution obligation in Finnish legislative that obligates fuel distributors to distribute 30 % of all fuel sold as renewable fuel by 2029. This thesis offers indicative results of biofuel policy effect and answers to the main research question below:

How does Finnish and other biofuel policies encourage investments to biofuel production?

In addition to biofuel distribution obligation, Finnish biofuel policy consists of penalties reinforcing the required share of biofuels and lower excise taxes for biofuels. Penalties decrease the profitability of fossil fuel production by a significant amount and creates a sanction-based incentive to fuel distributors to produce biofuels. Overall penalties create a sanction based financial incentive to produce biofuels as taxes paid for biofuels are less than paid from fossil fuels. To answer the main research question comprehensively, sub questions are answered to gain overall picture of Finnish biofuel policy implications to profitability:

What are the main support policies influencing the profitability of biofuel investments in Finland and elsewhere?

Current biofuel policies in Finland include the distribution obligation requiring 30% of all fuels sold to be renewable fuels, penalties needed to be paid for not achieving the distribution obligation target annually and additionally lower excise taxes to biofuels. Overall, the renewable diesel production alone is not profitable in any policy scenario with price of diesel, however co-production of renewable diesel and fossil diesel is profitable in policy scenario (3) including penalties and excise taxes. Including excise taxes as policy support the net present value for co-production of fuels becomes profitable, compared to policy scenario (2) with penalties only. Penalties have a significant negative impact to the profitability of fossil fuels and the fuel producer is encouraged to produce biofuels.

How do different factors influence the profitability of biofuel production under these policies?

Interesting results about the co-production of fuels was found, that co-production is profitable in policy scenario with penalties and taxes even though renewable diesel production alone is not profitable resulting in a negative net present value. Sensitivity analysis revealed that operating cost have a significant effect in profitability in no policy scenario and policy scenario with penalties and taxes. Capital costs have a small effect on the profitability compared to other variables. However, sensitivity analysis indicates that the most influencing parameter to financial feasibility is the price of fuel in all the policy scenarios, indicating that current policies does not create financial support to produce renewable diesel. Overall, the increase in price of fuel would make renewable diesel production alone profitable.

Is co-production of renewable diesel and diesel profitable under distribution obligation?

Co-production of renewable diesel and diesel is profitable in policy scenario (3) that combines penalties and tax relieves. Still the renewable diesel production alone is deeply negative indicating that the price of the average price of diesel in Finland has a too low price for production to be profitable. Overall, according to the results in this thesis the losses generated by renewable diesel production can be offset with fossil diesel production at a certain level of crude oil price. Indicating that the fuel mix of renewable diesel and fossil fuel production is profitable.

Overall Finnish biofuel policy promotes the use of biofuels with biofuel distribution obligation requiring each fuel supplier a 30 % share of biofuels of all fuels distributed to consumption. Renewable diesel production is more expensive than fossil diesel production, thus governmental support is needed to increase the consumption. Penalties are used to increase the production of renewable fuels since the penalties needed to be paid for non-compliance will result to high losses for fuel producer. However, with current policy support the price of diesel is expected to rise in Finland since renewable diesel production alone was not profitable with any policy support.

Information from this thesis can be used as guidance for policymakers and investors trying to understand the impact of biofuel policies to the profitability of a fuel producer. Results offer indications about the profitability of renewable diesel and fossil diesel blend. Fuel blend including 30% of biocomponent to understand the impact of the biofuel share required by Finnish legislative to be distributed to consumption by 2029.

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