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Implications of innovation policy instruments on the diffusion of biofuels for road transports

Comparative case studies between Germany and Finland with insights for Sweden

Master's thesis within the Industrial Ecology program

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Abstract

The transport sector accounts for a large share of released CO_2 emissions to the atmosphere and employment of renewable alternatives are at this point highly demanded to combat climate change. One of the considered options to address the climate change issue is to use biofuels. However, transition towards sustainable transport using alternative technology such as biofuels might encounter multi-faceted challenges in the innovation and diffusion processes, which calls for implementation of innovation policy instruments.

This thesis investigates the implications of innovation policy instruments on the diffusion of biofuels using cross-national comparative based case studies between Germany and Finland. Currently, Germany applies greenhouse gas (GHG) reduction quota as well as tax exemption and biofuels quota in the preceding years, while Finland implements biofuels obligation, taxation system and subsidy for new investments. Comparison between these different policy instruments may generate insights for mutual policy learning for other country, such as Sweden. Assessment of policy instruments in the case studies is based on the policy characteristics and their influences on the establishment of technological innovation functions/processes, which is reflected on the diffusion outcome in form of production and consumption levels of biofuels. The assessed characteristics comprise of stringency, flexibility, predictability, depth, differentiation, consistency, coherence, credibility and comprehensiveness; whereas the innovation processes consist of market formation, legitimation, resource mobilization, and reduced support for fossil fuels.

Findings show that in Finland, production and consumption of biofuels have been growing progressively as a result of strong characteristics in the existing policy instrument mix that are able to settle the innovation functions/processes impeccably. On the contrary, diffusion of biofuels in Germany is not optimized due to the weak policy instrument characteristics that all policy instruments have been having, and thus innovation functions/process have not been able to be established firmly. From the comparative analysis, several lessons can be taken for Sweden if it aims to diffuse biofuels, for example an instrument mix giving long term assurance for investments and good collaboration between actors like in Finland, as well as competition between biofuels suppliers and recurring legitimation issue in Germany that Sweden should avoid.

Keywords: sustainability transition, innovation, diffusion, innovation policy instruments, instrument mix, biofuels, road transport.

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Linda Dyab & Vanessa Gloria, Gothenburg, July 2017

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1
Introduction

This chapter delineates the problem background and purpose of the study as well as explains the research questions and scope of this thesis.

1.1 Climate change and the EU directives

In the last decade, the degradation of the environment and climate change have gained a lot of attention and become one of the most important global issues. Science has shown that the need for a world free from fossil fuels is at this point highly demanded to be able to stabilize the temperature of earth and avoid major irreversible environmental effects. Aside from environmental reasons, there are uncertainties regarding price and supply of fossil fuels connected to political aspects. This drives a debated question about energy security and independence from fossil fuels and is another reason to bring alternative fuels into the market (Sterner & Coria, 2011). The transportation sector stands for a large share of the CO_2 emissions, currently about 30% of all emissions from the developed countries, and is highly dependent on fossil fuels (UNECE, 2016).

In 2009, the European Union introduced a directive where a binding share of 20% of all energy consumption in the EU must be provided by renewable energy in 2020. In addition to this, 10% of the transport fuels have to be provided by renewable sources also by 2020. The directive included several mechanisms that the member countries could adopt to achieve the goals and sustainability criterion for biofuels. As an example, until 2017 the biofuels must have greenhouse gas reduction of 50% in comparison with fossil fuels. The emissions are calculated by considering the whole life cycle taking the cultivation, processing and transport phases into account. Further, the sustainability criteria also protects land with high carbon stock and biodiversity by not allowing biofuels to have been grown and produced from such land areas (EU Parliament, 2016). There are several types of biofuels and each kind contributes differently to the abatement of climate change. The methods used to produce the feedstock and the processes in which the fuels are manufactured affect the amount of released greenhouse gases. By looking at the life cycle for the biofuels, in some cases, methods and processes might cause higher emissions than the use of corresponding fossil fuels. What type of biofuels that are used in a large scale at the market is essential for sustainable development (Greenfacts, 2008).

The transition towards a more sustainable transport is considered as a challenge.

The urge for a change is apparent by the changes in the environment and the rising temperature of earth, but a fear for higher costs and reduced economic growth is affecting the actions towards higher sustainability in the transport sector. The fact that abating climate change would be costly in general and affect the economic balance negatively is however something rebutted (UNFCC, 2014). It has been shown that with the right mix of policies and incentives, the adoption of new technologies reducing the greenhouse gases will also enhance an economic development. New innovations will promote job growth and wealth creation, this also specifically in the transport sector (UNFCC, 2014).

1.2 Theoretical problem

Kivimaa & Kern (2016) mentioned briefly that alternative technologies can rely on their own ability to evolve. However, this process would occur too slow. Now, with the urgency to weaken incumbent technologies towards a sustainable future (Kivimaa & Kern, 2016), implementation of policy measures is therefore advised due to its ability to address this matter of urgency (Flanagan & Uyarra, 2016).

New innovations encounter several challenges when the development and diffusion is about to take place. High costs, uncertainty regarding returns and uncertainty regarding the adoption of the new innovation are examples of a few of these challenges (Long, Blok, & Coninx, 2016). When observing the technological innovation system of biofuels, there are additional challenges connected to the fact that biofuels are intended to replace fossil fuels in the process of addressing the negative environmental externalities. Recent scientific research within sustainability transitions field is pointing out the importance of the shift itself, where the change of major socio-technical systems are imposing multifaceted challenges in terms of correcting several market, system and institutional failures (Weber & Rohracher, 2012). Regulation to steer the development towards sustainability requires therefore to address all these different challenges, where a combination of policy instruments is being put forward as the possible solution (Borrás & Edquist, 2013; del Rió, 2014). Different policy instruments have different functions and purposes where the correct combination of instruments can create synergistic interaction to direct the development (del Rió, 2014).

In this thesis, the implications of a policy instrument mix will be studied specifically for the case of biofuels. Scholars within innovation policy studies have been mainly focusing on the policy instruments themselves and the processes induced by the policy implementation (Kivimaa & Kern, 2016; Rogge & Reichardt, 2016; Weber & Rohracher, 2012), whereas this thesis will have main focus on the outcomes in terms of physical amount of produced and consumed biofuels.

1.3 The Swedish situation

At this moment, the Swedish share of biofuels in the transport sector is larger than 10%, meaning the 2009 EU directive is fulfilled (Svebio, 2016). However, the Swedish government is taking the lead for the use of renewable energy by setting a goal that until 2050 there should be zero greenhouse gases released to the atmosphere from any activity in Sweden. Regarding the transport sector, the vehicle fleet should be independent from fossil fuels in 2030 (Swedish Government, 2016).

In Sweden, biomass energy is currently accounting for 37% of the total primary energy supply (Hellsmark & Söderholm, 2017). Domestic production of biofuels is still largely concentrated on conventional biofuels (made from cereal crops) (Swedish Energy Agency, 2015b). At the same time, several advanced refineries focusing on HVO (Hydrotreated Vegetable Oil), agricultural-based fuel and forest-based resources combined with production of dissolving cellulose at the mill, are already in place. These productions are mainly manufacturing fuels in combination with other products (Hellsmark & Söderholm, 2017).

Several pilot projects for advanced bio-refineries, for example the thermochemical and biochemical conversion of lignocellulosic biomass feedstock, have been demonstrated and supported by governmental means. The testing process has been successful and resulted in a broader network where different actors have created value chains. Many of these technologies are suited to be integrated with already existing industrial operation like the petrochemical and oil industry, pulp and paper industry or the existing bio-refineries, which is advantageous for the establishment. The development of the advanced bio-refineries in Sweden up until the demonstration phase has been progressing but the R&D investments made has not yet resulted in any returns from establishing these technologies in a commercial scale (Hellsmark & Söderholm, 2017).

The main reason of this problem is not perceived as being the technology development, rather un-addressed weaknesses in the system affecting the establishment and reach of maturity level. This innovation process is not given the right pushes to thrive. A technological innovation system approach was used to assess the system weaknesses for the case of the Swedish bio-refinery have specifically identified numerous reasons which include: lack of policy instruments in niche market and commercial growth, week coordination between ministries, agencies and regional actors, weak industrial participation and industrial absorptive capability, weak collaborations over knowledge and organizational boundaries, unclear roles, collaborations, ownership, and financing of research infrastructure, and the competition from fossil fuels and alternative use of raw material (Hellsmark, Mossberg, Söderholm, & Frishamnar, 2016).

In order to achieve the set targets to have a carbon free vehicle fleet until 2030, Sweden has the choice of taking several actions where one option should be the establishment of biofuels in a larger scale (Tekniska Verken, 2016). Considering the theoretical problem at hand, and the current issue of further diffusing biofuels, Sweden can look up at the learning experiences from other countries in terms of how and what kind of political strategy they have used in order to up-scale the diffusion of biofuels.

1.4 Purpose and research questions

This work focuses on the sustainability transition in the road transport sector concentrating on the replacement of fossil fuels with biofuels through implementation of policy instruments. The specific purpose of this thesis is to (i) assess and compare the implications of two different instrument mixes for the diffusion of biofuels for road transports in two different countries, Germany and Finland, from an innovation policy perspective and (ii) based on this provide recommendations for the development of policy instruments for the diffusion of biofuels in Sweden.

The thesis aims to contribute with knowledge about the implications of innovation policies. The focus is thus on the outcome of policy implementations, as well as the iterative learning process of innovation. This distinguishes from the many innovation policy studies which mainly concentrates on the design of innovation policy itself.

To accomplish the outlined purposes, following research questions are proposed:

1. What implications have the instrument mixes had on the diffusion of biofuels in Germany and Finland?
2. What can Sweden learn from the German and the Finnish cases?

1.5 Delimitation

This thesis concentrates on the diffusion of the use of biofuels as a transport fuel in the road transport sector and analyzes the role of existing policy instruments in achieving this. The power and heat sector, marine or aviation sector or the potential for biogas production for example, where biomass as well can be used as an alternative to fossil fuels, are not considered in this thesis. Society and policy makers at EU level are not considered actors. Only biofuels producers and corresponding associations, researchers, as well as energy authority, in respective countries are considered as interesting stakeholders. Further, policy instruments targeting biofuels implemented by the EU or policy instruments targeting the closely connected automotive sector are not specifically being analyzed or assessed. In addition, since this thesis focuses on the diffusion process of biofuels, it will not consider other type of policy instruments such as for research and development or pilot and demonstration phases.

This thesis does not generate any quantitative outcome in terms of the actual contribution to the sustainable development.

2

Theoretical framework

This chapter explains the research theory that is used to motivate the analysis of this thesis.

2.1 The innovation process

2.1.1 Definition of innovation

Innovation is defined broadly and differently depending on the context and person defining it (see for example the definition of Joseph Schumpeter in "Theorie der wirtschaftlichen Entwicklung" from 1912 or the definition of Everett Rogers in "Diffusion of Innovations" from 1962). In this thesis, the following definition are assumed to be appropriate for the context:

"Innovation consists of the generation of a new idea and its implementation into a new product, process or service, leading to the dynamic growth of the national economy and the increase of employment as well as to a creation of pure profit for the innovative business enterprise. Innovation is never a one-time phenomenon, but a long and cumulative process of a great number of organizational decision-making process, ranging from the phase of generation of a new idea to its implementation phase. New idea refers to the perception of a new customer need or a new way to produce. It is generated in the cumulative process of information-gathering, coupled with an ever-challenging entrepreneurial vision. Through the implementation process the new idea is developed and commercialized into a new marketable product or a new process with attendant cost reduction and increased productivity." (Urabe, Child, & Kagono, 1988).

Other definition on innovation points out a situation in which economic and societal circumstances are newly constructed as a result of firms' activity (Borrás & Edquist, 2013). Innovation is known to be a complex, dynamic process that does not progress on a linear pattern (Kline & Rosenberg, 1986). More specifically, the journey of new innovations into diffusion can be described by an S-shaped curve. When observing a technology, the maturity stand can be divided into five phases: concept development phase, demonstration phase, niche market phase, commercial growth phase, and maturity phase (see for example Figure 2.1) (Hellsmark & Söderholm, 2017).

The first three phases represent the stages in which the different actors learn about the new technology, specialists are trained, and new production methods and value chains are created (Hellsmark & Söderholm, 2017). The new technology enters the commercial growth phase when the price and performance ratio are at a competitive level at the market. The industry must have the required opportunity to diffuse the technology on a global scale. When an innovation is established and moves into the maturity phase, there will be a selection process among actors and it will be more difficult for new technologies to compete with this technology (Hellsmark & Söderholm, 2017).

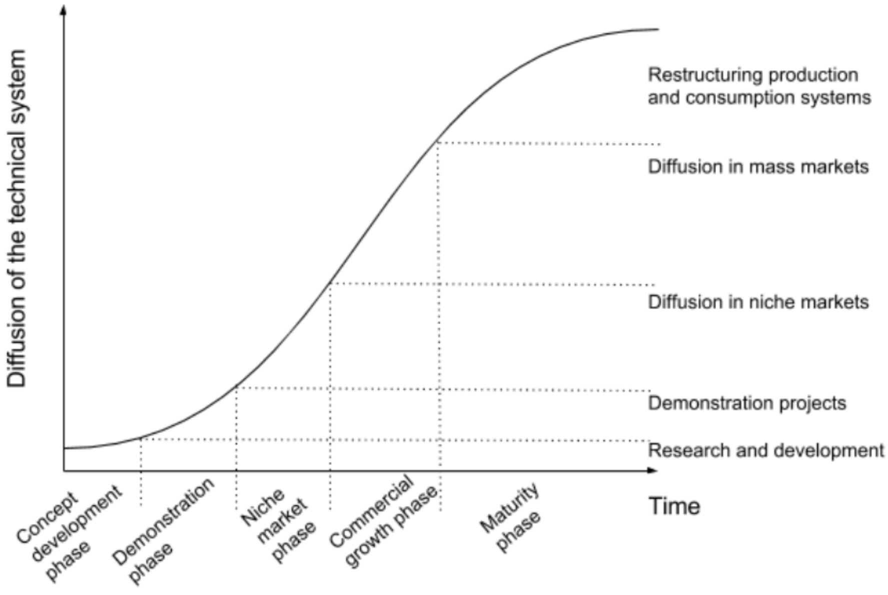

Figure 2.1: Stages in innovation process as depicted on an S-curve (Hellsmark & Söderholm, 2017)

Exploration and exploitation of opportunities for improvements are central in an innovation process as the inventors adjust their product according to advancements in the research field as well as to changes in market demand. The challenge (and impossibility) to forecast the future and to investigate how the product actually will be received on the market creates uncertainty regarding cost and performance. This will also have to be dealt with experimentation and/or improved understanding through research. The process of innovation is in this aspect a matching, iterative learning process (Mowery, Nelson, & Fagerberg, 2005).

2.1.2 System perspectives on innovation

For analysis focusing on technology and innovation, it is argued that a system perspective is needed. A system is composed of different components, working together toward achieving a common purpose. In an innovation system, the components consist of actors, networks and institutions. Their common purpose can be seen as developing, diffusing and utilizing a new product or service (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). A system perspective tries to consider all relevant components and relations. The application of a system perspective on innovation can therefore be used to better illustrate and understand the dynamics and performance (Foxon & Pearson, 2008).

Innovation system approaches has been carried out in different scopes and contexts, whereas technological innovation is the focus in this master thesis. In order to capture the structural characteristics and dynamics of a technological innovation system (TIS), and also include the dynamics of the processes, referred to as "functions", directly impacting the development, diffusion and use of the new technology, a now well-established framework is presented by Bergek et al. (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008). These functions compose of processes essential for innovation (Bergek et al., 2008), where a combination of processes dealing with the destabilization of undesired incumbent technologies can be added (Kivimaa & Kern, 2016).

The definition of the different processes or "functions" slightly differ among researchers but are to most extent similar. Table 2.1 presents definitions of the different functions by Jacobsson and Bergek, 2011, for the innovation of a new technology (labeled C for creation) and the definition by Kivimaa and Kern, 2016 for the destabilization of incumbent technology (labeled D for destruction). In this thesis, the main focus lies on the diffusion part of the innovation process of biofuels, which include phases from niche market and further in the S-curve (see Figure 2.1). This means that the analysis conducted further on in the thesis assumes that the technological development, meaning the phase from the invention itself up to the niche market phase, has already taken place.

Table 2.1: Functions presented by (Jacobsson & Bergek, 2011; Kivimaa & Kern, 2016).

Function/process	Description
(C1) Knowledge development and diffusion	Breadth and depth of knowledge, including development, diffusion and integration of knowledge into the system
(C2) Entrepreneurial experimentation	Application of the new technologies in market in which creation of new opportunities and learning process occur
(C3) Influence on the direction of search	Incentives for actors to enter the technological field. These may be embodied in form of visions and expectations of development potential from actors, articulation of demand, etc.
(C4) Market formation	Identification of driving forces that stimulate market formation. This may come in form articulation of demand, institutional alteration, change in price or performance of the technology
(C5) Development of positive externalities	Creation of positive economic side-effect due to innovation and diffusion process, e.g. investment by one firm may benefit the investment by other firm
(C6) Legitimation	Social reception and compliance towards relevant institutions. It is not given but formed through conscious actions from actors
(C7) Resource mobilization	Mobilization of available human and financial capital as well as complementary assets by actors
(D1) Control policies	Creation of policy measures that put pressure on the incumbent technology
(D2) Significant changes in regime rules	Reconfiguration in the institutional rules which are favourable to the status quo/path dependent evolution of the regime
(D3) Reduced support for dominant regime technologies	Removal or reduction of support towards the incumbent technologies
(D4) Change in social networks, replacement of key actors	Replacement of incumbent by new actors, and also replacing existing skill and knowledge of actors with new ones

2.2 Innovation challenges and role of innovation policy

In every innovation process, there will be challenges and several types of barriers are mentioned when the development and diffusion of a new technology is about to take place.

The main key factor mentioned is the financial cost related to technological innovation. The cost of many technological innovation are high, especially in the early adoption stages of the new technology. Establishing production facilities, as technology developers transforms into technology producers, imply high investment costs many times leading to difficulty of generating returns as well as increased costs of the product or service (Long et al., 2016). In addition, innovators feel uncertain to fully benefit from their investments that intended for development of knowledge around the innovation when it can be copied by other actors easily. The social returns of the innovation will in this case exceed the private returns, making it not encouraging enough for the private firm to take such an initiative (Foxon & Pearson, 2008).

The capability of the industry to adopt the new innovation and the capital life time of the incumbent technology also affect the cost of innovation (Long et al., 2016) and are more connected to the diffusion of the innovation. Literature also highlights socio-economic and physiological/behavioral barriers having an important role - the innovation must be accepted in order to be adopted (Hoffman & Henn, 2008). Further aspects important for innovation diffusion are described as the relative advantage of the innovation compared to previous products, the complexity or simplicity of the innovation, its trialability/testability refering to the possible extent of experimenting with the new innovation, and also the observability of it, meaning how easy other can observe its use and effects (Long et al., 2016).

Further, there are more specific arguments for the implementation of innovation policy targeting sustainability transitions. A central feature is the negative externalities. These can be described as the un-priced negative environmental effects different activities have (Foxon & Pearson, 2008), or the non-market side effects of production and consumption (Sterner & Coria, 2011). These types of market failures need to be internalized into the societal costs (Foxon & Pearson, 2008), giving intervention of innovation policy an important reason.

Traditionally, when looking at an innovation system, the approach used mainly focuses on stimulating economic growth and the ability for national economies to actually generate innovations. However, an innovation intended to replace an incumbent technology calls for different approaches where the overall societal challenges imposed by the transition must be taken into account (Weber & Rohracher, 2012). The challenge sustainable development impose can only be met by broadening the innovation policies to include long-term strategic orientation and integration with other policy fields. The policies implemented to give momentum to such development must focus on the shift of whole systems of innovation, production and consumption (Weber & Rohracher, 2012).

Further, the societal challenges imposed by a transition can be argued to be dealt through an approach in which incumbent technologies are destabilized along with the innovation process of emerging technologies. More specifically this can be described as weakening reproduction of core regime elements to create windows of opportunity for the up-scaling of niche innovations (Kivimaa & Kern, 2016). The need to destabilize the incumbent technology along side with the innovation when looking at a sustainable innovation system is not only to easily decrease the competition for the new technology, but also to take several actions and attempts to decrease emissions and combat the urgency of climate change and resource depletion (Kivimaa & Kern, 2016).

The combination of the innovation system approach and the transition-based approach resulting in a broader view of system failures (Weber & Rohracher, 2012). The failures in need of correction compose of market, structural and transformational failures, for the purpose of legitimizing and devising policy interventions. This combined approach used to handle transformational failures was conducted through a multi-level perspective of socio-technical transitions motivated by its ability to deal with devising policies explicitly in support of goal-oriented transformative change. An additional reason to use an approach like this compared to a traditional innovation system approach is to put focus on the consumption and production side of the system transformation, whereas the traditional view puts focus only on the supply side. In addition, it better addresses coordination between researchers, technology and innovation policy and recognizes the importance of reflexivity for the shaping of long-term transformation paths (Weber & Rohracher, 2012), all important highlights when observing sustainability transitions.

2.3 Innovation policy instruments

2.3.1 Mix of policy instruments rationale

As explained earlier, the process towards sustainability transition may constitute different forms of challenges. In general, these challenges can not be solved single-handedly using one policy instrument (Borrás & Edquist, 2013; del Rió, 2014). Often, these complexities appear as multi-faceted barriers in form of various market, system and institutional failures, which eventually calls for an intervention of policy mix implementation instead of individual policy instruments (Braathen, 2007; Lehmann, 2010; Weber & Rohracher, 2012). Under the innovation term, policy mix can be defined as a combined set of policy instruments that are put together to address complexities in the innovation processes (Borrás & Edquist, 2013). A refined concept on policy mix also highlights the dynamic process in which the instruments within the mix emerge and interact (Flanagan, Uyarra, & Laranja, 2011; Rogge & Reichardt, 2016).

Innovation scholars also refer to this combination of policy instruments not only as policy mix, but also as instrument mix. The two terms are often used interchangeably and not always clearly distinguished (c.f. Borrás and Edquist, 2013). However, Rogge & Reichhardt (2016) attempt to clarify the two terms by arguing that instrument mix forms a part of the broad concept of policy mix. In the instrument mix, the policy instruments interact with each other and create interdependent relationships, which becomes central when it comes to achieving policy objective (Flanagan & Uyarra, 2016). Thereby, the concept of interdependence within the instrument mix gains importance for the overarching policy mix as well. For the purpose of ontological simplification, this thesis does not discuss further difference between these typologies and hence continuously and only use the term instrument mix.

2.3.2 Examples of innovation policy instruments

Examples of types of policy instruments are presented by several innovation policy researchers. In terms of mitigating environmental issues, Sterner & Coria (2011) divided policy instruments into four categories. The first category, *using markets*, includes subsidies and taxes/chargers, as well as deposit-refund systems. The second category, *creating markets*, involves creating property rights for natural resources, fundamental for developing and transitional economies. The policy instruments included in this category is property rights and decentralization, and tradable permits and rights. The third category, *environmental regulations*, refer to the regulation of temporal and spatial features of an activity. This category is also connected to lawmaking and politics by including licenses and liability rules. Examples of policy instruments in this category is standards, bans, permits/quotas. The fourth and last category is *engaging the public*, where information disclosure and public participation are included. The importance of dialogue is promoted here, where an opportunity between the polluters, environmentalist/researchers and the public may lead to environmental protection as well (Sterner & Coria, 2011). However, this categorization lacks of a direct connection with innovation and thus depends on the circumstance, objective, and context of innovation where these instruments are applied, it can later be called as innovation policy.

Another classification of environmental policy instrument is presented in Bergek & Berggren (2014) that study how use of environmental policies might affect the innovation process of a technology. Bergek & Berggren (2014) divided environmental policy instruments into several categories such as economic and regulatory instruments as well as general and technology-specific instruments. Economic instruments are formed to create a sort of economic incentives for actors that motivates them to invest in low carbon technologies, while regulatory instruments are more normative in its nature and in favor of restricting actions of actors. On the other hand, general instruments focus on certain group of technologies (e.g. renewable energy technologies), without making any distinction between the maturity level of technologies, whereas technology specific instruments aim at promoting a certain technology directly.

Specifically from the innovation point of view, Borrás & Edquist (2013) categorized innovation policy into three groups in which the classification is to a certain extent similar to what Bergek & Berggren (2014) have. First group is regulatory instruments which controls market interactions through use of legal tools and binding compliances. Due to its obligatory nature, actions of actors are limited to a certain boundary within the regulation. Typically, regulatory instruments entail consequences in case of failure of compliance. This can appear in e.g. financial sanctions, temporary withdrawal of rights. Examples of regulatory instruments are intellectual property rights, competition regulation concerning innovative activities by firms in the market, and other industrial regulations which affects innovation process (Bergek & Berggren, 2014; Borrás & Edquist, 2013).

Second group is economic transfers which aims to encourage financial incentives. This type of instruments is often used to support innovation process from the preliminary stage up to the commercialization phase. Examples are research funding, tax exemption, financial support to venture and seed capital (Borrás & Edquist, 2013). On a specific discussion of environmental innovation, Foxon et al. (2005) analyzed how particular financial incentives can be used to target a further progress on different stages of innovation process if managed properly. Examples given included grants and programs for RD in the initial stage; public procurement, grants and programs for demonstration phase; statutory obligations and fiscal incentives for intermediate maturity phase; environmental taxation, regulations, or trading on fully commercialized stage.

Third group is soft instruments, in which the instruments act as complementary to the first two groups and help to complete the work that instruments from previous group could not execute properly. Soft instruments are non-coercive and formed on a voluntary base. Voluntary agreements, public-private partnerships in knowledge sharing, voluntary standardization, public communication e.g. campaigns, are examples of soft instruments.

From the aforementioned categories of policy instruments, these researchers share a common perception on the innovation policy classification which is economic and regulatory instrument. These two types of policy instruments seem to dominate the policy instruments currently in use (c.f. del Río and Mir-Artigues, 2014). Therefore, this thesis refers to this classification when assessing the policy instruments in the analysis.

2.3.3 Policy characteristics

Recent research on environmental policy with its relation to innovation argues that the effects on the innovation process as result of implementation of (environmental) policy instruments depend more on the characteristics of the designed instruments than on the choice of instrument types (Kemp & Pontoglio, 2011). Thereby, identification of these characteristics is of importance to see to which extent the innovation process is affected by the policy measures in place. As referred to Johnstone, Hascic, Kalamova (2010) and Rogge & Reichardt (2016), following characteristics are outlined as ideal features a policy instrument should have (see Table 2.2):

Table 2.2: Characteristics of policy instruments according to (Johnstone, Hascic, & Kalamova, 2010; Rogge & Reichardt, 2016)

Characteristic	Definition
Stringency	Describes the ambition level of the policy (regulatory and economic instruments) in achieving a target, e.g. emissions abatement
Predictability	Captures the degree of certainty associated with a policy instrument and its future development. Measures the certainty level of a policy with regards to capital-intensive investments and R&D decisions
Flexibility	Describes how much freedom given to actors to fulfill their compliance towards the regulation using their own preferences of methods
Depth	Concerns the availability of incentives in developing range of potential abatement technologies in reaching the policy objective
Differentiation	Deals with the differentiation specified in the policy instruments in respect to industrial sector, power plant size, technology or geographical position

The above mentioned characteristics however only discuss features that influence the performance of a single policy instrument. Since this thesis also focuses on the implications of instrument mix implementation, an additional assessment on the characteristics of the instruments as a mix should also be looked into. This perspective is central because the characteristics would determine whether the instruments in the mix are compatible to each other in attaining a certain target and addressing different failures in the system. This aspect is examined by Rogge & Reichhardt (2016) and the additional characteristics for instrument mix are presented in Table 2.3.

Table 2.3: Characteristics of policy mix (Rogge & Reichardt, 2016)

Characteristic	Definition
Consistency	A condition where instruments within the policy mix can work well together contributing to the achievement of policy goals.
Coherence	A synergistic and systematic process between policy making and the implementation of the policy instrument itself in achieving policy objectives.
Credibility	The degree in which policy mix can be relied on. The existence of credibility depends on the political commitment as well as consistency of instrument mix.
Comprehensiveness	The ability of instrument mix in resolving the underlying barriers and failures in the system thoroughly.

2.4 Framework for policy assessment

In promoting innovative technologies, use of policy mix is emphasized by researchers in the innovation field (c.f. Quitzow, 2015; Reichardt, Negro, Rogge, and Hekkert, 2016). With particular focus on diffusion, implementation of policy mix is required in order for environmental technologies to progress (Quitzow, 2015). In addition, the diffusion of a certain technology is much influenced and supported by the formation of technological innovation system (TIS) (Reichardt et al., 2016). Taking these concepts into account and together with the argument of policy characteristics described in the earlier section, this thesis analyzes how the characteristics of both individual policy instrument as well as within the instrument mix affects the establishment of TIS functions and eventually the outcomes of the policy instruments in terms of production and consumption level. The generated result from the analysis can be used to provide recommendations for mutual policy learning. The assessment of policy characteristics is considered to be of importance since it can point out the performance of the policy instrument and contribute a significant influence on the establishment of the chosen TIS functions. The variable outcome can be explained as a result of the interplay between the instrument mix and the TIS functions. Finally, the thesis compares the result for two different cases representing the situation of biofuels in two different countries and provide insights for the situation in Sweden.

The literature presented above concerns innovation and transitions toward a sustainable future in general terms. As for the purpose of this master thesis, a selection among characteristics and functions has been made and considered to be relevant for the case of biofuels, and more specifically for the diffusion part of the innovation of biofuels.

2.4.1 Innovation policy characteristics

Following characteristics are chosen to analyze the different policy instruments in the respective countries: stringency, predictability, flexibility, depth and differentiation. The importance of stringency role in policy instrument has been increasing since it is perceived as a driving force that contributes to innovative efforts (Bergek & Berggren, 2014). Predictability is vital since large investments have to be done in the biofuels technology if diffusion will take place and thus assurance from the policy is required. Further, Johnstone et al. (2010) argue that the more flexible policy regime is, the more likely an innovation process will occur. From this point of view, flexibility is considered to be a feature which will help innovation to progress by giving the actors options to comply with the existing regulation. Depth discusses whether the policy gives sufficient incentives for the potential technology to reach the target (Johnstone, Hascic, & Kalamova, 2010; Rogge & Reichardt, 2016), which is a discussion valuable in this context. Differentiation is chosen to see whether the policy instruments treat the fuels differently and create benefits for certain fuels, e.g. distinction between fossil fuels and biofuels or within the biofuels type itself, can be of interest when conducting the analysis.

In analyzing the performance of single policy instruments, it is also relevant to examine the performance of the policy instruments as a mix based on its design features. Therefore, this thesis takes into account all characteristics that are suggested by Rogge & Reichhardt (2016). These characteristics comprise of consistency, coherence, credibility as well as comprehensiveness. The motivation to take these characteristics into consideration lies behind the fact that interaction between the instruments within the mix has also significant influence in determining the effectiveness of instruments in achieving policy objective, e.g. in steering the direction of innovation (Flanagan & Uyarra, 2016; Rogge & Reichardt, 2016).

Thus, together with the characteristics that each policy instrument owns, this thesis also investigates the aforementioned interplay within the mix and its relation to the establishment of selected TIS functions.

2.4.2 Innovation/transition-related processes

Out of the given preliminary TIS functions that are presented in Table 2.1s, this thesis only selects functions that have potential influence and are closely related to the diffusion and further adoption of a technology. These functions include market formation, legitimation, resource mobilization, and reduced support for dominant regime technologies. Specifically, the latter function is considered to be of importance when new technology such as biofuels tries to breakthrough and overtake the dominant position of incumbent technology gradually such as fossil fuels, which also becomes the interest of this thesis.

Exclusion of other functions is explained for the reasons that they concentrate primarily on the early development phase or already included to the other chosen functions. For example, influence on the direction of the search and change in social networks can be related to the market formation to a certain extent. In addition, this thesis studies the implication of implementation of both economic and control instruments and does not look into reconfiguration of institutional rules for fossil fuels in particular, which motivates why functions such as control policies and significant changes in regime rules are being left out.

2.4.3 Diffusion outcome

For the case of biofuels, this thesis looks into how the instrument mix in regards to biofuels, through establishment of aforementioned innovation processes, generates outcomes in form of physical amount of production as well as consumption level of biofuels. These variables are decided for the assessment because they reflect whether the policy instruments are able to allow diffusion of biofuels to happen in terms of enhancing production volume as well as elevating consumption of biofuels and its corresponding market share.

This thesis recognizes that each mix of innovation policy instruments is unique and that it is designed to address certain innovation bottlenecks that differs between countries. Thus, the differences between the policy design, implementation, and learning experiences in the studied countries will be able to set up valuable sources for collective policy learning. Having that said, this thesis aims to synthesize the implications of the implementation of different policy instruments on the diffusion of biofuels in Germany and Finland and eventually provide useful recommendations of how Sweden should take its lead on managing the existing biofuels market through deployment of innovation policy mix.

Figure 2.2 shows the illustration of the framework, in which lessons to Sweden will be taken from each of the three boxes from Germany and Finland.

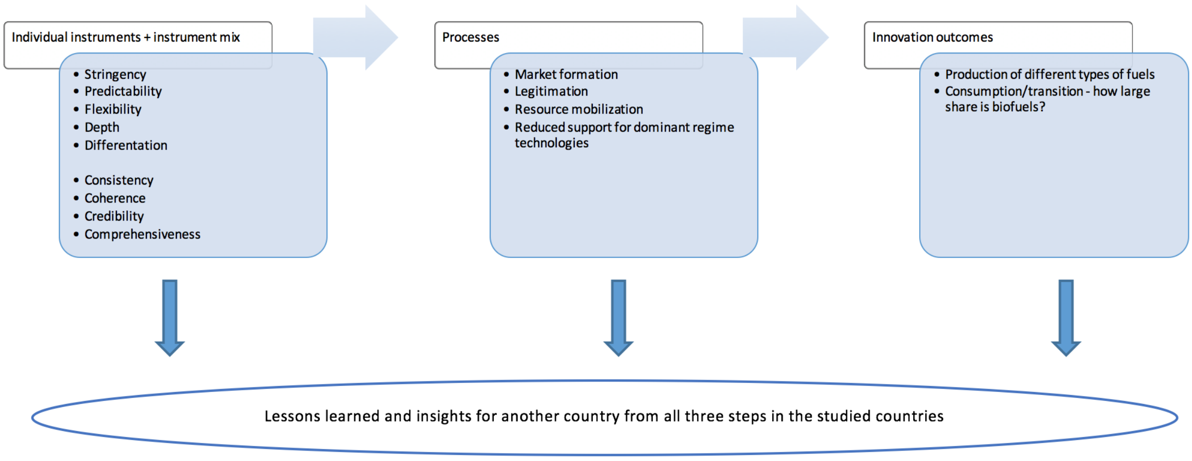

Figure 2.2: The framework assessment of this thesis.

3
Methods

This chapter outlines research methodology upon this thesis was built on.

3.1 Overall study design

This thesis intended to investigate the implications of policy instruments in promoting the diffusion of biofuels in the road transport sector by using Germany and Finland as references. In achieving this, assessment on the policy instruments based on their characteristics and how these influenced the establishment of the TIS functions and eventually the production and consumption volumes of biofuels was carried out. The analysis was done by comparing the implementation of policy instruments in the studied countries in which its result could be used for policy learning in other country, such as Sweden.

The selection of research design determined how the required data was collected and analyzed (Saunders, Lewis, & Thornhill, 2016). This became the reason why the discussion of the research design in this chapter started from the outer layers (see Figure 3.1).

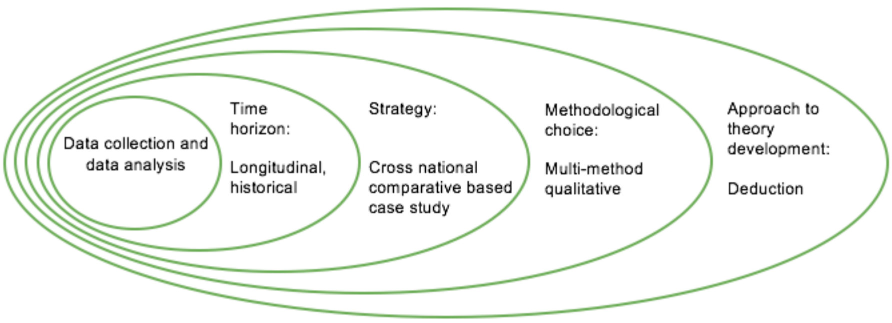

Figure 3.1: Research setting of the thesis based on the concept of research onion by Saunders, Lewis, and Thornhill, 2016.

According to Hakim (2000), cross-national comparative studies could be considered as an approach for research studies that examine numbers of countries as well as observation of trends over time. Cross-national comparative studies could also be applied especially when the research aimed for identification of similarities and differences between the observed countries (Hakim, 2000). In general context, studies with comparative purpose were recommended to use case study in the research strategy (Bryman, 2015). Moreover, this argument was emphasized by Hakim (2000), in which she specifically suggested to adopt case studies in the cross-national comparison since they are more common to be used for the assessment of policy research on national level. Since these arguments were aligned with the intended outcome of this research study, authors decided to employ cross-national comparative based cased studies as part of the research design.

A case study depicted an in-depth investigation of an event within its real-life setting, using multiple sources of evidence (Saunders et al., 2016). In general, case study was often criticized for the misconception about generalizability and replicability (Flyvbjerg, 2004). Discussion about this subject could be found under Section 3.5. Specifically referring to this thesis, a drawback for using case study was a considerable degree of prior knowledge in policy instruments and the biofuels situations in each observed country that was highly required from authors in order to build these case studies and to make an assessment out of it.

Alternatively to case study, researcher could also consider to carry out survey in the research strategy. Similar to case study, survey also represented the real-life context of certain phenomenon in the society, but its data collection was performed within quantitative manner (Saunders et al., 2016). However, compared to case study, the collected data from survey could be utilized to provide reasons for relationships between variables and these could then be visualized through use of numerical model or illustrative graphics (Saunders et al., 2016). Moreover, application of survey strategy would allow researcher to have more control in the research process especially in the generation of desired findings that was statistically representative. However, some weaknesses were also detected in this particular research strategy. Design of a survey would not be able to cover the thorough situation of a research subject thoroughly since survey strategy had certain limitations in its design. For example, for data collection purpose, there would be a limit on numbers of questions that could be asked for a questionnaire. Thus, the collected data could not be as wide ranging as case study. Also, the discussion about implications of certain events would be narrowed down by the chosen variables, which would then affect the conclusion of a research study. Having a limited discussion on the implications of policy measures on the diffusion of biofuels was an example of an issue that this thesis wanted to avoid. Looking from these contra arguments of survey, case study was chosen to be the research strategy in this thesis.

Previous studies on the similar subject seemed to have split preferences between qualitative and quantitative in their research strategies (see for example Costantini, Crespi, and Palma, 2017; Huttunen, Kivimaa, and Virkamäki, 2014; Rogge and Reichardt, 2016). The first two researchers employed qualitative method in analyzing the role of policy instruments in supporting innovation and sustainable transitions processes using renewable technologies as their case studies, while the latter applied quantitative method that created a link between policy mix characteristics and impact on eco-innovation activities based on data econometrics.

This thesis was conducted by close connection to the field of innovation policy and sustainability transitions. The theoretical basis gave the qualitative characteristic in terms of being able to approach the topic in a descriptive manner and argue from different perspectives. A quantitative approach could have provided more exact outcomes and conclusions, in terms of numbers. However, this thesis found that the qualitative approach was mainly most appropriate based on the theoretical foundation where creation of discussion and different actors perspectives have been central. In addition, this thesis did not strive to provide numerical information, which also became the argument why quantitative method was not chosen.

To complement the qualitative research, this thesis adopted research theory of deductive approach in analyzing the acquired data. By using this approach, authors had the possibility to apply the defined theoretical framework to the empirical findings and assess them accordingly. This way, the generated outcome would have a logical sense in it since it would be directly related to the given theory. Other alternative of research theory options included inductive and abductive approaches. The first approach aimed for generation of new theory based on empirical findings, while the latter used empirical findings to refine an existing theory and tested this through continuous additional data collection (Saunders et al., 2016). For this thesis, use of inductive or abductive approach would be less suitable because this thesis analyzed the effects of policy implementation based on the theory of innovation and innovation policy research and did not seek for generation of particular new theory or modification of the existing theory on the innovation field.

To support the description and comprehensiveness of case studies as well as the analysis, this thesis gathered data from various sources, known as multi-method data collection. More detailed information on data collection was presented in Section 3.3.

Furthermore, the case studies in this thesis pursued longitudinal time horizon because it followed the change and development of diffusion process of biofuels over the years in each observed country due to implementation of various policy measures based on the collected data. However, according to the concept of longitudinal studies, data for the research study ought to be collected for several occasions and analysis should be performed over series of time (Bryman, 2015), in which this thesis did not intend to. Thus, looking from these perspectives, this thesis could also be argued as historical study since the observation mainly looked back at historical records and authors only collected data once, namely by the time this thesis was written, and authors did not directly follow the development over time by themselves.

3.2 Case selection

Bryman (2015) introduced five types of case studies: critical, extreme (or unique), representative (or typical), revelatory and longitudinal cases. For a critical case study, researcher picks a case that could deliver a comprehensive understanding of a certain circumstance based on a well-established theory. The case can be used to test the correctness of hypotheses in the given scientific theory. Meanwhile, extreme case study captures unusual events that deviate from common norm or occurrences. This case study is typically used in the clinical studies. The next type of case study is representative, in which it exemplifies the common circumstances that happens in everyday situation. The revelatory case study is used when a researcher makes an observation or analysis on events that previously was not accessible for scientific investigation. The last type of case study is longitudinal in which the case study is observed under two or more different time periods. This kind of case study looks into changes in the observed subject that unfolds during these time periods (Bryman, 2015).

Out of the presented categories, the case study used in this thesis combined critical, representative and longitudinal rationales since these could provide descriptive information that exemplified the biofuels situations in each country including its diffusion process, which could be followed over certain course of time. Since this thesis observed the connection between policy characteristics and technological innovation functions and how these influenced the diffusion (of biofuels) based on the theory of innovation and sustainability transition, the case studies in this thesis could be categorized as critical. From its time perspective, the case studies presented in this work could be argued as historical as well since the data collection was only done once and not continuously as suggested by longitudinal study. Further, the representative case study would enable researchers to unfold key social processes in relation to certain theoretical interest (Yin, 2014). For this thesis, the key social processes was depicted as the diffusion process (of biofuels) due to implementation of innovation policy instrument mix in each studied country.

Other mentioned alternatives were not applicable to this work because they were considered to not be able to set the foundation for comparison and achieve the goal of this study. For example, this study did not look at particular unusual events like extreme case tried to explore since the research focused on the normal/common reality of biofuels, nor revealing a new observation since similar research on this subject was already conducted before (c.f. Reichardt and Rogge, 2016).

As mentioned previously, Germany and Finland, were the main focal points of this thesis. The choice of typical case study for the comparison between systems in both countries could be considered to be suitable since it would be able to represent biofuels situations that most probably vary in the studied countries due to use of different policy measures that contrast to each other in terms of promoting diffusion for biofuels. Currently, Germany implements greenhouse gas reduction quota while Finland runs biofuels quota, taxation system, and subsidy for investments.

Further, the comparison between these case studies could point out the differences and similarities that these policy instruments (mix) shared, such as characteristics and process functions, that explained the different diffusion outcome of biofuels in each studied country, which could eventually enable creation of learning experience in terms of implementation of innovation policy instruments mix for other countries such as Sweden. In addition to constrasting policy measures that they have, Germany and Finland were selected since Swedish actors including researchers discussed and showed their interests in the German and Finnish political strategies within the biofuels field (see Hansson, 2013; Hansson and Roth, 2016). Also, from political perspective, both studied countries share common compliance with Sweden towards EU obligatory framework, which made it interesting to analyze.

3.3 Data collection

Hakim (2000) mentioned that in order to generate a more rounded and comprehensive accounts of the issues for the case studies, researcher may utilize multiple sources for data collection. This data collection procedure is known as multi-method qualitative study (Saunders et al., 2016). In this thesis, data was gathered in two ways. It started with collection of secondary data through literature studies that provided authors with background information on the research topic. It served its purpose in giving authors an overview of current conditions of biofuels in the three observed countries. The literature review ranged from books, scientific papers and journals, e.g. Science Direct, search engines, e.g. Google Scholars, Chalmers library, and websites of official agencies from each country, e.g. the energy agency and the transportation agency. These sources were narrowed down into referring only to the topic of biofuels diffusion within road transports and innovation policy. Since discussion on policy instruments for innovative technology is available in a broad range, narrowing it down to a relevant scope around biofuels posed its own challenge that needed to be addressed by creating limitations and selecting only related studies within the scope of the topic. In addition, limited availability of information on country specific policy instruments created an additional obstacle. This problem was covered using in-depth interview technique with individual actors involved in biofuels diffusion with diverse areas of expertise, such as industries, research and policy makers.

The collection of primary data was done through face-to-face in-depth interviews with respondents. The in-depth interviews were performed in a semi-structured manner, which allowed interviewers to come up with new questions based on the interviewee's response. This technique brought an advantage because at the same time, interviewee was given the flexibility to also steer the conversation and bring additional information that might be relevant for the subject (Hakim, 2000). The direct interaction between interviewer and interviewee allowed both parties to explore and elaborate further around the research topic. For example, in several occasions, interviewees shared additional materials that were not provided online, such as slide presentations, figures, brochures, and discussed the correlations between findings and reasoning based on these materials which brought benefits for the empirical observations for this study. To ensure that the interviews were conducted efficiently, a list of questions that referred to the main research topic had been prepared and sent to interviewees in advance and became priority for the interview. The list of interview questions could be found in Appendix B. Although interview rounds were time consuming since authors were required to mobilize between countries, authors considered this step to be very necessary and of high importance for data collection.

For each country, four until six interviews were performed. With three countries listed for observation, the few number of interview sessions was motivated considering the time and scope constraints that this thesis had, which led authors to prioritize and select only several type of actors as interviewees. The limitation on interview sessions resulted in restricted perspectives and amount of information that this thesis could have explored as well as how much and what kind of conclusions this thesis could deliver. However, this issue was settled through adjustment on the research questions that represent the scope and purpose of this study.

Before interviewees were contacted, authors performed a small research on the internet and looked for important actors and their roles as well as experience in the industry of biofuels and/or policy making for biofuels. List of potential respondents was obtained from various sources of literature studies authors had gathered beforehand. Then, authors sent out emails which content explaining the general overview of thesis, intention of the interviews as well as proposed time and date for interview sessions. After the potential respondents agreed, the respondents were further notified about permission for recording. Also in the same email notification, authors sent out a list of questions to respondents at the latest a week before the interview session took place.

The type of potential respondents ranged from researchers, biofuels associations, industrial actors, and policy makers (see Table 3.1). Respondents being interviewed in Sweden, Germany and Finland shared similar type of actors. Authors found that the diversity of type of actors contributed to different perspectives that were interesting to be analyzed in this thesis. Due to limited scope of this thesis and access to contacts, society, NGOs, and governmental representatives (except for Sweden) were not taken into account. Their views could have been beneficial since it could capture a comprehensive picture of the overall situation of biofuels diffusion. In addition, their perspectives could provide more objectivity, neutrality, and holistic values to the outcome of this work. However, the performed interview rounds were found to be representative enough to cover the analytic purpose of this study.

The first interview rounds were carried out in Sweden with governmental agency, biofuels associations, and industrial actors. The second interview sessions were done in Germany with biofuels as well as oil associations and researchers. In Germany, authors did not manage to get in touch with industrial actors, whose perspective would have been informative for this thesis. This resulted in missing first-hand experience in the biofuels industry and opinions from the biofuels producers that could have been compared in parallel to the Finnish case. Contacts in Germany acted as the so-called gatekeepers for authors since they introduced authors to more connections especially in Finland. The third round of interviews in Finland were completed with researchers, oil/biofuels companies, and oil/biofuels associations.

During the interviews, an installed voice recorder app on smartphones and a recording device were used. As an alternative to avoid technical errors, notes were also taken by authors. Each interview session lasted for 45 until 60 minutes. Due to the amount of interviews conducted, statements or quotations from interviewees could be followed using numbers in brackets that appeared in the texts. For example: "...biofuels have not developed in this country (16)", where 16 refers to interviewee X. The interviewees are listed as following:

Table 3.1: List of respondents for data collection.

Country	Numbering	Institutions or companies	Roles of interviewees
Sweden	1	Perstorp Bioproducts AB	A Swedish chemical company that produces biofuels. Interviewee holds a strategic executive position in the business unit biofuels
	2	Preem Petroleum AB	A Swedish oil company that produces different kinds of biofuels. Interviewee holds a strategic executive position at the company
	3	Energimyndigheten	Engl.: Swedish Energy Agency. The agency works on sustainable energy system in Sweden. Interviewee is senior expert in sustainable fuels
	4	Svebio	Engl.: Swedish Bioenergy Association. The organization represents bioenergy industry in Sweden. Interviewee holds strategic executive position at the association
Germany	5	Fachagentur Nachwachsende Rohstoffe e.V. (FNR)	The institution coordinates research, development and demonstration projects in renewable resources, including biofuels. Interviewee is an advisor in the area of biofuels
	6	Verband der Deutschen Biokraftstoffsindustrie e.V. (VDB)	Engl.: Association of German biofuel industries. Interviewee holds strategic executive position at the organization
	7	Union zur Förderung von Öl- und Proteinpflanzen e.V. (UFOP)	Engl.: Union for the promotion of oil and protein plants. The organization represents interests of companies involved in domestic oil and protein plants. Interviewee is consultant at the association
	8	Öko-Institut e.V.	One of Germany's environmental research institute. Interviewee is a researcher with an area of expertise in alternative fuels, including biofuels
	9	Mineralölwirtschaftsverband e.V. (MWV)	Engl.: Association of German oil industries. Interviewee is responsible for public relations work
	10	International Institute for Sustainability Analysis and Strategy	A transdisciplinary research organization that works on sustainability issues. Interviewee holds strategic executive position at the institute
Finland	11	VTT Techincal Research Centre	Finland's research institute for technology. Interviewee is research professor for energy use in transportation
	12	VTT Technical Research Centre	Interviewee is an expert in solid biofuels and has leading position in bioenergy network
	13	St1 Oy	A Finnish energy company that also produces biofuels. Interviewee holds strategic executive position for the business area of biofuels
	14	UPM	A Finnish pulp and paper (forest) company that also produces advanced biofuels. Interviewee holds strategic executive position at the company and is responsible for the biorefining business area
	15	Öljy & Bio Polttoaineala	Engl.: Finnish Petroleum & Biofuels Association. The association represents oil & biofuels companies in Finland. Interviewee holds strategic executive position and is responsible for energy and climate policies

After each interview was finished, authors directly transcribed the recordings into written documents. This procedure is also recommended by Bryman (2015) to avoid misinterpretation or mixing of data from various interviews. Although time consuming, this way allowed authors to have enough comprehension about the content of earlier interview. It also gave authors sufficient time to reflect on lack of information or minor errors that should be improved in the next interview sessions.

The transcribed recordings became the primary data and together with literature study as secondary data, they created a foundation in which the analysis of this thesis was mainly built upon. During the interviews, authors used specific terms that referred directly to the basic innovation theory and dimensions from theoretical framework. Some scientific and academic terms, e.g. S-curve, were rephrased to words that could be easily understood by respondents. These terms acted as catalysts to extract required information from interviewees. This way, it was easier for authors to structure the interview process and eventually to group the acquired information according to the characteristics, processes/functions, and outcome that were predefined in the theoretical framework. The classification of data was performed following similar responses or issues that were discussed during the interview rounds.

Hakim (2000) also mentioned the possibility of conducting focus group discussion or group interview as another alternative to depth interview with individuals. In this type of interview, four to twelve participants are presented with one particular research topic and may discuss this for few hours with the guidance of a moderator. This technique enables generation of additional information that is derived from, e.g. disagreement of each individual or new perspective on specific matter that emerges during the discussion (Hakim, 2000). However, the collective nature of this technique would diminish individual motivations and views behind the research topic (Hakim, 2000). This implies that the result from the group discussion would tend to emphasize interests of the group as a whole and thus reduce range of objectivity from individual perspective, which was of greater interest for this research. Another possible drawback of this interview technique would be time constraint for each respondent from different countries to gather together under one specific occasion. Out of these reasons and the benefits that in-depth interview offered, authors decided not to choose focus group discussion technique for data gathering and went for the in-depth interview instead.

3.4 Data analysis

3.4.1 Operationalization of analytical framework

The collected data was analyzed by the framework presented in Section 2.4. The characteristics of the instruments, the process functions and the outcomes were interpreted according to Table 3.2. For example, when analysis claimed an instrument to have "high stringency", it was meant that the instrument had high ambitious level compared to the obligation from EU. The same reasoning was applied for "low stringency". Further, the process functions were analyzed based on the degree of influence by the instrument mixes. The question asked was "how did the instrument mix affect market formation?", for example. Furthermore, the outcomes were facts about the outputs from the system. Finally, a comparative analysis of each of the three parts of the analytical framework was conducted between the results of the German and Finnish analysis to point out similarities and differences which generated lessons for Sweden.

Table 3.2: Table of construct

Analaytical elements		Operationalization
Policy characteristics	Stringency	High ambition level compared to the 10% share of renewable sources in the transport fuels obligation from EU Renewable Energy Directive (see Appendix A)
	Predictability	High certainty on return on investments, including long-term assurance
	Flexibility	The policies were designed to give multiple options for actors in meeting their obligations
	Depth	High incentives to develop innovative technologies and to encourage actors in achieving obligation beyond the target and reduce emissions to zero
	Differentiation	The policies distinguished between conventional and advanced biofuels or between fossil fuels and biofuels and treat them differently
	Consistency	To what extent the instruments were complementing each other within the mix and supported each others functions
	Coherence	To what extent the work of instrument mix could create systemic process that aligned with the national policy target
	Credibility	To what extent the instrument mix gained trust from the actors
.	Comprehensiveness	To what extent the instrument mix could address existing multiple failures in the system
Process functions	Market formation	The degree of the policy impact on the market formation process, including how the production and consumption level qualitatively have been influenced, which actors and fuels have benefited/not benefited by the instrument mix
	Legitimation	The degree in which the policies influenced public acceptance
	Resource mobilization	The degree in which the policies affected the mobilization of human (development of knowledge between actors) and financial capital (funding for investments) as well as choice and availability of raw materials for the production of biofuels
	Reduced support for dominant regime technologies	The degree in which the instrument mix contributed to the weakening of fossil fuels regime as incumbent technologies
Diffusion outcome	Production of fuels	The amount of biofuels produced domestically as the effect of implementation of policy instruments
	Consumption of fuels	The amount of biofuels consumed domestically as the effect of implementation of policy instruments as well as the market share of biofuels in comparison to fossil fuels

3.5 Validity, Reliability, Generalizability

Validity evaluates the degree of accuracy in data collection method and examines whether the method is used accordingly to measure what it intended to measure (Saunders et al., 2016). As proposed by Saunders et al. (2016), a validity review on the acquired data can be done through triangulation, which is mostly done when a research uses multiple sources of data collection. Through triangulation, multiple data sources were combined to complete each other's information. As mentioned before, this thesis implemented multi-method qualitative study as data were collected in two separate ways: literature study and interview rounds. Information from interviewees was not always explicitly clear, implying a missing link on their explanation. To address this issue, authors used information from the literature study, such as statistics, various reports and articles, to complete the missing link. which referred to application of triangulation as suggested by Saunders et al (2016). Data verification through triangulation allowed authors to perform reality check between primary and secondary data. This way, the validity value for this thesis could be ensured.

Reliability can be understood as the degree in which data collection technique generates corresponding findings or similar conclusion if other researchers conduct a new study (Saunders et al., 2016). The weakness of having empirical findings from interview technique lies in the replicability issue because the collected data only reflected situations at particular time span, which may be subject to change (Saunders et al., 2016). Hence, other researchers should put more consideration to this particular data gathering method if reproduction of this work was attempted. To address this weakness, in this thesis, authors tried to explain in great detail how this research study was performed. This included description of research design, employed methodology, data collection process and data analysis. This way could increase transparency of this thesis and could help other researchers to follow step by step on how this work was carried out. If other researchers wished to replicate this thesis under the same terms and conditions, meaning not only the same methodology, but also using the same sources and same time span as authors did, they should expect to achieve the same findings.

The definition of generalizability can be referred to the grade in which the key findings of a study is applicable to other settings (Saunders et al., 2016). In general, case studies based on qualitative methods are often criticized for its incompatibility reasons for generalization purpose (Flyvbjerg, 2004). This assumption is typically directed at qualitative research with limited data sampling (Saunders et al., 2016). Therefore, Hakim (2000) argued that the level of generalizability can be enhanced with increasing the number of case studies. Unfortunately, given the limited scope, this is not a best practice to be carried out in this thesis. Other means that could be used to cover the generalizability issue in qualitative research is to repeat the research setting (Buchanan, 2012). For example, research setting of one research study can be applied to another study if the second research study intends to have similar findings as the first study. Although the outcome of this thesis did not necessarily strive for generalizability, future researches with akin problem background, that aim to achieve similar purpose like what this thesis had, could look up for the research settings used in this work.

4

Case studies

This chapter describes the underlying policy instruments in promoting the diffusion of biofuels in Germany and Finland. National policy target of each country is also briefly discussed in order to clarify what each country aims for in terms of emission abatement or specific target for employment of renewable sources especially biofuels in the transport sector. Moreover, analysis of policy characteristics, innovation processes and diffusion outcome in form of production and consumption of biofuels due to implementation of the policy instruments are also included in this chapter.

4.1 Case I: Germany

4.1.1 National policy target

Towards compliance with the 2015 Paris Agreement, the German government initiated a set of strategic measures to address the issues of climate change in the long run. This results in Climate Action Plan (*Klimaschutzplan*) 2050, which was adopted by the German government at the end of 2016.

Climate Action Plan (CAP) 2050 aims at domestic reduction of greenhouse gas emissions in amount of 55% by 2030 and 80% - 95% by 2050 in comparison to 1990. To achieve this emission reduction target, contribution is required from different sectors and industries, such as energy, buildings, transport, trade and industry, agriculture and forestry. In respect to the transport sector, around 40% emission has to be reduced until 2030.

The first program of measures is expected to run in 2018 and should deliver the impacts evaluation of suggested measures in politics, economics, social and ecological aspects. To guide different sectors and industries to settle in the transition process and also to monitor the work progress, the German government established a commission, which focuses primarily on growth, sectoral change, and regional development.

CAP 2050 will be adjusted continuously to maintain its consistency with the Paris Agreement goals. This includes review of national climate policies, the interim targets and milestones and suggested measures within the CAP. The adjustment will be carried out in order to follow through novelties in technological, societal, political, social and economic developments (Federal Ministry for the Environment, Nature

Conservation, Building and Nuclear Safety, 2016).

Before CAP 2050 was ratified, the German government presented a national renewable energy action plan in 2010 which consisted of different targets for renewable energy development across sectors and also Germany's contribution towards EU's 2020 target. For road transportation, the German government emphasized the importance of electrical mobility, in which its electricity source comes from renewables. 1 million electrical vehicles are planned to be manufactured until 2020. To support the expansion of electrical mobility, the government has prepared a legislation called National Development Plan for Electrical Mobility that pursues this objective to come into realization (Federal Republic of Germany, 2010).

4.1.2 Policy instruments

Figure 4.1 depicts the policy instruments for biofuels that has been implemented in Germany along with the motivations of replacements. It is worth to know that biofuels producers and oil companies are two different types of actors.

Figure 4.1: Policy instruments for biofuels in Germany

Further elaboration on the policy instruments is presented below.

4.1.2.1 Tax exemption (2004 - 2006)

In response to support climate change mitigation and carbon emission reduction from transport, Germany started to initiate the use of biofuels in the transport sector. Similar to other disruptive technologies, biofuels also faced economical challenges when first introduced in the fuel market. This situation called for a regulatory framework that could guide biofuels to be financially competitive on the fuel market. During this time, biofuels (biodiesel and bioethanol) were only available in liquid pure form and have not been produced or consumed in a large volume (European Commission, 2004).

To address the financial difficulty, the German government introduced tax exemption for biofuels in 2004. The European Commission consented tax exemption scheme to be in place until 2009. This policy instrument allowed biofuels to be freed from fuel tax (later on in 2006 it was amended to energy tax) that used to be borned by consumers. With this policy instrument, the German Federal Government expected that it could motivate consumers to start using biofuels and also indirectly biofuels producers and thus elevate the diffusion progress of biofuels in the market (European Commission, 2004)

Tax exemption is a policy instrument which is closely linked to EU state aid regulation and hence required to be evaluated regularly to avoid overcompensation issue. In the course of time, biofuels in Germany were assumed to be overcompensated and should no longer receive financial aid. Moreover, since the cost of tax exemption was borne by the state, it led to a loss of state income in amount of 2.2 Million Euros in 2006. To deal with these situations and with the aim to develop biofuels on a long term and more stable basis, tax exemption was terminated in 2006 and was replaced by biofuels quota (Deutscher Bundestag 18. Wahlperiode, 2016).

4.1.2.2 Policy characteristics of tax exemption

Tax exemption can be categorized as economic transfer instrument since it provided financial incentive for the diffusion of biofuels to occur. From the features that it has, tax exemption can be called to not have *stringency* in itself since it did not specify particular ambition level of how much fuels should be produced or consumed. The only expectation during the time of implementation was to boost production and consumption level and to have "more" volume at the market. Since tax exemption needed continuous approval from the European Commission for its implementation, it was not *predictable* which caused uncertainty for investment decisions to be made. The aspect of *flexibility* is difficult to be defined within the tax exemption since it only gave economical support for consumption and did not pose any restriction or obligation on actors, especially biofuels producers. The tax exemption scheme alone did not encourage actors to innovate alternative option of biofuels beside than to increase production/consumption, thus it cannot be called to have sufficient *depth* in it. The privilege of being exempted from fuel tax clearly indicates that the tax exemption made *differentiation* between fossil fuels and biofuels.

4.1.2.3 Biofuels quota (2007 - 2014)

As a replacement for tax exemption, the German federal government introduced biofuels quota. Under this policy scheme, oil companies were obliged to sell biofuels that corresponds to certain percentage of the energy content of the total sales of fossil fuels each year. Until 2009, the quota level was constant at 5.25%. Later on, the quota level increased to 6.25%, but it remained constant from 2010 to 2014. To fulfill the quota obligation, oil industries were allowed to carry out a quota trading, where industries could contractually transfer the quota obligation to a third party. In case oil companies were not able to fulfill its responsibility, a financial sanction would be applied. The amount of the sanction referred to the energy content of the deficit quantity. If the oil companies exceeded the required quota, the surplus amount could be transferred and be considered for the following year's obligation (Deutscher Bundestag 18. Wahlperiode, 2016).

For the quota calculation, both options of blending in biofuels into gasoline or diesel and selling in pure form were possible. According to the Ordinance on the Implementation of Arrangements pursuant to the Biofuels Quota (36. BImSchV), biofuels produced from residual matter and waste were weighted double when calculating the quota. This alternative eased oil companies in reaching their quota obligation

(Deutscher Bundestag 18. Wahlperiode, 2016).

Since 2009, the German government has already known that biofuels quota was going to be replaced with another policy instrument. Therefore, for several years during the design and planning phase of the new policy, the quota level was retained at 6.25% (Deutscher Bundestag 18. Wahlperiode, 2016). Furthermore, the German government decided that use of biofuels should enable more ambitious abatement of greenhouse gas emission. To this extent, the German government considered to develop biofuels based on EU's Fuel Quality Directive (7). Hence, biofuel quota was restructured into another scheme where emission of greenhouse gases became the focus. This process resulted in greenhouse gas (GHG) reduction quota that replaced biofuel quota starting from 2015.

4.1.2.4 Policy characteristics of biofuels quota

Biofuels quota can be classified as a regulatory instrument since it obliged actors (in this case, oil companies) to fulfill certain quota level of biofuels every year. However, the *stringency* level of this quota scheme can be seen as low, since the mandatory quota level lied below the 10% EU target from Renewable Energy Directive. Moreover, it only strived for a constant minor share of biofuels based on the annual sales of fossil fuels for several years of implementation, which again could be referred to low ambition level. The quota scheme held *predictability* for investment plans since it guaranteed that certain amount of biofuels ought to be brought into the market. Thereby, investors had sufficient level of certainty in terms of making new investments in biofuels plants. The quota scheme was *flexible* as it allowed actors to carry out quota trading with a third party as well as to choose between blending or selling pure biofuels. The characteristic of *depth* can not be assessed explicitly since this scheme may have two contradicting perspectives to it. On the one hand, the low ambition level of this quota scheme that was described earlier showed that this regulation did not motivate actors to pursue higher quota than what was required, which implies that this quota instrument possessed no *depth* in it. On the other hand, the double counting procedure opened the possibility for actors (especially biofuels producers) to innovate biofuels using waste and residual materials so that their products could help obligated party to reach the quota requirement easily, which refers to sufficient *depth.* The aspect of *differentiation* is reflected through the double counting mechanism in which it favored advanced biofuels (biofuels made from waste and residues) over the conventional biofuels (made from crops) in achieving the quota target.

4.1.2.5 Greenhouse gas reduction quota (since 2015)

Based on the Federal Emissions Protection Act (*Bundes-Immisionsschutzgesetz* or BImSchG), the biofuel quota was modified and transformed into a new kind of quota system: a greenhouse gas (GHG) reduction quota. The GHG reduction quota intends to reduce carbon emission gradually from transport sector through use of biofuels (UFOP, 2015). The concept of this policy instrument follows the key point of EU's Fuel Quality Directive (FQD), which aims at GHG emission reduction of 6%

by 2020. It came into force since 2015 and affects the entire biofuels supply chain in particular and biofuels industry in general.

Instead of assessing eligibility of biofuels based on its energy content, the biofuels are now assessed against its ecological performance on GHG reduction potential. Biofuels producers have to be able to reduce its energy consumption during manufacturing process and select only raw materials with the lowest greenhouse gas emission in order to decrease its carbon footprint. Therefore, greenhouse gas efficiency plays an important determinant in the biofuels market and the value of potential reduction decides the price for the market. For example, biofuels that is potential to save 60% of greenhouse gas is more attractive for oil companies than biofuels with 40% since it helps them to achieve the quota obligation with use of a lesser amount of biofuels. However, this attractiveness might come with a higher retail price of biofuels since the suppliers have to do additional efforts in form of employment of new technologies especially in the production lines in order to increase the carbon efficiency (5, 6). This appears to be not a problem since oil companies do not have to buy as much as they used to do before since they only need small amount to be blended in the fossil fuels to achieve the quota target (6).

The GHG reduction quota is carried out in different targets that increase gradually over the years (§ 37a Paragraph 4 Sentence 2 of the BImSchG) (see Table 4.1):

Table 4.1: GHG reductions in percentage (UFOP, 2015).

Year	Reduction target
2015 & 2016	3.5%
2017	4.5%
from 2020 onwards	6%

The calculation for the mandatory quota refers to the so called reference value and actual value of GHG emissions from fossil fuels and biofuels. The amount of GHG reduction is determined through the multiplication between the required percentage of reduction and the reference value of fuel volumes sold. The quota is called to be fulfilled when this amount is equal to the difference between reference value and actual value.

In case oil companies fail to fulfill the required quota, financial penalty of 0.47 €/kg CO2 eqv. will be charged to the deficit amount of greenhouse gas reduction according to § 37c Paragraph 2 Sentence 6. On the contrary, if oil companies manage to reduce more greenhouse gases than what is required in a certain obligation year, the excess quantity can be transferred upon request and added to the reduction obligation under certain circumstances as stated in § 37a Paragraph 8 Sentence 1 of the BImSchG (UFOP, 2015).

Unlike the previous quota system, in GHG reduction quota, double counting calculation is no longer recognized and no exception is made for any type of biofuels like it used to be before. Furthermore, it does not acknowledge biofuels that are based on animal fats and bio-based oils that underwent co-refinery process together with fossil-based oils (UFOP, 2015).

Under this scheme, oil industries as obligated party can choose the options between blending in the biofuels to the fossil fuels pools or selling biofuels in pure form. In addition, oil companies can carry out quota trading with a third party. This means oil companies are allowed to transfer their quota obligation to other companies in order to fulfill their responsibility towards the mandatory quota. Terms and conditions of the trading agreement differs depending on if the the third party is also obliged to the quota regulation or not (UFOP, 2015). So far, the quota has always been met by the oil companies (9).

4.1.2.6 Policy characteristics of GHG reduction quota

The GHG reduction quota can be categorized as regulatory instrument since it binds the actors (especially oil companies) to comply to certain requirement and entails financial consequences in case of failure of compliance. With regards to *stringency*, it is difficult to specifically link it to the EU's RED target since the quota is developed on the basis of EU's FQD. However, looking at the fact that the quota system only duplicates the concept of EU's FQD and does not aim for additional higher target in comparison to RED, it can be considered to be not stringent. Moreover, the quota does not strive for a higher market share of biofuels as expected by the actors in the biofuels industries (5, 6). These arguments show that Germany only pursues the minimum requirement as prescribed by the EU directives which again refers to low stringency.

As explained before, biofuels with high GHG savings is claimed to be much preferred because with small amount of biofuels, obligated party (in this case oil companies) will be able to achieve the quota target easily (5, 6, 7). However, production of biofuels with high GHG savings also comes with a challenge of supplying it at reasonable cost (10), since the biofuels producers have to choose the most carbon and cost efficient way to provide biofuels, starting from selection of raw materials, production method, to the distribution of fuels (5, 6). At the same time, this situation creates an uncertainty in the production planning for biofuels producers since it is unknown how much volume of biofuels will be of demand in the market (8). Thereby, the quota scheme can be called to fail in providing *predictability* for future potential investment decisions to occur mainly due to the high financial risk associated with the unknown supply and demand volume. Although the quota scheme is intended to be implemented after 2020, it still does not give sufficient assurance for any return on investments to be realized in years to come.

Further, this quota system provides *flexibility* for actors in fulfilling the mandatory quota as it gives options for oil companies as obligated party to blend in or sell pure biofuels and allows quota trading to be conducted. Since carbon efficiency becomes the main reference and treats all type of biofuels equally regardless its source of raw materials, it encourages biofuels producers to innovate continuously by reducing the GHG emissions along the production and supply chain. Hence, GHG reduction quota can be said to have *depth* in it. However, together with no predictability and low stringency, the quota scheme does not motivate obligated party to achieve beyond than the required target simply because there is no incentive to do that. Therefore, the quota can also be called to have no *depth* in it at the same time. From the perspective of *differentiation*, this quota scheme diminishes the boundary between conventional and advanced biofuels, which means that there is no differentiation made for the variety of fuels. However, differentiation can also be claimed indirectly in which the reduction quota promotes biofuels with high carbon savings.

4.1.2.7 Policy mix characteristics

In Germany, there has been only one main policy instrument being implemented at a time. The regulations described above are replacing one policy instrument to another and each policy instrument was/is intended for the diffusion of biofuels. Thus, the term instrument mix can not be literally applied to the German biofuels instruments. However, it is still possible to identify whether these aforementioned policy instruments are designed to be compatible to each other and have the characteristics of instrument mix, and see if they have worked cooperatively and thoroughly in achieving the political objective, e.g. national target.

The constant change in focus of the biofuels policies shows that the implementation of these instruments lacks of *consistency* among themselves. Each policy instrument tends to concentrate on different things and does not illustrate a clear connection between them due to uncommon goals that they share. This situation is motivated by the fact that Germany does not have specific and concrete national target for the diffusion of biofuels and instead only refer to the overall targets set by EU. Although these instruments do not build their aims on each other, their implementations can still be considered *coherent* since they are basically designed with a purpose to create systematic process in reducing emission in the transport sector, which is part of the national policy target. Still related to the changes in policy that occurred quite regularly, the policy instruments in Germany can be called *unreliable*. It is difficult to gain trusts for the policy when political actors do not show sufficient degree of commitment towards biofuels and constantly alter the regulation over time. The characteristic of *comprehensiveness* can not be directly determined since each instrument is implemented individually and is not designed to be able to overcome multiple failures in the system at once.

4.1.2.8 Policy influences on the functions

This section analyzes how each process/function has been influenced by the policy mix and the importance of various characteristics.

1. Market formation
   Tax exemption worked as a monetary incentive that allowed biofuels to progress in its diffusion process. When tax exemption was introduced in Germany, the volumes of sold biofuels experienced a significant growth in the transport sec-

tor (5, 6), even though there was no specific ambition level attached to it. As result of differentiation, the tax exemption was able to lower the retail price of biofuels for consumers (5), making it economically competitive against fossil fuels and be able to diffuse further in the market. The tax exemption managed to give support in establishing a considerable market share of biofuels at the market and setting the initial phase of the market formation. Increase in production and consumption of both biodiesel and bioethanol was noted during the implementation of tax exemption. During the first years of tax exemption, the production of biofuels could not keep up with the increasing consumption which resulted in import of biofuels. However, this situation changed as more investments were made in production capacity (UFOP, 2012), making Germany more self-reliable in terms of domestic supply and demand of biofuels. Clearly, it was biofuels producers, especially agricultural based at that time, that were benefited by this policy.

As replacement for tax exemption, biofuels quota ensured that a certain quantity of biofuels was inserted to the market following the annual sales of fossil fuels (Deutscher Bundestag 18. Wahlperiode, 2016). With this mandatory quota, advanced biofuels acquired a space to be fostered in especially due to the double counting procedure. Through this scheme, it is the advanced biofuels producers that were mostly promoted due to differentiation within the biofuels type. The certainty that biofuels quota had, caused a stable production volume of biofuels during the years in which biofuels quota was in place (see UFOP, 2016). The situation was a bit different with consumption of biofuels. As result of low ambition level in comparison to the EU RED target, biofuels quota did not manage to diffuse biofuels further in the market, as seen in the use of biodiesel that started to decline gradually over the years, causing export of biodiesel to other countries. The same case did not apply for bioethanol, as the consumption increased steadily. However, even though predictable, innovation in terms of expansion of production capacity did not seem to occur, causing more fuels to be imported (see UFOP, 2016).

Beside the compliance towards EU FQD, the redirection of biofuels quota towards carbon efficiency into GHG reduction quota could be related to a certain extent to the ILUC directive for the cap it puts on conventional biofuels (see Appendix) and also supported by the fact that biofuels were considered to have passed through the niche market phase and thus are mature enough. Under this policy, carbon efficiency becomes the main interest for demand and thus the real product in the market. The development of advanced biofuels continues to be promoted particularly due to its capability in saving carbon emissions more than what conventional biofuels can achieve (5). Therefore, producers of advanced biofuels (e.g. used cooking oil) gets the advantage out of this scheme (10). Moreover, providing this kind of biofuels at a cost that is accepted by the market is seen to be another challenge that the biofuels suppliers have to encounter (10). This situation implies an ongoing competition between biofuels suppliers in providing the "finest" biofuels in terms of carbon savings potential to the market. In addition, oil companies can be said to have an advantage out of this situation because they can freely choose which biofuels retailers are able to offer the most carbon efficient product at a reasonable cost.

Since the introduction of GHG reduction quota, the market share of biofuels has experienced a decline in consumption that concerns the biofuels producers mostly. It is estimated that the biofuels consumption will continue to decrease in the upcoming years (6). It is explained because with increasing value of carbon savings, less volume of biofuels will be needed to achieve the quota target (UFOP, 2015). Moreover, it can be linked to the low stringency of GHG quota. Related to predictability, the quota scheme does not give enough assurance for potential investments for the expansion of production capacity, which also motivates why the national production volume of biofuels remains constant in the past two years (VDB, 2017). Again, this situation affects the business of biofuels suppliers to a large extent. The same blending obligation still applies for oil companies, however they are not really affected by the new quota scheme.

The instruments have substantial influence on the production and consumption levels in Germany. For biodiesel, import to Germany has decreased gradually over the years with quite stable constant amount of domestic production. The declining consumption of biodiesel can be motivated because the domestic production still rely on food and feed crops which is a very sensitive issue in Germany. As the consequence, biodiesel is less desired in Germany and thus the remaining amount of production has to be exported to other countries. Meanwhile, advanced biodiesel such as HVO (from stand-alone facilities) is still fully dependent on the import from other countries due to the fact that there is no production capacity currently available in Germany following a ban by the government to not have biofuels produced together with mineral oil, the so-called co-refining process, which is a common practice to produce HVO (DBFZ, 2016). For bioethanol, the produced amount has not been able to meet the consumption level over the past years mainly due to limited production capacity (DBFZ, 2016). Thus, import of bioethanol is required to cover the shortfall.

These conditions prove that even though this policy instrument is already designed to have differentiation and depth in which it favors advanced biofuels, it does not create enough driving forces to stimulate the industrial actors to diffuse biofuels further nor to expand the domestic production of biofuels. This could be reasoned since the current emission reduction quota is not stringent and predictable and hence can not give assurance for any innovation process to occur, especially in terms of realization of long-term investment decisions. More detailed quantitative information about production and consumption is explained in Section 4.1.2.9.

2. Legitimation

In general, public acceptance towards biofuels has been an ongoing issue and this subject has impeded the diffusion process of biofuels in Germany. Ever since the tax implementation was introduced, there has been a strong opponent view against biofuels. During that time, the issue of acceptance mainly came from oil companies and was motivated by the fact that the growing volume of biofuels managed to take up market share against fossil fuels (6). The opposition against biofuels has gone even more pronounced since use of crops for biofuels production is closely associated with global socio-economic and environmental problems such as competition with food and feedstocks production, hunger and famine, unsustainable agriculture practices, and land use change (Baumann, 2014). The biofuels quota seemed to still be unable to address these issues (8) and thus has not influenced the legitimation aspect to a larger extent. The change to GHG reduction quota is perceived to be the response from the government in resolving the criticisms against biofuels (8). However, the decision to shift the focus towards emission reduction appears to have not resulted in a significant positive effect on the social reception yet, presumably because this effort would take a longer time until it is firmly established.

3. Resource mobilization

   In terms of human capital, it is unknown how all policies in Germany have influenced the management of human capital especially in the diffusion process of biofuels. Information about education in specific scientific or technological field around biofuels in Germany is not widely available or accessible and therefore can not be further analyzed. Most likely the competencies in biofuels are already formed since the research and development stages, resulting in change in the domestic industry due to investments in production capacities that enables creation of job opportunities.

   Apart from the function of tax exemption in giving financial support for both production and consumption, it is unknown how the other policies in Germany have influenced the mobilization of financial capital. However, during an interview with a German researcher, the importance of having investment program especially for the advanced biofuels was emphasized (10). Similar arguments are also proposed by leaders of biofuels organizations (5, 6, 7) under the circumstance that there is a strict obligation, e.g. to develop advanced biofuels, especially for boosting consumption (10). This can be interpreted that most probably the aforementioned investment aid is currently not in place and hence signaling a troublesome situation for biofuels producers or potential investors. However, further analysis on this aspect should be carried out in order to generate more robust conclusion.

   The tax exemption was designed to provide certain financial incentive to upscale the production and consumption level of biofuels in general rather than to interfere with the choice of raw materials. Therefore, this policy instrument has not influenced the mobilization of raw materials resources in certain way. In contrast, it was biofuels quota that started to embrace the use of waste and residual matter particularly for the production of advanced biofuels through the concept of double counting that it had. Thus, it was clear that biofuels quota tried to influence the selection of raw materials and to promote use of certain sources of raw materials. This pattern is indirectly continued as the reduction quota entered into force. Since the GHG reduction quota does not distinct different types of biofuels, it does not concern what kind of raw materials are used to produce biofuels, as long as they are able to save carbon emission throughout its whole lifecycle. However, because advanced biofuels can save more carbon emission, they are still being promoted although indirectly from this scheme. From this argument, it can be said that due to the indifferent feature that it has, the emission reduction quota contributes an important influence on the choice of raw materials used.

4. Reduced support for the dominant regime
   The introduction of tax exemption showed that there was an effort to begin the destruction process of fossil fuels regime. To such extent, tax exemption made it possible for biofuels to increase its competitiveness against fossil fuels which allowed biofuels to diffuse further in the market. This step was then continued by the succeeding policy in place, biofuels quota. The decision to develop biofuels on a more reliable approach using the quota scheme points out a clear indication that the German government longed to increase the volume of biofuels both in terms of production and consumption and aimed for a stable and gradual attempt to weaken fossil fuels. Unfortunately, this aim was not equipped with an aggressive target for the up-scaling of biofuels. Instead, the biofuels quota created a brake for biofuels by setting a constant market share (energy-content wise) for several years and made biofuels solely dependent on the annual fossil fuels sales.

   Although it aims to improve environmental condition by having less emission, the implementation of emission reduction quota can be criticized for not focusing on decreasing the use of the fossil fuels themselves, which are actually the main pollutant. On the contrary, the current quota scheme pushes biofuels as an alternative to replace the fossil fuels to be carbon efficient as much as possible. This target is considered to be inaccurate since it is the position of fossil fuels that should have been weakened in some way, e.g. less consumed, and not the innovation of biofuels in terms of carbon efficiency that should be "fixed". In addition, it is the latter situation that has entailed a side-effect in creation of competition among the biofuels producers (5, 6). Moreover, the policy instrument does not allow biofuels to dominate the fossil fuels nor encourage the increasing uptake of biofuels volume in the market. All in all, it can be said that the policies in Germany have not been specifically designed to directly impair the fossil fuels regime.

4.1.2.9 Diffusion outcome

The market of biofuels in Germany is mainly dominated by biodiesel, bioethanol and hydrotreated vegetable oil (HVO). The first two fuels are produced locally, while the latter is imported from other countries to fulfill the domestic demand and thus is only briefly discussed in this section.

1. Production level of biofuels
   Since different policy instruments are introduced to support the diffusion of biofuels, the production volume has shown fluctuating level. Domestic production of biodiesel primarily relies on the use of rapeseed (Federal Office for Agriculture and Food, 2016). During the time of tax exemption, biofuels production continued to rise steadily. In 2005, biodiesel was produced in amount of approximately 1.7 million tons and until end of 2006, 2.7 million tons of biodiesel was manufactured domestically (UFOP, 2012). Different than biodiesel, bioethanol started its industrial production between 2005 and 2006. Even though it can be categorized as new, the production volume was able to grow also during the time of tax exemption (IISD, 2012). This indicates that tax exemption gave sufficient incentive and allowed more production volume of biofuels to occur and early market formation for biofuels. In addition, the growing production showed that the issue of legitimation had almost no influence on the production level.

   By the time biofuels quota was in place, the production of biodiesel was quite stable between 2007 and 2014 with a slight increase in 2011 and 2014. 2.9 million tons and 3 million tons of biodiesel was produced in 2007 and 2014 respectively in Germany (UFOP, 2012, 2016). This situation is caused by different reasons. First, the biodiesel suppliers encountered difficulty that took some time for them to adjust the production line and also the products as the market structure changed from selling biofuels in pure form to blending-in market and from tax exemption to biofuels quota (DBFZ, 2016). Second, the increase in biodiesel volume in 2011 and 2014 was reasoned by economic cost of raw materials from other countries such as Asia and South America that was available in a very affordable price which gave them reasoned to be to be imported in a mass volume (DBFZ, 2016). The same pattern was also shown by the domestic production of bioethanol which used cereal crops such as wheat, rye and sugar beets as its raw materials. The manufactured volume increased gradually between 2007 and 2010, remained constant in 2011 and grew again until 2014 at around 0.7 million tons (DBFZ, 2016; VDB, 2017). This shows that the assurance that biofuels quota gave in terms of certain biofuels share was able to stabilize the production of biofuels and managed to bring biofuels to a further progress in the market. It could be said that legitimation did not influence the production level during the implementation of this quota. However, no indication of mobilization or development of advanced biofuels was detected even though it was promoted within the scheme, most probably due to lack of fiscal funding for research and development from the government.

   The effect of regulation change from biofuels quota to GHG reduction quota is less pronounced on the amount of domestic production of both biodiesel and bioethanol. In fact, the production volume, which mainly concentrates on the conventional biofuels, is stable at a constant level around 3 million tons and around 0.7 million tons respectively for biodiesel and bioethanol between 2015 and 2016 (VDB, 2017). Also included in this number is the production of biofuels with high carbon savings, that are said to be the focus of this quota. However, the support towards this kind of biofuels is not reflected in terms of increasing level of production yet. Looking from the production perspective, it is difficult to judge whether the reduction quota has affected market for domestic biofuels production in a wider sense since the policy is recently new in place and no change in the production level is seen so far.

2. Consumption level of biofuels
   In comparison to production, influence of innovation process is more clearly to see on the consumption side. The tax exemption managed to stimulate more biofuels to be demanded mainly due to discounted price for consumers that leveled up the competitiveness against fossil fuels. Both biodiesel and bioethanol gained more market access and were consumed in increasing volume, indicating progress on the early market formation.

   This condition did not last long as biofuels quota was enforced. With increasing use of fossil diesel, domestic consumption of biodiesel continued to shrink and thus more volume of biodiesel was continuously exported to other countries. In 2010, with a portion of 12.6% compared to fossil diesel, 4 million tones of biodiesel was consumed, but this volume declined to almost its half at 2.32 million tons and share of 6.5% in 2014 (UFOP, 2015). In the mean time, obligated party always succeeded to meet the quota requirement and even exceeded the target. It is assumed that this excess amount of quota was being transferred to next obligation year which made the demanded volume of biodiesel to be lessened annually.

   Different than biodiesel, bioethanol was able to gain more importance in the fossil pools. The consumption level went on to increase from 0.46 million tons in 2007 to almost three times at 1.23 million tons in 2014 (DBFZ, 2016; VDB, 2017). Share of use of bioethanol in gasoline grew from 2.2% in 2007 to 6.6% in 2014 (UFOP, 2012, 2016). Unfortunately, this consumption level was not accompanied with matching production volume, causing imported bioethanol to flood in to Germany. Also included in this import is advanced biofuels such as ligno-cellulosic which was privileged by the double counting procedure (DBFZ, 2016). The consumption rise can be motivated by the fact that according to EU FQD, bioethanol is allowed to be blended more into gasoline (up to 10%) in comparison to biodiesel into diesel (only 7%). In addition, the imported bioethanol are not made from food nor feed stock materials, which in certain perspective might influence consumers' decision. Overall, the market share of biofuels accounted for 5.2% in 2014 (VDB, 2017).

   Even though the quota was always achieved, it prove that the low stringency and flexibility of biofuels quota caused oil companies to "get away" easily from the mandatory blending through transferring excess quantity. In addition, the insufficient depth did not encourage oil companies to strive for more consumption volume. Moreover, declining consumption of biodiesel and limited national production of bioethanol condition could also be related to the resource mobilization of raw materials and legitimation issue that Germany constantly encounter when it comes to conventional and advanced biofuels. This shows that the endorsement that biofuels quota had on the basis of choice of raw materials made consumers to favor imported advanced over locally produced cereal crops based biofuels.

Since the implementation of the GHG reduction quota, the consumption of biodiesel stayed steady at 2.15 million tons in 2015 and 2016, whereas use of bioethanol also remained constant at 1.17 million tons in 2015 and 2016 respectively (VDB, 2017). Import of biodiesel continues to decline as the consumption also decreasing since the era of biofuels quota, but the constant production is balanced with increasing export of domestic biodiesel. Similar to previous years, import of bioethanol remains to flow in to the national market mainly due to the reason of insuffucient domestic production capacity. Overall, the transition from biofuels quota to the reduction quota and low ambition of the latter policy caused a slight decrease in total biofuels consumption and also its share in the market. Total biofuels used in 2014 was marked at 3.5 million tons with 5.2% market share; while in 2015 when the new reduction quota came into force, it dropped a bit to 3.3 million tons with market share of 4.8%; and in 2016, market share of biofuels is accounted of 4.7% (UFOP, 2016; VDB, 2017). Although it appears that the consumption of biofuels only decreased slightly, it is not balanced with use of fossil fuels that continues to grow. 52.9 million tons and 54.5 million tons of fossil fuels were consumed respectively in 2015 and 2016 in Germany (VDB, 2017), which results in a shrink in the size of biofuels market formation and its corresponding market share and thus contradicts to a direct reduced support towards fossil fuels.

Although the emission reduction quota is claimed to promote biofuels with high GHG savings and able to provide the best fuels in terms of carbon savings in the market, unfortunately this is not reflected on the production nor the consumption level of biofuels in Germany yet. This problem can be traced back again to the mobilization of raw materials and legitimation issue as well as low stringency of the existing policy instrument. The declining market share was already foreseen by the industry and it is expected that the volume of consumed biofuels will continue to decrease in the upcoming years, mainly reasoned by the lack of commitment from the government to pursue further diffusion of biofuels (5, 6, 7), especially in securing legitimation aspect for the long term. In addition, the decreasing consumption is also assumed to be the intention of the government because Germany is now concentrating on having electromobility as enlisted in the national target.

4.2 Case II: Finland

4.2.1 National policy targets

On 24th of November 2016, the Finnish government approved a national energy and climate strategy. The strategy included specific and concrete goals as well as solutions to reach the targets until 2030 agreed upon by the Finnish government and the EU. In the long-run, Finland will have an entirely carbon-neutral energy system mainly based on renewable energy sources. By 2020, the rate of renewable energy of total energy consumption should have raised to 50% (Ministry of Economic Affairs and Employment, 2016).

In July 2016, the European Commission presented a legislative proposal regarding emission reductions in the non-emission trading sector (ETS) for all Member States during the period 2021-2030. The European Commission decided that Finland have to reduce their greenhouse gas emissions from this sector by 39% compared to the levels of 2005. The non-ETS sector includes buildings, agriculture, waste management and transport, totally accounting for almost 60% of all EU emissions in 2014 (European Commission, 2016). In Finland, the road transport system is considered to have the biggest potential for emission reductions. The Finnish climate strategists suggest a cut of 50% of emissions from road transport to have a chance to reach the European target. In 2005, the transport sector accounted for 30 Mton of CO_2 by which 92% came from road transport and the rest from rail, water and aviation. Within road transport, 57% is passenger cars. To comply with the EU directive, one option can be to replace almost all the passenger cars with electric vehicles. This would imply an implementation of around 2.3 million new electric vehicles until 2030 which is one hard task and a strong reason the Finnish government have their main focus on biofuels (11).

Finland has in the national energy and climate strategy decided to reduce the domestic use of the fossil fuels, including petrol, diesel, fuel oil, jet fuel and kerosene by half until 2020, compared to the total amount of energy in 2005. The country is also aiming to have a minimum of 250 000 electric vehicles within their alternative vehicle fleet including fully electric vehicles, hydrogen-powered vehicles and rechargeable hybrids. The amount of gas-fueled vehicles will be minimum 50 000 until 2030 (Ministry of Economic Affairs and Employment, 2017). Regarding biofuels, their share should account to 20% until 2020 (14), from the current approximately 14% (Ministry of Economic Affairs and Employment, 2017). The national strategy includes that the physical share of biofuels should increase to 30% until 2030 (Ministry of Economic Affairs and Employment, 2017).

4.2.2 Policy instruments

A biofuel obligation system and a tax system are currently in place. In addition, subsidy for investments in renewable energy to commercialize new technologies are especially directed to institutions producing biofuels in the Energy and climate strategy of Finland (11, 12, 14).

4.2.2.1 Biofuel obligation system (since 2008)

The biofuel obligation is designed to gradually increase the share of biofuels at the market and by 2020 meet the Finnish national target of 20% share of biofuels. It came into force in January 2008 with an obligation of 2% but was later revised in 2010 with higher shares shown in Table 4.2 (Finlex, 2010; Res Legal Europe, 2017).

Table 4.2: Quota obligation targets (Finlex, 2010; Res Legal Europe, 2017).

Obligation period	Quota obligation
2011-2014	6.0 %
2015	8.0 %
2016	10.0 %
2017	12.0 %
2018	15.0 %
2019	18.0 %
from 2020 and onward	20.0 %

The share is calculated in energy content, meaning the energy content of the biofuels must be 20% of the total energy content from petrol, diesel and biofuels for 2020 and onward, for example. The energy content is measured in megajoule/liter (MJ/l) or megajoule/kg (MJ/kg), and considered to be delivered at 15°C (Finlex, 2010; Res Legal Europe, 2017). Table 4.3 shows the valid values.

Table 4.3: Energy content of the different fuels valid under the tax system in place (Finlex, 2010; Res Legal Europe, 2017).

Fuel	Energy content (MJ/l)
Petrol	32
Diesel	36
Bioethanol	21
Biodiesel	33
Synthetic biodiesel (BTL) or equal	34

The biofuels produced from waste, residues or inedible cellulose or lignocelluloses are double counted, meaning their energy content is calculated as double in the final amount of biofuels (Res Legal Europe, 2017).

The companies distributing petrol and diesel are obligated to year by year fulfill the quota. This is regulated and checked by the government by the requirement of having the companies send in an annual report showing the share of sold petrol, diesel and biofuels. Excess amount of the quota during one calendar year is taken into account the following calendar year. If the company has not been able to fulfill the quota, a penalty must be paid to the tax administration. The penalty is currently 0.04 € for each MJ by which the retailer has failed to fulfill the quota (Res Legal Europe, 2017) (Finlex, 2010).

In case the company has presented false information, the tax administration has the right to charge the company with an error payment of maximum 5000 euro. The costs for biofuel obligation is paid by the consumers by the addition of a surcharge for the fuel by the companies (Finlex, 2010; Res Legal Europe, 2017).

4.2.2.2 Policy characteristics of biofuel obligation system

The biofuel obligation system is a regulatory instrument because it controls the market interactions through a binding compliance. It includes fines when the companies have not been able to fulfill the requirements which is a typical feature for a regulatory instrument.

This regulation is considered *stringent* because it matches the national targets of Finland in abating emissions from the road transport sector and to have 20% biofuels until 2020 and onwards. It is more ambitious than the Renewable Energy Directive from EU where 10% of transport fuels must come from renewable energy in 2020 (EU Parliament, 2016). The biofuel obligation is setting good basis for future investments in building new biorefinery plants, making it *predictable*. The instrument will be valid after 2020, giving the companies certainty and assurance that their investments will generate returns because there will be a need to have the plants in operation. Furthermore, the instrument give companies sufficient *flexibility* in meeting their obligation. The biofuels obligation is designed in a way enabling biofuels suppliers to cooperate with each other. In its implementation, the policy allows quota trading between companies and banking of extra biofuel volumes delivered to the market. It also allows oil companies to choose between blending in biofuels into their fossil fuel products or selling them in pure form. The companies are allowed to distribute the biofuels unevenly during the year, meaning a larger share of the biofuels can be distributed during summer time rather than winter time when the weather conditions in northern Finland are hard. Furthermore, the biofuel obligation gives incentives to reduce emissions and to develop the advanced biofuels. Although it does not give incentives to reduce emissions from the transport sector down to zero, it can be considered to have a sufficient level of *depth*. The *differentiation* in the instrument can be noted by having a distinction between the conventional and advanced biofuels, where the advanced biofuels are double counted and therefore are having extra advantage by this instrument.

4.2.2.3 Taxation system (since 2011)

Complementary to the biofuel obligation, there is also a tax regulation in Finland in force since 2011. All fuels are taxed according to their use and are under the regulation, including biofuels. The tax is established on the basis of the Renewable Energy Directive from EU (Directive 2009/28/EC) and divided into two parts, one part taxing the energy content of the product (€/MJ) and one part taxing the CO_2 emissions on a well-to-wheel basis calculated by the Joint Research Centre of the Commission. CO_2 is taxed with a price of 62 €/ton of CO_2 and also set in €/MJ (Ministry of Finance, 2013).

The EU RED categorizes the biofuels according to their CO_2 reduction performance compared to equivalent fossil fuel. The calculations are done through life cycle analysis. The biofuels are separated into three different categories within the CO_2 tax, which are (Ministry of Finance, 2013):

1. If the biofuel have CO_2 emission savings on 35% or lower, it fails to meet the sustainability criteria and will therefore be subject to the same CO_2 tax as the corresponding fossil fuel.

2. If the biofuel have CO_2 emission savings on 35-60%, it meets the sustainability criteria and have 50% reduction in the CO_2 tax compared to corresponding fossil fuel. This category is eligible for first generation biofuels for example.

3. If the biofuel is produced from waste origin and are eligible for double counting it pay zero CO_2 tax. These biofuels have CO_2 emission savings on 70% or over, and are usually second generation biofuels.

The clean burning fuels, defined as paraffinic fuels, have a reduction in energy tax in the Finnish tax regulation. Fuels originated from either fossil or renewables receive a reduction in the energy tax amounting of 5 cents/liter if they fulfill the European Standard EN 15940 (European Committee for Standardization, 2016). HVO is an example under this category (11). The costs of tax relief are borne by the state (Res Legal Europe, 2017).

In Table 4.4, the difference between the total tax payment of the least favored versus the most favoured types of fuels by the regulation are shown. As can be seen, the tax expenses are double for the fossil diesel compared to the biodiesel. The safety storage fee is equal for all fuels. P stands for paraffinic and T stands for eligible for double counting (11).

Table 4.4: Example of energy and carbon tax for fossil fuel and biofuels (Finlex, 2016)

Product	Product group	Energy tax	Carbon tax	Safety storage fee	Total
Fossil diesel (cent/l)	50	32.77	19.90	0.35	53.02
Biodiesel P T (cent/l)	57	25.95	0.00	0.35	26.30

4.2.2.4 Policy characteristics of the taxation system

The taxation system is an economic instrument giving financial incentives for the diffusion of biofuels. It can not be considered *stringent* because it does not require actors to produce or consume biofuels, but rather gives financial support if biofuels are chosen to be produced. The taxation system is difficult to be evaluated in terms of *flexibility* because it does not restrict actions of obligated actors to comply with in the same sense as the biofuel obligation for example. The tax reductions are however *predictable* since the tax system is in place with no time restriction and grants cost reductions when fulfilled. It can not be considered *deep* as it is voluntary and does not give incentives to produce or consume biofuels in a wider range, or to decrease emissions to zero. The *differentiation* characteristic is noted in the advantage that paraffinic fuels have in the energy tax as well as the advantage the biofuels eligible for double counting receive in the carbon tax, making the system more or less advantageous for different types of biofuels and generally only disadvantageous for the fossil fuels.

4.2.2.5 Subsidy for investments (exact year of implementation unknown, currently in place)

There are possibilities to receive subsidy for the investment costs of a new biorefinery. The company needs to present their business case for the Ministry of Economics Affairs and prove that this business idea will not be successful or able to take place without public funding (14).

4.2.2.6 Policy characteristics of subsidy for investments

The subsidy can be considered to give incentive for companies to invest in new biorefineries and thus is an economic instrument. This instrument can however not be considered *stringent* as it does not oblige actors to make investments to reach the national targets. The subsidy is difficult to evaluate in terms of *flexibility* as it does not offer flexible options to comply with, which is how *flexibility* is defined in this analysis. It is however *predictable* when complied with by the assurance of receiving the subsidy and does *differentiate* between the biofuels and fossil fuels to benefit the production of biofuels. The aspect of *depth* in this instrument can be considered to not exist as it is voluntary to comply with it.

4.2.2.7 Policy mix characteristics

The three instruments in Finland can be seen as complementing to each other. As mentioned earlier, the quota obligation was firstly introduced in 2008 and the taxation system came into force in 2011. The purpose of both system is to ease the diffusion of biofuels, especially the advanced biofuels. The quota system ensures that the share is gradually increasing at the market, at the same time as the taxation system is decreasing the costs of the biofuels compared to the fossil fuels. This interplay between the instruments can be characterized as both *consistent* and *coherent*. In addition, the instruments are aligned with each other toward achieving the national target of having a share of 20% until 2020, showing *coherence*.

The elements of the policy mix and the processes in which the instruments have been implemented are seen as believable and reliable by the actors in Finland (11-15). The political engagement have been high and directly focused on the diffusion of biofuels, a feature showing *credibility* in the policy mix. *Comprehensiveness* is how well the policy mix addresses all types of failures, such as market, system and institutional failures. The evaluation of *comprehensiveness* is difficult and extensive to make. However, if high cost of producing biofuels and negative externalities in the environment are assumed to be seen as market and system failures, the instrument mix in Finland is addressing these issues by requiring and incentivizing a larger share of biofuels to replace fossil fuels and therefore decrease the negative externalities in terms of GHG emissions.

4.2.2.8 Policy influences on the functions

1. Market formation
   The biofuels in Finland have experienced a rapid growth at the market in the last 10 years. The tax regulation has made it economically profitable to invest in biofuels. The paraffinic biodiesel eligible for double counting pays half of the tax the fossil diesel does, giving investors a price signal and incentive to produce biofuels (see section 4.2.2.3). Along with the tax regulation, the biofuel obligation have given investors a long-term assurance to make investments to produce biofuels. The instrument mix gives strong signals that biofuels are part of the sustainable transport system in Finland, easing the path of creating a market for the biofuels (11).

   The interplay between the biggest actors; the government, VTT, Neste, UPM and St1 has resulted in a steady increase of the advanced biofuels at the market. In the initial phase of the market formation, Neste took an initiative to explore the business in 2001 due to the EU preparation of a distribution mandate, and later made an investment decision before the national regulations were in place. St1 started producing biofuels in 2007 (Tekes, 2014) at the same time as the biofuel obligation system was about to be implemented, and UPM started their production in 2015. The three companies are as mentioned the biggest actors within the biofuels industry and have been greatly financially benefited by the instrument mix. An important factor affecting the speed of the increasing share of biofuels at the market can be noted as the decision made by the government to implement instruments supporting the waste and residues biofuels. Since Neste started producing biofuels before the regulation was in place, the EU distribution mandate was their only incentive in form of regulations. The raw materials was chosen according to availability and price and the same applies, at a later stage, for UPM and St1 (11). This correlation between the raw materials chosen and the design of the instruments supporting these raw materials is intentional, which together with the long term assurance the instrument mix provides can be seen as a strong feature pushing the diffusion of biofuels.

The instrument mix has helped to create new value chains within the domestic production of biofuels in Finland where an interpretation of the situation can be considered that the market is currently being in the bridging phase.

Part of the success is as well due to meeting demand without any price changes. The flexibility in the biofuel obligation providing a system where the distributing companies can chose to blend in the biofuels in the fossil fuel pool have together with the tax regulation system resulted in no significant price changes for the consumers (14), also a feature driving the market formation and at this stage making Finland totally independent from importing biofuels from abroad (11).

2. Legitimation
The instrument mix in Finland has not influenced the perception of biofuels. The exact dynamic process in which organizations and individuals have formed the legitimation of biofuels in Finland is unknown and beyond the work of this master thesis. However, to some extent, the legitimation issue can be explained by its connection to culture and traditions (14). In Finland, the public perception of biofuels is and have been very positive ever since implementing the instrument mix. The biodiesel sold by UPM was marketed as a product coming from the Finnish forest, connected to the pride in the Finnish society. The sales were very successful based on the perception of it being a "green" and environmental friendly product coming from domestic resources (14). The oil producers in Finland have welcomed the biofuels as well. The largest oil company, Neste, is taking a steady direction in its business evolvement towards biofuels and as mentioned started to produce HVO some years before the national regulations were in place (15). One additional reason for this initiative can be seen as the good perception biofuels have in the Finnish society, which made Neste feel assured the product will be received good at the market.

3. Resource mobilization
Even though the focus of this analysis lies on the diffusion of biofuels by the instrument mix implementation, the competence and human capital allocated to establish biofuels on the Finnish market should be noted as strong since before the instrument mix got into place. The connection between the government (through VTT) and the industry have been prioritized and resulted in exchange of information to both develop the technology and diffuse the biofuels (11).

To what extent the instrument mix have affected the financial input capital is noted as small. The investment subsidy offered by the government have not been used by Neste or UPM when building the power plants because their business cases were considered "solid" and not in need of subsidy to be able to take place. The instrument mix has although had a large effect on the financial output capital. The biofuels industry in Finland have grown big and resulted in large revenues for the big biofuels actors such as Neste, UPM and St1.

The instrument mix has not affected the choice of raw material in Finland, which is an essential process if any domestic production will occur. As mentioned, the industry in Finland has instead chosen the raw materials suited because of financial reasons and the government have supported their choice by implementing instruments which approve the use of these raw materials.

4. Reduced support for the dominant regime
The instrument mix in Finland can be considered as removal of support for dominant regime technologies, in this case the fossil fuels. Both regulations have features that give disadvantages for the fossil fuels. The biofuel obligation is calculated based on energy content. The increasing share of energy content coming from biofuels at the market is implying shares taken from the fossil fuels. In other words, it is reducing the share of fossil fuels and therefore provide as a sufficient regulation towards achieving the national targets of Finland to reduce the use of fossil fuels.

   The tax regulation system is emphasized to treat all fuels equally. The energy tax is based on the amount of energy each fuel consists per litre and the carbon tax is based on the amount of carbon released by a well-to-wheel calculation. Taxing the amount of energy contained in each fuel can be seen as equally treating all fuels, although choosing to design the policy on these terms treats the fossil fuels disadvantageous. The fossil fuels contain slightly more energy per litre than the biofuels and therefore receive a higher tax, which is considered as reduced support for fossil fuels. The differences in the energy tax between the fuels are however small compared to the differences imposed by the carbon tax. Based on GHG savings, the biofuels receive 0, 50 or 100% reduction in the carbon tax and the biofuels eligible for double counting pay zero carbon tax. In this part of the taxation system, the differences on cost between the biofuels and the fossil fuels are more notable, indicating a clear reduced support for the fossil fuels.

4.2.2.9 Diffusion outcome

The implications of the instrument mix in forming a strong growing market for the biofuels, reduce support for the fossil fuels, be able to inline with the Finnish society in their perception of biofuels and have the ability to mobilize resources, have resulted in a large volume of domestically produced biofuels in recent years. Neste's production capacity has grown rapidly to currently produce 400 000 toe/a (Neste, 2017). Their main production is HVO from waste, fats, residues and vegetable oil (11). The second largest Finnish actor, UPM, is currently producing 100 000 toe/a of HVO from tall oil, a by-product from their pulp and paper industry (14). The third producer, St1, have a production of 10 000 toe/a of ethanol produced from food waste (St1, 2017). The implemented instrument mix has helped Finland to manufacture a total amount of about 500 000 toe biofuels each year (Ministry of Economic Affairs and Employment, 2017). In addition, Finland is also able to export large amounts of exceeded HVO partly to Sweden (1), implying self-sufficiency in the domestic production and consumption of biofuels.

All biofuels sold at the Finnish market are blended into the fossil fuel pool, except the 100% renewable diesel Neste started selling in 2007 (11). Numbers from 2015 are shown in Figures 4.2 and 4.3.

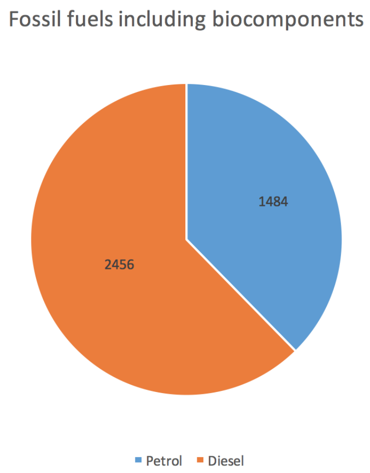

Figure 4.2: Fossil fuels consumption including biocomponents in kt in 2015 (Tilastokeskus, 2017).

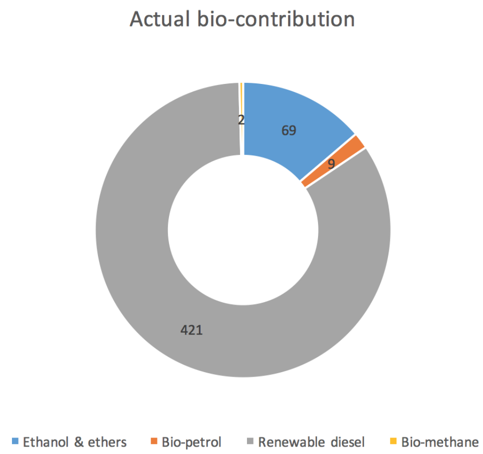

Figure 4.3: Actual bio-contribution in ktoe in 2015 (Tilastokeskus, 2017).

4.3 Comparative analysis

The instrument mix in respective countries are in general terms designed and implemented very differently, resulting in two contrasting learning curves of diffusion of biofuels. This section compares the similarities and differences of the regulations in the studied countries and presents the main lessons learned.

4.3.1 Policy characteristics

As described earlier, the instrument mix for biofuels in Germany are affected by three individual national policy instruments that runs at different periods of time, starting with the tax exemption in 2004, biofuels quota in 2007, and the current GHG reduction quota since 2015. Since these instruments are replacing each other and were being implemented in different periods of time, it can not be classifed as a traditional instrument mix. In Finland, the biofuels quota came into force in 2008 (revised in 2010) and the tax system in 2011. Unlike Germany, the two regulations in Finland have been enforced in parallel up to present.

When comparing the policy characteristics of the instruments in the two countries, the distinction is made based on the type of policy instrument: economic instrument such as tax exemption in Germany and tax system as well as subsidy in Finland; and regulatory instrument such as biofuels and emission reduction quota in Germany and biofuels obligation system in Finland. Lastly, the characteristics of instrument mix between the regulations in the two countries are compared to each other.

Tax system in both countries share common characteristic in terms of stringency since both only gives monetary incentives to have more volume of biofuels in the market and do not include to achieve any particular target. The difference is tax exemption in Germany was intended to increase more consumption and indirectly the corresponding production, while the tax mechanism in Finland was intended to upscale the domestic biofuels production. The aspect of predictability in both countries is contrast to each other. Finnish tax system can guarantee investment decisions to occur since it does not acknowledge time limitation for its implementation. On the contrary, German tax system was rather short-term mainly due to the recurring overcompensation issue. Furthermore, both tax regulations are not designed to restrict actions of actors nor creating obligation for actors and thus its flexibility feature is difficult to be assessed under compliance with the interpretation and definition in this work. Another feature that both tax systems share in common is that they do not possess sufficient depth to encourage actors to take further actions in diffusing biofuels. Different than German tax exemption that promoted biofuels in general, the tax system in Finland treats fuels differently, in which it brings more advantage for the biofuels over the fossil fuels.

Another additional economic instrument that is introduced in Finland is subsidy for investments in new facilities of biofuels. This kind of incentive is currently unknown in Germany. Similar to the characteristics of the tax system, this policy instrument is not stringent or deep but differentiate between biofuels and fossil fuels.

Although basically the obligation quota in both countries have similar concept, there are some aspects that these regulatory instruments do not have in common. For example, in regards to stringency, both quota systems (biofuels and GHG reduction) in Germany have low ambition level, while Finnish biofuels obligation system can be called to be stringent when it comes to pursuing ambitious national targets. Yet, the latter is criticized for not having a specific concrete plan for the 2030 national target. Predictability aspect for mandatory quotas is divided in Germany. The assurance of market share within biofuels quota gave predictability for investments, while the emission reduction quota does not have this kind of assurance for additional investments due to the unknown supply and demand volume of biofuels. In contrast, Finnish biofuels quota ensures return on investments due to the intention of having the quota in place for a long term. In terms of flexibility, all three quota systems are flexible since they allow quota trading, transfer of excess quota amount to the next obligation year, as well as options to blend in or selling pure biofuels. The depth characteristics is assessed differently in Germany. Although both quota schemes encourage innovation of biofuels which indicates that they have sufficient depth in it, unfortunately they do not motivate actors to achieve more, which does not reflect the definition of having sufficient depth. Meanwhile, the biofuels obligation system in Finland pushes for further development and innovation of advanced biofuels, which implies a sufficent depth in the policy. With regards to aspect of differentiation, biofuels quota can be categorized of having differentiation since it favored advanced biofuels, while the boundary between types of biofuels is not acknowledged in the emission reduction quota, even though it also indirectly promotes the advanced biofuels. The differentiation aspect of biofuels quota in Finland is very similar to German biofuels quota, which distincts advanced biofuels from the conventional ones by having double counting mechanism.

The comparison between instrument mix characteristics in Germany and Finland follows the pattern that was used for the assessment in the previous sections. German policy instruments show that there is no consistency between them due to lack of specific target for the diffusion of biofuels, while in Finland they are present to complement each other's operationalization in bringing biofuels to a further diffusion. The instruments in both countries are coherent with respective national targets. However, it should be noted that both countries does not share the same national policy target: Finland desires to have more volume of biofuels, while Germany aims for emission reduction. Since the policy instruments in Germany constantly change, they cannot be accounted for its credibility. This opposite situation is shown in Finland where political commitment in biofuels diffusion is able to help the instrument mix in achieving its credibility from the actors. Comprehensiveness is not applicable on German case since each policy instrument is not intended to resolve various market failures. However, in Finland, the instrument mix is able to address multiple failures at the system, namely economical cost and environmental externality.

4.3.2 Functions

1. Market formation
   The diffusion of biofuels in Germany and Finland have been developed by two different learning curves and paces. The produced volume of biofuels in Finland have had a steady growth since 2008 when the first regulation was in place. The main focus have been on the production of advanced biofuels which is what the whole market of biofuels in Finland consists of (11, 14). The country is self-sufficient with possibilities to export extensive volumes. In

Germany, the produced and consumed volumes have fluctuated over the years but has recently been flatted out with neither an increase or decrease. This does however not imply that the volumes produced domestically have been consumed domestically as well. The quality of the biofuels in terms of how much GHG savings they contribute to be compared to the corresponding fossil fuel have caused competition between the biofuels suppliers. This is assumed to be the reason to the exchanges at the fuel market where an increase of export and import have been noted for biodiesel and bioethanol for example. This dynamic imposed by the current regulation in Germany is not diffusing biofuels. The same type of competition have not disturbed the diffusion process in Finland, where the parameters in focus instead have been energy and carbon content and the instruments mix in itself does not have features enhancing this type of competition.

The competition noted among the biofuels and different actors in Germany is contrasting to the noticed well-working cooperation in Finland. This difference in interplay can also be assumed affecting the diffusion of biofuels differently.

2. Legitimation
By this analysis, the instrument mix in Germany and in Finland have not been noted to have any impact on the legitimation of biofuels. The public perception is seen as rooted in the culture and traditions of the respective countries, and reflected in the establishment process of the biofuels induced by the instrument mix. The poor public perception and the discussions about food versus fuels can be seen as a factor affecting the lack of further diffusion of biofuels in Germany. In Finland the good perception, both of the public and the oil industry, have enhanced and welcomed the diffusion of biofuels.

3. Resource mobilization
As it is for this thesis unknown how human and financial mobilization for the diffusion of biofuels in Germany, the analysis will not go any further into that. As for raw materials the different instruments enhance different types of biofuels, where the two recent regulations, the biofuel quota and the GHG reduction quota, have more or less gave more incentives to produce advanced biofuels. The conventional biofuels are however mainly produced in Germany, contradicting the instruments. This can be explained by the low predictability level of the both quota systems where new investment incentives are not likely to take place. In Finland, there has not been any distinction between conventional and advanced biofuels, as the focus always been on the advanced biofuels. The national regulations, the tax system and the biofuel obligation system, got into place after the two biggest biofuel producers already had made investment decisions to produce advanced biofuels. The regulation implemented by the government supported their choice, which can not be seen as the instrument mix affecting the resource mobilization in terms of raw material. The mobilization of human capital is considered strong as both VTT and

the two biggest biofuel producers, Neste and UPM, have had a special focus on the diffusion of biofuels. The financial capital affected by the implementation of the instrument mix have grown to currently be an well-established industry.

4. Reduced support for the dominant regime
Most countries in EU have targets and obligations to reduce their GHG emissions and gradually phase out the fossil energy, including Germany and Finland. Regarding the transport sector, the two aforementioned countries have, again, chosen different paths and focuses to do so. The tax exemption in Germany was noted to give a disadvantage to the fossil fuels and increase the competitiveness of the biofuels. The same would have applied with the biofuel quota if the target of it were set high enough, which was not the case. With the current regulation, the competition of biofuels against fossil fuels is again high due to the pressure of producing biofuels with the highest GHG saving, causing competition between the biofuels themselves rather than against the fossil fuels. In Finland, the instrument mix is clearly different. The design of the policies is intentional to weaken the fossil fuel regime. Reductions in tax costs and a specified quota system ensuring increasing share of biofuels each year. The biofuels in Finland are clearly favored by reduced costs and high quota levels, easing the way for the diffusion.

4.3.3 Outcomes

The policy instruments in Germany can be criticized for not having enough push for innovation of biofuels especially in the production side although there is an opportunity to do that given the differentiation that biofuels quota had for advanced biofuels as well as the promotion of carbon savings potential that can be achieved more efficiently through use of advanced biofuels in the current quota system. This is reflected for example in the absence of bioethanol production expansion and increasing exported volume of locally produced biodiesel. In addition, some innovation processes such as market formation, resource mobilization of financial capital, and legitimation, that are required to establish the diffusion of biofuels do not have significant influence on upscaling domestic production of biofuels. The opposite situation is found in Finland. The instrument mix in place has given the right push for industries to produce biofuels in a bulk volume and has driven the processes needed for diffusion of biofuels to be firmly embedded. Moreover, the successfully established processes contribute a significant effect on the rise of domestic production volume.

Tax exemption in Germany has managed to promote use of biofuels in the road transport sector, seen in the increasing consumption volume during its implementation. However, as soon as the regulation changed into the obligatory ones, the domestic consumption level turns out to be very fluctuating. This is seen from the continuous decline in the consumption of biodiesel and increase in bioethanol use during biofuels quota, then the stable, but not increasing, consumption of both biodiesel and bioethanol during GHG emission reduction quota. This can be reasoned due to the weak characteristics that the policy instruments have in general. Furthermore, the characteristics have not been able to firmly establish each innovation process, which results in situations such as continuous import of bioethanol annually with no ambition to enlarge national production as well as increasing export of locally produced biodiesel due to less domestic consumption. On the contrary, in Finland, export of national produced biofuels to other countries shows the country's ability in fulfilling its priority for the quota obligation by meeting the required demand of biofuels which makes Finland a self-sufficient country in terms of biofuels supply and demand. Furthermore, it is implied that the mix of economic and regulatory instruments with rigorous characteristics in Finland has not only been able to set the innovation processes to support production volume but also manage to stimulate more consumption as well as production level of biofuels in the market at the same time.

4.3.4 Main lessons learned

To contribute importantly to the diffusion of biofuels, policy instruments need to have strong characteristics, meaning stringent ambition level, predictable for investments, flexible for actors to meet the obligation, deep to encourage further innovation and differentiate to (have advantage over) fossil fuels. Learning from the comparison between the Finnish and German case, it appears to be more beneficial to have a mix of policy instruments rather than individual ones if the goal is to increase the production and consumption of biofuels. They should be designed to complement and be consistent towards each other's purposes and also coherent to the national targets. In addition, the implementation of the instrument should seek a long term perspective to guarantee predictability for investments and also to gain credibility from actors. Policy instruments in a mix will also be able to address multiple failures in the market comprehensively. These characteristics are required in order to settle the innovation processes required for the diffusion process. The establishment of innovation processes should consider the right stimuli to induce the production and consumption levels; setting public perception; help the mobilization of available resources, e.g. human and financial capital, raw materials; and strive for reduced support towards fossil fuels. All in all, the instrument mix for the diffusion of biofuels should be able to continuously boost the production volume and increase the market share of biofuels in terms of consumption.

5

Implications for Sweden

This chapter discusses the lessons learned from the comparison of case studies and relates to the situation and policy development in Sweden.

5.1 Status in Sweden

In the light of supporting renewable energy development, the Swedish government has prepared cross-sectoral strategic targets to be achieved in the intermediate and long-term time span. In the intermediate time perspective, Sweden's vision includes achieving a fossil fuels independency in its vehicle fleet by 2030, while for the long run, Sweden aims at establishing a sustainable and resource efficient energy system with no net greenhouse gas emissions released into the atmosphere by 2050 (Regeringskansliet, 2010).

In 2013, the energy use in the road transport sector in Sweden accounted for approximately 79 TWh (Swedish Energy Agency, 2015a). In the road transport fleet, a recurring trend shows that the use of diesel has been increasing while gasoline has been declining. Therefore, biodiesel dominates sold volume of biofuels in Sweden (Swedish Energy Agency, 2015a). Current biofuels within use include biodiesel in form of FAME (fatty acid methyl esther) and HVO (hydrotreated vegetable oil); ethanol, biogas, DME (dimethyl ether) and ETBE (ethyl tertiary butyl ether). The two latter fuels are used in limited volumes (Grahn & Hansson, 2015). Diesel is blended with 5% FAME and varying shares of HVO, while almost all gasoline contains 5% of bioethanol (European Biofuels Technology Platform, 2016).

According to a report from Swedish Energy Agency in 2014, almost all ethanol and FAME produced were crop-based. Production of ethanol was dominated by cereals and FAME by rapeseed. On the other hand, production of HVO and DME relied on waste and residues materials (Swedish Energy Agency, 2015b).

Based on the preliminary statistics for 2015, biofuels accounted for 14.7% share of total fuel consumption in the road transport sector (Swedish Energy Agency, 2016). By 2020, the share of renewable energy shall account at least 50% of the total energy use (Regeringskansliet, 2010). In addition, renewable energy shall contribute at least a share of 14% to the transport sector by 2020 (Regeringskansliet, 2010). Based on the preliminary statistics from Swedish Energy Agency, current share of renewable energy in the transport sector is at the level of 23.7% and has already exceeded the EU expectation for 2020 (Swedish Energy Agency, 2016). Thus, concrete efforts should be justified and coordinated to link the 2020 and 2030 targets (Regeringskansliet, 2010), especially since the 2020 target has been fulfilled.

5.2 Policy instruments

5.2.1 Tax exemption and its implications

In 1991, the Swedish government implemented a tax exemption to support the early market formation and development of the biofuels technology (Regeringskansliet, 2010). All fuels in Sweden are regulated under the tax system in which the taxation is divided into one part taxing the energy content and one part taxing the CO_2 content (SPBI, 2017).

One main rule decided upon by EU is to tax the alternative fuels in the same way as their corresponding fossil fuel. For example, when one liter of gasoline is replaced by one liter of ethanol, the ethanol is taxed according to the same rates valid for the gasoline. By this rule, the Swedish ethanol pays 388 öre/liter in energy tax, and 262 öre/liter in CO_2 tax in 2017 (SPBI, 2017).

In the past 25 years, the Swedish biofuels have been tax exempted from the EU rules described above (SPBI, 2017). Since 2009, the biofuels fulfilling the EU sustainable criteria described in RED 2009/28/EC are eligible for reduced taxes. The energy tax is generally reduced, whereas the CO_2 tax is fully exempted. The tax reductions for eligible biofuels from 1st of January 2016 are presented in the Appendix section A.7. Biofuels not fulfilling the EU sustainability criteria are taxed as corresponding fossil fuel (European Commission, 2015).

The current tax exemption will expire on 31st of December 2018, by which the Swedish government again must inquire an approval from the EU Commission, if they want to extend it (European Commission, 2015). As for many other policy instrument implemented to enhance the development of renewable energy, the main objective of tax exemption is to protect the environment since replacing fossil fuels with biofuels with higher greenhouse gases reductions will bring benefits for the environment (European Commission, 2015).

The reduced taxes for sustainable biofuels are indirectly bringing advantages for producers of biofuels for blending purpose. The scheme applies to biofuels produced in Sweden as well as imported biofuels (European Commission, 2015).

The tax exemption has been very beneficial for the establishment of the biofuels industry in Sweden. It is an uncomplicated instrument which assures less tax payments for the producers of sustainable biofuels (3). In addition, knowing that the product will generate positive revenues gives incentives for producers to invest and thus it enables creation of new value chain for the industry (2, 4).

However, the permission to give tax exemptions and reductions from the European Commission are given 1-2 years at a time, making it difficult for the industry to get the long-term assurance needed for investments. The state aid guidelines change every 4 years, which also causes high uncertainty for investment decisions (1, 2, 3, 4). Although this is problematic, the industry may have to learn to adopt to short term regulations if this continues (1).

Further, the ILUC directive together with the tax regulation changes the prerequisite and becomes another challenge for Swedish biofuels. The directive does not allow further state aid to biofuels produced from food or feed crops, the basis crops in Swedish biofuels production (3).

5.2.2 Proposal on GHG emission reduction quota

In March 2017, Sweden made a proposal to the European Commission for a policy scheme that intends to replace the current tax exemption for biofuels. This regulation is prepared to come into force in 2018. The proposal draft suggests a greenhouse gas emission reduction from domestic transports, excluding aviation, of at least 70% by 2030 in comparison to 2010 by blending biofuels into the fossil fuels pools (Regeringskansliet, 2017). The target of emission reduction differs depending on type of fossil fuel and increases gradually over the years (see Table 5.1).

Table 5.1: GHG emission reduction for respective fossil fuel (Regeringskansliet, 2017)

Year	Gasoline	Diesel
From July 2018	2.6%	19.3%
2019	2.6%	20%
2020	4.2%	21%

To be acknowledged in the reduction obligation, biofuels have to meet the sustainability criteria as regulated according to the Sustainability Criteria for Biofuels and Liquid Biofuels in 2010 (2010:598). A penalty fee of 7 SEK per missing CO_2-eq. will be charged to the obligated party if it fails to fulfill the mandate. Excess of excised duty of each fuel can be reckoned for the next calendar year or transferred to another obligated party within the same obligation year under written agreement. Furthermore, obligated party should report its quota obligation fulfillment no later than 1st of April each year to the corresponding authority. A delay fee of 1 000 SEK will be charged to the obligated party if it fails to provide such document to the authority on time (Regeringskansliet, 2017).

5.2.2.1 Analysis of possible implications and suggestions for improvement of GHG emission reduction quota

The GHG emission reduction quota can be classified as regulatory instrument since it creates obligation for the industrial actors to comply to. Seeing it from the characteristics of policy instrument, the proposed quota system can be called stringent as it complies with the EU directive to decrease emissions in the transport sector, although not directly by increasing the share of biofuels to 10% which is already covered in Sweden. However, the quota scheme can be argued of not having sufficient predictability and hence can not give assurance for investment decisions for biofuels to occur. The ability for obligated party to do quota trading and transfer the excess quota to the following year, signaling sufficient flexibility the quota scheme has for Swedish biofuels actors in order to adjust the production and consumption volumes. In addition, through the gradual increase in the targets, the quota system encourages biofuels actors, especially the producers, to continuously innovate biofuels with highest carbon savings potential and thus it can be categorized as deep. Furthermore, the quota scheme distinguishes the reduction target based on the fossil fuels type, implying differentiation.

Although it is an individual policy instrument, the emission reduction quota can still be assessed using the characteristics of an instrument mix to a certain extent. It can be categorized as coherent since it aligns with the 2030 national target of fossil fuels independency. Credibility from the biofuels industry might be difficult to be gained since the time frame of the policy implementation is currently limited until 2020.

The newly proposed GHG emission reduction quota appears to resemble the one currently implemented in Germany. They also share similar characteristics except one main difference between regarding the ambition level in abating emission, in which Germany strives for a low one. Therefore, similar but not necessarily exact the same situation in Germany could be expected in Sweden. Unlike Germany, the ambitious stringency level that the Swedish quota has, might open opportunities for innovation processes that could create new value chains, such as development of advanced biofuels from Swedish forestry residues. At the beginning, Sweden would probably experience a slight decline in the market share since the market needs to adapt to a new structure. However, with the stringent ambition of the Swedish quota, most likely it would not lead to a recurring decrease of market share of biofuels, different than Germany that already plans for it intentionally. Moreover, Sweden should anticipate the competition between biofuels producers in providing the most carbon efficient biofuels. The distinction that Swedish quota has towards different type of fuels should be seen as a positive subject because it implies that the quota considers the different consumption volumes of each type of biofuels (in which Swedish domestic consumption is mainly dominated by biodiesel and followed by bioethanol) and thus give reasonable argument to reduce the emission correspondingly.

As mentioned, there is a weakness attached to this quota scheme namely the time span. The time perspective of the quota system should be extended to ensure the predictability, certainty and stability for new investments and also for further innovations to occur. In addition, this should be complemented with corresponding stringent target that increase gradually until 2030 and if necessary, 2050. However, even though long time span is important, the decisions of each member country to implement long term instruments is very dependent on the regulations from EU. Member countries would most likely feel insecure and uncertain in pursuing a path in which in the future might not be approved or aligned with EU regulations. Shorter or intermediate time span would be understandable, although problematic for investment decisions.

Furthermore, financial incentives such as subsidy for investments in new facilities, as the Finnish one, can be considered to be an alternative if Sweden plans to enlarge its production capacities. Learning from both cases, legitimation is an essential issue in establishing biofuels position in the society. Although this aspect does not signal a significant problem in Sweden yet, legitimation should be considered to be strengthened through, for example collaboration between actors, which works successfully in Finland. If managed accordingly, legitimation is very likely to enhance the development of market formation of biofuels and thus affect the physical amount of production and consumption volumes of biofuels.

Another concern is directed towards reduced support for fossil fuels. It appears that the reduction quota does not put emphasis on cutting down the consumption of fossil fuels and instead concentrates on "repairing" the carbon footprint of biofuels. Thereby, it is questioned whether the national targets for 2030 and 2050 can be achieved using this individual mandatory quota. Probably, it is worth to consider to implement an additional policy instrument such as an economic one that complements the quota. The Finnish strategy to downplay the fossil fuels in the long run, by giving them the economic disadvantage through taxation system, is an example of how it can be done.

6
Conclusions and recommendations

The first section of this chapter contains answers to the research questions asking what implications the instrument mixes have had on the diffusion of biofuels in Germany and Finland, and what Sweden can learn from the German and Finnish cases. The second section gives recommendations for the Swedish policy makers when implementing policy instruments targeting the diffusion of biofuels based on the lessons learned from studying the German and Finnish cases. The third section discusses suggestions for future studies.

6.1 Conclusions

The conducted study concludes that the implications of the instrument mix implemented in Germany and Finland have remarkable differences. The conventional biofuels are dominating in Germany and were established by the tax exemption which gave sufficient financial incentives for consumers and indirectly for producers to increase the production and use of biofuels at the market. The replacing policy instrument, biofuels quota, gave biofuels an assurance by having an obligation to provide a fixed amount each year and drove biofuels further in the S-curve. The GHG reduction quota that came into force in 2015 has not shown any significant changes volume-wise in domestic production and consumption. The two first regulations gave reduced support for the fossil fuels and increased the competitiveness for biofuels whereas the GHG reduction quota is mainly causing competition between the biofuels. The poor public perception of biofuels in Germany has shown to affect the consumption levels of biofuels in recent years, in which for example a decrease in biofuels market share and an increase in export of domestically produced biodiesel have been noted.

The advanced biofuels are dominating in Finland, where the main establishment and diffusion have occurred during the past decade due to the implementation of the instrument mix consisting of a quota obligation, tax system, and subsidy for new investments. The quota system gave sufficient incentives to invest in the biofuel industry when it came into force. The tax system, which was implemented a couple of years later, gave the diffusion of biofuels an additional push, whereas subsidy provides opportunity in form of financial incentive for expansion of production facility. Finland is at this point self-sufficient and aim for even higher targets with a larger share of biofuels at the market, which is a result of the incentives given by the instrument mix. The instrument mix is clearly giving reduced support to fossil fuels, also helping the diffusion of biofuels. The perception of biofuels in the Finnish society has been good and not caused any barriers in the innovation process, where by the biofuels have been welcomed by all actors including the public.

If Sweden aims to diffuse biofuels, several lessons can be learned from the German and Finnish experiences. Most notably, Finland have been very strategic when designing the policies to enhance biofuels and downplay fossil fuels. One main lesson for Sweden should be to keep a balance between the creation of the new and destruction of the old through an instrument mix. The instrument mix in Finland is consistent, coherent and credible, which all are important characteristics for the instrument mix that contribute to diffusion of a new technology like biofuels. The successful biofuels story in Finland is also due to the good relationships between the actors involved, where exchange of information occurred and different views were to some extent taken into account when the instrument mix was designed. This seemed to be absent in Germany. The current GHG reduction quota has caused competition between the biofuels producers which together with the legitimation issue have resulted in main barriers for the diffusion. Both by the Finnish and German experiences, the importance of high ambition level within quota systems can be noted. Long-term assurance in terms of predictable instruments as well as flexibility to comply with the regulations are also important features shown in the comparative analysis of the two countries.

6.2 Recommendations to Swedish policy makers

The Swedish policy makers should implement policy instrument(s) that have high ambition level in abating emissions, are flexible and predictable. Further, the willingness to go beyond the requirement of the instrument(s) and reduce emissions down to zero would as well imply a strong characteristic highly recommended if the 2050 target will be realized.

According to the recommendation above, the new GHG reduction quota system proposed by the government should be expanded in terms of time span to assure investment decisions. Along with making the instrument more long term, the stringency level of it should be increased by gradually setting higher reduction targets for the upcoming years. Apart from the GHG reduction quota system, Sweden can consider implementing a combination of regulatory and economic policy instruments which complete each other as what Finland has done. To combat climate change through use of biofuels within the transport sector, one main rule when designing the policy instrument(s) should be to apply a "creative destruction"-approach. The instrument(s) should give clear support to alternative renewable sources such as biofuels, while at the same time reducing support for fossil fuels.

6.3 Suggestions for further research

For future research, it is recommended to include other types of biofuels used in the road transport sector, such as biogas and biomethane and also to integrate other sectors in transport, such as marine and aviation, in order to capture a larger overall picture of how a mix of policy instruments affect the diffusion of biofuels. Furthermore, future studies should also consider to look into the entire technological development of biofuels, starting from the research and development phase until diffusion to commercialized market, in order to acquire a more comprehensive result of the biofuels development. Another suggestion is to expand the data sampling by carrying out more interview rounds with actors that were not covered in this thesis, such as society, NGOs, policy makers on EU level, as well as biofuels suppliers and oil companies in Germany. This could add more neutrality and diversity of the perspectives in the assessment. Another interesting alternative approach could be to conduct comparative case studies of policy measures on biofuels using more countries as references. This way, one could look into the variety dynamics of biofuels growth and therefore can get more diversified lessons on how to optimize the development of biofuels by using different policy instruments.

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A

Appendix I

This chapter explains the content of current EU legislation that regulates use of biofuels in transportation sector.

A.1 Renewable Energy Directive (2009/28/EC)

Renewable Energy Directive forms a general policy framework for the production and use of renewable energy sources in the EU. It sets a target for EU to have at least 20% share of its total energy consumption from renewable energy sources by 2020. Moreover, RED introduces an additional binding target specifically aiming at the promotion of clean transportation sector. All member states are required to reach at least 10% share of renewable sources in their transportation fuels. Member states are given the possibility to decide their own national action plans and policy measures in order to fulfill these 2020 goals.

Contribution of biofuels made from waste, residues, non-food cellulosic and ligno-cellulosic materials can be counted double towards the national renewable energy targets.

A.2 Fuel Quality Directive (2009/30/EC)

This directive regulates fuel specifications, evaluation mechanism of greenhouse gas emissions from the transportation sector, as well as the sustainability aspect of biofuels. It requires fuel suppliers to reduce greenhouse gas emissions from the fuels provided for road transportation by 6% per energy unit by 2020. Moreover, FQD regulates blending rate limit for biofuels due to technical reasons, e.g. 10% of ethanol into gasoline. This directive also prescribes appropriate information to be disclosed to consumers regarding biofuel content in gasoline and diesel.

A.3 Sustainability criteria

Both RED and FQD share similar sustainability criteria in common. This criteria ensures that biofuels used in the transportation sector are obtained in sustainable manner. Only biofuels that fulfill this criteria can be counted for national targets as well as the EU target. The criteria is described as following:

- Biofuels need to save at least 35% greenhouse gas emissions throughout its life cycle compared to fossil fuels. This savings rate increases to 50% in 2017 and 60% in 2018 (later on ammended in 2015).
- Raw materials used to produce biofuels shall not be cultivated in former areas with high carbon stock, e.g. wetlands, rainforests.
- Raw materials used to produce biofuels shall not obtained from areas with high biodiversity and ecological values, e.g. primary forest, grassland.
- Raw materials used to produce biofuels shall not come from (former) peatlands.

A.4 Directive to reduce indirect land use change for biofuels and bioliquids ((EU)2015/1513)

As biofuels started to gain more interests, discussion regarding indirect land use change appeared to the surface. Cultivation of raw materials for biofuels production may take place in areas where food and feed crops used to grow. As the result of the occupied cropland, food and feed production has to be relocated to areas that probably used to be grassland or rainforests. This process is known as indirect land use change (ILUC). In response to this arising concern, the European Commission made an amendment to its current biofuels regulations, RED and FQD, and it came effectively into force in 2015. The amendment is summarized as following:

- A cap of 7% is given to conventional (crop-based) biofuels until 2020.
- Conventional (food and feedstock) based biofuels shall no longer receive subsidy after 2020.
- Advanced biofuels shall account for 0.5% of the total energy use in transportation by 2020.
- Adjustments are made to feedstocks for biofuels that are double counted towards the 10% renewable energy target in 2020.
- Biofuels production which plants built after October 2015 shall achieve at least 60% greenhouse gas emission savings. Installations built before that shall save at least 35% emissions by 2017 and 50% by 2018.
- Use of renewable electricity in the road transportation is much encouraged towards 2020 target. Electricity used in rail transport is weighted double, while electric vehicles can be calculated 5 times the energy input of electricity from renewables.
- Fuel suppliers, member states and the European Commission are obliged to submit a range of reports regarding to greenhouse gas emissions and estimated indirect land use change emissions to the European Parliament.

A.5 Annex IX according to 2015 RED

Eligible feedstocks for biofuels to be credited for the EU targets are regulated in the EU Renewable Energy Directive after ammendment in 2015 and are listed as follows:

Part A. Feedstocks and fuels, the contribution of which towards the target referred to in the first subparagraph of Article 3(4) shall be considered to be twice their energy content:

(a) Algae if cultivated on land in ponds or photobioreactors.
(b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC.
(c) Bio-waste as defined in Article 3(4) of Directive 2008/98/EC from private households subject to separate collection as defined in Article 3(11) of that Directive.
(d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex.
(e) Straw.
(f) Animal manure and sewage sludge.
(g) Palm oil mill effluent and empty palm fruit bunches.
(h) Tall oil pitch.
(i) Crude glycerine.
(j) Bagasse.
(k) Grape marcs and wine lees.
(l) Nutshells.
(m) Husks.
(n) Cobs cleaned of kernels of corn.
(o) Biomass fraction of wastes and residues from forestry and forest-based industries, i.e. bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil.
(p) Other non-food cellulosic material as defined in point (s) of the second paragraph of Article 2.
(q) Other ligno-cellulosic material as defined in point (r) of the second paragraph of Article 2 except saw logs and veneer logs.
(r) Renewable liquid and gaseous transport fuels of non-biological origin.
(s) Carbon capture and utilization for transport purposes, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2.
(t) Bacteria, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2.

Part B. Feedstocks, the contribution of which towards the target referred to in the first subparagraph of Article 3(4) shall be considered to be twice their energy content:

(a) Used cooking oil.

(b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009 of European Parliament and of Council. [1]

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A.6 Renewable Energy Directive II

In November 2016, the European Commission submitted a proposal to succeed the current RED framework. The proposal looks at implementation of strategic targets related to renewable energy development between the time span of 2021 and 2030. The proposal contains following information:

- Renewable energy sources shall contribute a share of at least 27% of EU's gross energy consumption
- In the transportation sector, new regulations on biofuels were recommended by the Commission. Use of conventional (crop-based) biofuels will be limited in the future. This generation of biofuels will be given a cap of 7% on the final energy consumption in 2021 and will continually decrease to 3.8% by 2030.
- A quota for the development of advanced biofuels is also considered in this proposal. In 2021, advanced biofuels should account a minimum share of 1.5% to the total fuel consumption in transportation. It should comprise of at least 0.5% share of advanced biofuels which feedstocks listed in Annex IX Part A and less than 1% - 1.7% from Annex IX Part B.
- Until 2030, RED II proposes a sub-quota of 3.6% for use of advanced biofuels coming from Annex IX Part A. Consumption of biofuels from Annex IX Part B will be limited to a maximum of 1.7% share in the transport fuels. In addition, renewable electricity should contribute 1.5% share of fuels use in road and rail transportation. Use of advanced alternative fuels in the aviation and maritime sectors will be counted 1.2 times towards the 6.8% renewable fuels obligation.
- Double weighting of waste, residues, wood, and non-food cellulosic materials, will be no longer applied in the future.

[1] Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation) (OJ L 300, 14.11.2009, p. 1)

A.7 Energy tax reductions in Sweden

Table A.1. explains the reduction on energy tax that is currently implemented in Sweden.

Table A.1: Energy tax reduction for different fuels under the Swedish tax regulation (European Commission, 2015).

Type of fuel	Energy tax reduction
Ethanol for low-blending	74%
Biofuels for low-blending other than ethanol	100%
Fatty acid methyl-ester (FAME) for low-blending	8%
Biofuels for low-blending other than FAME	100%
FAME for high-blending	50%
Ethanol (E85) for high-blending	73%
Liquid biofuels for high-blending other than ethanol or FAME	100%
HVO	100%

B

Appendix II

B.1 Interview questions

This section delineates the questions that were used for the semi-structured interviews for data collection purpose in Sweden, Germany and Finland.

B.1.1 Sweden

- What is most important when implementing innovation policies for the diffusion of biofuels in Sweden?
- Right now, with the tax exemption, has this policy given a significant influence on the current development of biofuels in Sweden?
- From your point of view, how beneficial has the tax exemption been so far in regards of abating climate change?
- Do you think a tax exemption is a correct policy instrument to be used continuously? In your opinion, what drawbacks does the tax exemption have?
- How has the tax exemption in Sweden affected the production and consumption of biofuels and the development of new biofuels technologies?
- How have the biofuels actors been affected by the tax exemption?
- With the current policy, how do you see the chances for Sweden to achieve the carbon free transportation target in 2030?
- What is unique about the development of biofuels in Sweden?
- Right now, first gen biofuels (agricultural crops) and second gen biofuels (forest residues) are on different levels in the S-curve. Do you see a possibility for a diffusion of both types of biofuels by implementing the right policy mix? If yes, which policy instruments are needed to increase the diffusion of biofuels? What benefits and drawbacks would your proposed policy have, especially when implemented in Sweden?
- A wider diffusion of agricultural based biofuels might pose a threat to the food industry and biodiversity in the future. In your opinion, should the biofuels be expanded further or should it stay at the current development level in Sweden?
- Why is the second generation much better then the first generation in regards of abating climate change? In your opinion, should the focus now shift towards second generation?
- Do you think there is a need for both technology-neutral and -specific policies or are you in favor of either technology-neutral or -specific policies?

- If the tax exemption is changed to quota system, will it be better for the biofuels development in Sweden and Swedish biofuel actors? Are there any arguments for the Swedish government to not implement a quota system?
- To what extent are the Swedish biofuel industries involved in the development of biofuel policies and what role do the industries have?
- How will a rapid increase of biofuels in Sweden influence the fossil fuel industries and other related industries, e.g. food industry, automotive industry? Are they prepared for it? Will the expansion of biofuels be troublesome, e.g. from technical requirements to social acceptance?
- In Finland, they introduced the tax exemption and biofuels quota. What is your opinion about their system? Do you know who took the initiatives and which actors that are involved in the policy making and implementation?
- In Germany, they implement quota system based on greenhouse gas (GHG) emission reduction of the biofuels lifecycle. What is your opinion about introducing a similar system in Sweden?
- In Germany, a recent study showed that the sales of biofuels have declined already in the first year of implementation due to the moderate GHG emission reduction target. What are your thoughts about that?
- Recently, EU proposed to include ILUC in the sustainability criteria. Do you think this will influence the market for biofuels in Sweden?
- What is your biggest wish to the Swedish government in regards of implementing policies for biofuels?

B.1.2 Germany

- What are the barriers for the development of biofuels in Germany and for German actors?
- How has the policy helped to overcome these barriers?
- What is most important when implementing innovation policies for the diffusion of biofuels in Germany?
- What are the expectations of the German Federal Government and biofuel actors towards biofuel industry, especially biofuels development?
- To what extent are the German biofuel industries involved in the development of biofuel policies and what role do the industries have?
- What is unique from the development of biofuels in Germany?
- Do you think that the development of biofuels in Germany has reached maturity phase?
- In 2004, Germany introduced tax exemption for biofuels. What benefits and drawbacks does the tax exemption have and why was it changed to biofuel quota? What has (not) worked?
- After biofuel quota, the greenhouse gas reduction quota came into force. Why was it changed to GHG quota? What has (not) worked with the biofuel quota? Who took the initiative?
- From your point of view, how beneficial has been each policy instrument before GHG reduction quota (tax exemption and biofuel quota) in regards of environmental impacts from road transportation?

- What is your opinion about GHG-quota? Which benefits and drawbacks does it have? Do you think GHG-quota is better than the previous policy instruments? (seeing rom the perspectives of government and industries).
- How has each policy instrument (incl. GHG reduction quota) affected the production and consumption of biofuels and the development of new biofuels technologies?
- How has each policy instrument (incl. GHG reduction quota) affected the biofuels actors?
- Sales of biofuels has decreased since the GHG-quota was introduced in 2015. What target does the German government actually want to achieve? Is this situation already foreseen? Does the government have any strategy to bring up the sales again?
- In 2015, biofuels contributed only 4.8% to the total fuel use in transportation. How do you see the future of biofuels in Germany?
- With this GHG quota, how optimistic are you that Germany could reach the 10% renewable fuels in the transport sector by 2020?
- A wider diffusion of agricultural based biofuels might pose a threat to the food industry and biodiversity in the future. In your opinion, should the biofuels be expanded further or should it stay at the current development level in Germany?
- EU has recently proposed ILUC as an additional sustainability criteria. What is your opinion about this matter? How would this situation affect the biofuels in Germany? What is Germany's strategy to overcome this situation? Will Germany use another policy instrument? Advanced biofuels and other alternative fuels
- Does Germany plan to support the development of advanced biofuels?
- Does Germany have sufficient raw materials for the advanced biofuels?
- Apart from biofuels, how do you see the prospect of electric vehicles or hydrogen fuels? Is it more competition or complementary? Will your proposed policies also take them into account?
- Do you think there is a need for both technology-neutral and –specific policies or are you in favor of either technology-neutral or –specific policies? Should an additional policy, beside the GHG reduction quota, be introduced? Should it be for short or long term?
- In Finland, they introduced tax system and biofuels quota. What is your opinion about their system?
- If you could create your own policy for the diffusion of biofuels, what would it be? What purpose would it serve? What benefits and drawbacks would your proposed policy have?
- Do you have further comments or critics to this topic?

B.1.3 Finland

- What are the barriers for the development of biofuels in Finland and for Finnish actors?

- What are the expectations regarding the development from the government and the companies? What is wanted in this area?
- What is unique about the development in Finland?
- What is most important when implementing innovation policies for the diffusion of biofuels in Finland?
- How important has the Biorefine Programme from Tekes been for the development?
- What implications have the tax regulations had for biofuels? What benefits and drawbacks has the tax exemption had?
- From your point of view, how beneficial has the tax exemption been so far in regards of abating climate change?
- Do you think a tax is a correct policy instrument to be used continuously?
- How has the tax in Finland affected the production and consumption of biofuels and the development of new biofuels technologies?
- What implications have the biofuel quota had for biofuels? What benefits and drawbacks has it had?
- From your point of view, how beneficial has the biofuel qouta been so far in regards of abating climate change?
- Do you think a quota system is a correct policy instrument to be used continuously? Thoughts on quota trading?
- How has the quota system in Finland affected the production and consumption of biofuels and the development of new biofuels technologies?
- At the moment, biofuels have 10% share in the market. By 2020, the target increases to 20% and in 2030, renewable energy should account 40% share in transportation. Is the target feasible?
- How have the biofuels actors been affected by the tax and the quota system?
- What regulations has there been before the quota and tax? Any funding for RD or demo?
- What is missing in the Finnish regulation system regarding biofuels?
- In Sweden there are speculations about soon implementing a reduction quota, reduction of GHG emissions, what are your thoughts about a regulation like that?
- In Germany they already have a similar system, a recent study showed that the sales of biofuels have declined already in the first year of implementation due to the moderate GHG emission reduction target. What are your thoughts about that?
- Critics/comments towards EU directives especially RED 2 proposal?
- Recently, EU proposed to include ILUC in the sustainability criteria. How do you think this will influence the market for biofuels in Finland?
- The technology inventions are well established in Finland. But how is the Finnish system today supporting investment cost for new bio refineries? Is that wanted to build new ones?
- How do you see the correlation between the low blend and high blend fuels? Are you aiming to have both on the market? How are you supporting the wanted development?
- Do you differ between first generation biofuels and second generation biofuels?

- Right now, first gen biofuels (agricultural crops) and second gen biofuels (forest residues) are at different levels in the development. Do you see a possibility for a diffusion of both types of biofuels by implementing the right policy mix? If yes, which policy instruments are needed to increase the diffusion of biofuels? What benefits and drawbacks would your proposed policy have, especially when implemented in Finland?
- Why are you specifically pushing the second generation biofuels? Because of the double counting?
- Is the second generation much better then the first generation in regards of abating climate change? In your opinion, should the focus now shift towards second generation?
- Some are arguing that a wider diffusion of agricultural based biofuels might pose a threat to the food industry and biodiversity in the future. In your opinion, should the biofuels be expanded further or should it stay at the current development level in Finland?
- How does the biofuel industry in Finland rely on the tax and quota system without the EU commissions approval?
- Do you think there is a need for both technology-neutral and -specific policies or are you in favor of either technology-neutral or -specific policies?
- Do you think the automobile industry also should have stricter regulations? To make the high blend work for example.
- To what extent are the Finish biofuel industries involved in the development of biofuel policies and what role do the industries have?
- How will a rapid increase of biofuels in Finland influence the fossil fuel industries? Will the expansion of biofuels be a threat to them?
- With the current policy, how do you see the chances for Finland to achieve the carbon free transportation target in 2030?
- What is your wish to the Finnish government in regards of implementing policies for biofuels?
- Current regulation only favors second generation and not biogas nor EV. Thoughts?
- Does Finland have own sustainability criteria (apart the one from EU) for biofuels, e.g. greenhouse gas emission reduction? Or what is the emission reduction from waste based biofuels?