Policy to promote the production and use of bio-fuels to meet the energy challenge in the transport sector of developed countries

- a case study of Sweden

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Abstract

Increasing evidence of anthropogenic induced global warming calls for more effective policies to regulate levels of greenhouse gases emitted to the atmosphere. The transport sector is one of the sectors contributing the most to annual carbon emissions due to large dependency on fossil fuels. Since fossil fuels are non-renewable and becoming increasingly scarce, significant uncertainties regarding supply and prices are prevailing and affecting the global economy. As a response to climate change and the oil dependent transport sector, policies are developed to facilitate the introduction of renewable biofuels as a substitute to fossil fuels. Despite the potential to substitute fossil fuels and reduce climate impacts, biofuels have not yet been widely adopted on the fuel market.

The aim of this study is to recommend effective policies to promote the production and use of biofuels in order to aid the development towards a less carbon dependent transport sector in Sweden. A case study has been utilised where multiple methods have been employed to elicit data from multiple sources. The analysis showed that the main drivers in Sweden to biofuel policy development are energy autonomy, climate changes, scarce fossil reserves and a strong technological development and excess amounts of biomass and waste products suitable for biofuel production. Obstacles to successful, sustainable biofuel expansion are complex, inconsistent policies which reduce opportunities for economically and environmentally efficient implementation of biofuels and also present new possibilities for future biofuel dependency situations.

Recommendations drawn from the study are the implementation of general and flexible policy measures, so the market forces can direct the biofuel development towards a flexible, but still robust, future. The main finding derived from this study is that fuel substitution is vital, but not as important as improved energy efficiency and therefore, the main objectives of all energy and transport policies should be to create incentives for fuel saving rather than fuel substitution.

Key words: Biofuel, oil dependency, transport sector, energy policy.

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Lisa Mattsson
Silsoe, August 2006

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List of Acronyms

CH_4	methane
CHP	combined heat and power
CFC	chlorofluorocarbons
CO	carbon monoxide
CO_2	carbon dioxide
DME	dimethyl ether
EU	European Union
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Holland, Ireland, Italy, Luxemburg, Portugal, Spain, Sweden and the UK.
EU25	EU15 and Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia.
FTD	Fisher-Tropsch Diesel
GHG	greenhouse gases
IPCC	Intergovernmental Panel of Climate Change
MJ	mega joule, 1×10^6 joule
µm	micrometer, 1×10^{-6} metres
NO_X	nitrogen oxides
O_3	ozone
ppm	parts per million
PWh	petawatt hour, 1×10^{15} watt hours
RME	rapeseed methyl ester
TWh	terawatt hour, 1×10^{12} watt hours

Chapter 1

Introduction

1.1 Introduction

The enhanced greenhouse effect is slowly enclosing the earth in a less transparent atmosphere, so a reduced amount of energy is reflected back into space, resulting in increasing temperatures and climate changes. Various international and national policy packages are trying to prevent this warming from happening, but the success rates are often difficult to measure since great amount of uncertainty and risk are related to global warming and its potential effects.

The promotion of biofuels in the transport sector is one of the policy options seen today around the world. Biofuels are sometimes considered 'carbon neutral' since they are viewed by some people to emit no more carbon to the atmosphere than was captured when growing the biomass. In addition, biofuels have the potential to substitute conventional fuels, gasoline and diesel, in the transport sector and provide cleaner air, less noisy vehicles and additional benefits. Despite various beneficial properties, such as potential for energy autonomy and reduced climate change impacts, biofuels have not yet been widely adopted on the fuel markets.

This study focuses on finding more efficient policies for the promotion of production and use of biofuels in a Swedish context. Sweden is a forerunner in the area of biofuels and has a very well developed biofuel based heating and electricity sector and has also proved to be successful in developing biofuels for the transport sector. An explicit request to increase the total energy autonomy made by the Swedish Prime Minister has further pushed the technological development of biofuels ahead.

Within the scope of this thesis, the word biofuels are referring to fuels produced from living or recently dead biomass that has undergone none or insignificant chemical or biological processes. The biofuel itself may have been chemically or biologically processed or been used for other purposes initially and may be liquid, gas or solid form (Korsfeldt & Palmberger, 2003).

1.2 Research Problem

With increasing evidence of anthropogenicly caused global warming, with potential for abrupt and catastrophic outcomes, the need for effective policies that controls greenhouse gas emissions are growing and becoming progressively more vital for the stability of the economic market structures of the global society. Contemporary policy promoting the use and production of biofuels aims, to varying degrees, at being economically and environmentally optimal. The achievement of optimality is one of the more intricate economic tasks, to which many great economists have devoted all their research efforts.

The economies of the developed world are today to a great extent dependent on fossil fuels for transportation. Since fossil fuels are becoming scarce, increasingly expensive and in addition to that, present a major cause of global warming, more stringent policies are to be expected in the future. Nations must prepare for even more costly oil and more stringent greenhouse gas emission restrictions.

In order to develop better and more economically and environmentally optimal and efficient policies, the underlying reasons for policy development and implementation must be understood. The opinions and insights gained in the past few years by actors concerned with biofuel policy, such as policy makers, lobbying groups, producers and other parties with interest in the biofuel policy making process, must be considered and analysed in order to aid the development towards a more carbon independent economy and find a more optimal policy regime for biofuels.

The research problem enumerated above was investigated by pursuing the aim and objectives detailed in the next section.

1.3 Aim and Research Questions

This study aims to recommend effective policy to promote production and use of biofuels in order to aid the development towards a less carbon dependent transport sector in Sweden.

The three main objectives developed in pursuit of the aim are the identification of:

1. obstacles and challenges to the production and use of biofuels.
2. economic barriers and drivers to an oil independent economy.
3. efficient policies that aid the development of a less carbon dependent economy.

A number of research questions have been identified in the light of the literature review in chapter 2, in order to pursue the objectives. The research questions have been divided into three key topics; background, policy and future development, which are presented in Table 1.1.

Background Questions	• What are the reasons for the need of transport fuels other than fossil based fuels? • What is the role of biofuels in the transition to stimulate oil independency?
Policy Questions	• What are the current policies regulating biofuel production and use in Sweden? • How is this policy developed and implemented? • What are the main criteria for current biofuel policy? Economic or environmental optimality? • What are the obstacles, drivers and challenges to increased production and use of biofuels?
Future Development Questions	• What lessons can be learned from the past and other nations? • How can biofuel policy be made more economically and environmentally efficient? • What should future biofuel policies regulate? • What are the likely developments for the biofuel market for the next 50 years?

Table 1.1 Research questions

1.4 Scope of the Research

The focus of this thesis is to identify what perceptions policy makers, economists and lobbying groups have of the future development and implementation of biofuels for the transport sector in Sweden. It is the views of these professionals and researchers that will be interpreted and analysed in order to understand the potential for biofuels and what support it has in society on a formal decision making level.

As policy makers, politicians, academics and lobbying group have large impact on policy development it is of great importance to understand the origin and reasons for their thoughts and ideas and what it may result in.

1.5 Outline of Thesis

The thesis contains five chapters in total. Chapter 1 outlines the basics behind the need for biofuels and explains shortly the issues of global warming and oil dependency. Research problem, aim, objectives and research questions are also presented in this chapter. In Chapter 2 the literature review is presented in 8 sections considering fossil fuel dependency, biofuel and technological potential, biofuel policy development, economic theory for optimal policy and technological change and transition theory. A conceptual framework is developed from the literature and illustrated at the end of the chapter.

Chapter 3 consider the methodology and research design and how that methodology was applied when conducting the research. In Chapter 4, first the summarised findings from analysis of secondary data are presented, while a fuller account is available in Appendix 14. The findings from analysis of the primary data is presented in section 4.3 and related to the literature review conducted in Chapter 2. At the end of Chapter 4, a revised conceptual framework derived from the findings is illustrated. The final chapter, Chapter 5, contains conclusions and recommendations for biofuel policy development and a review of aim, objectives and research questions. Also limitations for the research and recommendations regarding future research are presented within that chapter. All appendices are provided on the compact disk attached to the thesis or can be attained from the researcher on request.

1.6 Summary

In Chapter 1 the research problem was presented and the aim and objectives pursued in order to decipher the problem was identified. Research questions, derived from the literature review, were also presented. The following chapter presents the findings from the literature review.

Chapter 2

Literature Review

2.1 Introduction

A review of literature was undertaken in order to pursue the aim and objectives presented in Chapter 1. Herein, the key findings from the literature on issues related to the use of fossil fuels and the need for the introduction of biofuels are presented. Firstly, the concept of oil dependence is examined and the Swedish dependency situation is outlined in section 2.2. Thereafter, the potential biofuels comprise and the role biofuel play or may play in the future, in the transition towards a less carbon dependent economy, is presented in section 2.3. Section 2.4 on biofuel policy development is followed by the economic theory behind optimal policies in section 2.5 and technological change theory in section 2.6. Subsequently, a conceptual framework developed throughout the work on the literature review is illustrated at the end of the chapter.

In order to provide the reader with a general but comprehensive understanding of the complexity of the climatic system and its feedback mechanisms a thorough background to the issues of climate change and global warming is presented in Appendix 1. In Appendix 2 the background of sustainable development is illustrated and in Appendix 5 and 6 biofuel options and conversion routes are presented. A fuller record on policy development in Sweden and optimal pollution level can be found in Appendix 7 and 8. It is highly recommended to the reader with little knowledge regarding these issues consider the appendices before moving on to the main part of the literature review.

2.2 Fossil fuel dependency

After the Second World War the demand for energy increased rapidly in Sweden. To cover the increasing demand, large amounts of energy were imported from abroad. Fossil fuels were cheap and easy to use in engines of all kinds and made the use of biofuels from the forests increasingly expensive and inefficient and brought an end to the use of wood as a fuel in private households (Korsfeldt & Palmberger, 2003).

During the 1950s fossil fuel dependence was brought up on the political agenda as an issue of security. Since imports increased rapidly, the potential impact of imported fuel dependence on the country's balance of trade became a major cause for concern. Environmental issues

related to the use of fossil fuels were brought up later, during the 1960s, when that environmental movement took off and gained public support (Dalenbäck, 2002). The oil crises in 1973 and 1979 brought along an increased will to minimise the dependence on fossil fuels (Korsfeldt & Palmberger, 2003), but did not fundamentally change the course of events but rather confirmed the importance of rapidly finding new energy alternatives and developing more efficient energy technologies (Dalenbäck, 2002).

Currently, more than 97 percent of the transport sector is fuelled by gasoline and diesel while merely 2.7 percent of the car pool is fuelled by biofuels according to Persson *et. al*. (2006a). The fossil based fuels correspond to 95 TWh per year. The current allocation between the major biofuels is presented in Table 2.1.

Fuel	Percentage, %	Quantity
Gasoline and diesel	97	8×10^9 litres
Ethanol	2.7	250×10^6 litres
E85		32×10^6 litres
Natural gas		19×10^6 normal m^3
Biogas		16×10^6 normal m^3
RME		11×10^3 m^3

Table 2.1 Road fuels in Sweden

Source: Persson *et. al*., 2006a

Roughly 67 percent of all fossil oil that is being used for energy purposes in Sweden is used by the transport sector (Korsfeldt & Palmberger, 2003), which corresponds to 26 percent of the total final energy use (Åkerman & Höjer, 2006). During the last 10 years public transport has increased with 14 percent and heavy traffic has increased with 26 percent which has contributed to a 9 percent increase of carbon dioxide emissions compared to the base year 1990 (Persson *et. al*., 2006a). Globally, the transport sector is currently responsible for 23 percent of all greenhouse gas emissions. Between 1990 and 2001 emission of carbon dioxide from transport within the EU25 increased with 24 percent, which is a major obstacle to sustainable development, which is further discussed in Appendix 2 (Åkerman & Höjer, 2006).

In Sweden there are currently 4.2 million private cars, 70 000 lorries and 8 000 busses for public transport (Persson *et. al*., 2006a) which places Sweden among the top 16 countries with highest car ownership in the world; 452 cars per 1 000 people (Burgess et.al., 2006). In addition to this, the fuel use for private cars in Sweden is in average 20 percent higher than the average EU15 usage of fuel. This figure can be explained by older and heavier vehicles and a lower representation of diesel vehicles of the total car pool. Diesel vehicles are

considered to utilize 25-30 percent less fuel than normal gasoline fuelled vehicles (Persson *et. al*., 2006a; Kågeson, 2006).

The main fossil fuel reserves are located in the Middle East and countries with generally unstable social conditions, e.g. conflicts, war and insufficiently developed democratic system (Persson *et. al*., 2006). Shrinking supply of fossil fuels may lead to major problems regarding food and water supply and can result in conflicts or set off latent conflicts or worsen existing ones. Significant economic damage may arise and huge streams of environmental refugees may need international support (Change, 2006).

According to various scenarios set up by Azar *et. al*. (2003) it is expected that oil eventually will be completely phased out in the heating and electricity production but slowly increase in the transport sector, despite more stringent carbon constraints, until around 2050 when hydrogen becomes the most important fuel. In Appendix 3 and 4 illustrations of Sweden's oil dependency is provided. The next section provides a presentation of potential for biofuel production, use and technological prospects.

2.3 Biofuel and Technological Potential

Biomass is all the living matter in the earth's biosphere. Continuously, the biological matter is replenished by the flow of solar energy that reaches the surface of the earth and via the photosynthesis process energy is fixed in the biomass, which currently represents almost seven times the world's total primary energy consumption (Boyle, 2004). The biomass can be combusted and used as a fuel but provide different heat contents and release different amounts of carbon dioxide per kilo, which is shown in Table 2.2 below.

Fuel	**Heat content per GJ t^{-1}**	**CO_2 released per kilo GJ^{-1}**
Coal	30	80
Oil	42	70
Natural gas	55	50
Air-dry wood	15	0-80*

Table 2.2 Heat content and CO_2 emissions

Source: Boyle, 2004.

** If the wood is grown sustainably and combustion is complete, its lifecycle CO_2 emissions should be close to zero.*

When burning fossil fuels, elements that were geographically stable and not part of the biogeochemical cycles, are introduced in the biosphere, whereas the burning of biomass

releases elements that already take part in the biogeochemical cycles (Reijnders, 2006). The only way to preserve a depletable resource is by recycling or economic replenishment, i.e. let the price mechanism, market powers and technological progress handle the use of the non renewable resource (Tietenberg, 2003).

Biofuels are the most diverse of the renewable energy sources, compared to solar, hydro and wind energy, as biomass is fairly easily may be utilised for production of transport fuels, heat and electricity generation. Biomass has played an important role in the total Swedish energy mix for the past thirty to forty years with increasing significance. In 1970 merely 9 percent of all energy was produced from biomass while in 1998 biofuels were responsible for 15 percent, or 90TWh, of the total energy supply (Dalenbäck, 2002).

Biofuels is sometimes regarded as “carbon neutral”, i.e. the carbon dioxide released to the atmosphere when the biomass is combusted is offset by that absorbed by plants and trees during their growth period. Nonetheless, all additional energy inputs used in production or during utilisation of the fuel will affect this carbon neutral balance negatively (DTI, 2005). According to Boyle (2004) there are no energy systems in the present day that could claim to be entirely carbon neutral since carbon emissions during the complete process of production to use must be considered, e.g. emissions associated with fertilizer production, use of fossil fuels in processing or transporting the biofuel.

The main biofuels that are under development or being used for transport currently are presented in Table 2.3 (Korsfeldt & Palmberger, 2003).

Main Biofuels
• Ethanol
• Methanol
• Dimethyl ether, DME
• Rapeseed methyl ester, RME
• Fisher-Tropsch Diesel, FTD
• Biogas
• Hydrogen

Table 2.3 Main Biofuels

A more thorough overview of the raw materials and conversion routes used for these biofuels is presented in Appendix 5 and 6.

The availability of biomass and land for production of biomass in Sweden is relatively good and estimates on potential supply of total renewable energy in Sweden has been made by Åkerman & Höjer (2006) and Azar *et. al*. (2003) to close to 72 PWh. Despite large potential biomass is currently more efficiently used when producing heat or generating electricity. Azar *et. al*. (2003) and Cannell (2003) states that emerging consensus suggests that biomass initially should be used for heat generation and co-generation rather than for biofuels, which is supported by Åkerman & Höjer (2006) who verify that the general viewpoint is that marginal cost for energy reduction in the transport sector is higher than for other sectors. But as only 11 percent of the heating for residential and commercial buildings are fossil fuel based, the transport sector is regarded as the next area of improvements in energy efficiency (Persson *et. al*., 2006).

According to Ryan *et.al*. (2006) both biodiesel and bioethanol show positive energy balances. European bioethanol yields CO_2 savings of 13 to 83 percent contrasted to conventional gasoline vehicles and biodiesel have potential of 36 to 83 percent CO_2 savings in opposition to conventional diesel. Brazilian bioethanol may yield even higher CO_2 savings due to high productivity of sugarcane crops and use of by-products that provide energy to most processing plants.

The IPCC has estimated the potential energy savings in the transport sector to 35 to 80 percent by 2025, where more efficient drivetrains and reduced vehicle road load are key factors to this improvement. Stricter emission limits of particulate matter and NO_X may conflict with efficiency improvements and with current trend of increasing transport, sustainable transport will not be achieved in the near future (Åkerman & Höjer, 2006).

Since most biofuels are related to high costs today the government has to implement various policies in order for biofuels to enter the market and gain experience and develop further to eventually be commercially strong in it self. The following section is shortly presenting how biofuel policy is developed and implemented and what targets the Swedish government are guided by.

2.4 Biofuel Policy Development

In 1998 the Swedish Parliament adapted a new environmental legislation, referred to as the "Environmental Code" and a new structure for work towards Environmental Quality Objectives (Regeringskansliet, 2004a). Fifteen specific Environmental Objectives were launched in January 1999 and one additional objective was adopted in 2005 (Sveriges Miljömål, 2006). The objectives mostly related to climate change, transport and biofuel issues are presented in Table 2.4.

Environmental Objectives related to biofuels
• Reduced climate impact
• Clean air
• Natural acidification only
• A protective ozone layer
• Zero eutrophication
• Sustainable forests
• A varied agricultural landscape
• A good built environment
• A rich diversity of plant and animal life

Table 2.4 Environmental Objectives related to biofuels (Sveriges Miljömål, 2006).

The achievement and responsibility of these objectives are shared between several actors such as public authorities, county administrative boards, municipalities, organisations and trade and industry. Due to globally important characteristics, such as transboundary greenhouse gas emissions, international initiatives play a key role regarding current and future policy development and should be encouraged (Regeringskansliet, 2006c).

Before a new policy is introduced both the Ministry of Finance and Ministry of Sustainable Development have to have their say and the matter is also being referred for consideration. Thereby, opportunities exist for all interested parties to object or support a suggested policy. Several independent organisations like The Swedish Environmental Protection Agency, The Swedish Road Administration, The Swedish Society for Nature Conservation and various lobbying groups are given the opportunity critically analyse all proposals and present a statement on the matter submitted (Regeringskansliet, 2006h).

In 1995, when Sweden entered the European Union, an additional level of government was obtained. Sweden was now subject to the EU *acquis communautaire* (Regeringskansliet, 2004), i.e. the body of common rights and obligations that bind all the Member States together within the EU (European Commission, 2006), and participate in the decision-making processes where common rules are outlined and agreed upon (Regeringskansliet, 2004b). In Appendix 7 further information is provided regarding policy implementation processes in Sweden. In the following section the economic background of optimality and efficiency is presented.

2.5 Economic Theory for Optimal Policy

Immense benefits are provided to society by the environment; it sustains our livelihood and gives us means to exist and enjoy our lives. Despite the importance of the environment, we often fail to asses the full costs and benefits of natural resources due to difficulties in valuing the surrounding environment (Grafton *et. al*., 2004). The main underlying cause to the environmental degradation is human behaviour and activities, and in the case of greenhouse gas emissions, the transport sector is the major contributor to degradation, as stated by Åkerman & Höjer (2006).

Growing population and development of industrial economies contributes to the acceleration of the environmental deprivation. In order to reverse the negative development, a change in behaviour, values and attitudes is needed, which affect the direction of policies. By assigning an economic value to an environmental asset it provides us with a basis for comparison and thereby also a criterion that will aid in the policy-making process (Helm, 1991).

When an economic value is assigned to an environmental feature, the asset becomes an economic good which can, theoretically, be traded, rationed or given free access to. In order to deal with the good in an economically efficient manner policy design is crucial. The importance of valuation and careful design of policies is expressed by Tietenberg (2003, p. 30) who states that if policy is not made by design, it is made by default.

With the help of these environmental values it is possible to define an optimal level of pollution which may guide decision-makers when constructing policies controlling e.g. greenhouse gas emissions. The concept of *Pareto Efficiency* is often employed when searching for optimal solutions, which implies that an outcome is efficient if it is not possible to change the distribution of assets and resources to make one person better off, without making another person worse off (Grafton *et.al*., 2004).

Greenhouse gases are regarded as transboundary flow pollutions (Grafton *et.al*., 2004), which may accumulate if the emission exceeds the assimilative capacity of the environment. The marginal damage caused by a unit of pollution increases with the amount emitted. Marginal control costs increase with the amount controlled, through e.g. prevention, abatement, mitigation or climatic engineering (Tietenberg, 2003). The efficient level of pollution exists when the marginal cost of pollution control is exactly identical to the marginal benefit of pollution control. This is demonstrated in Figure 2.1 below (Grafton *et.al*. 2004).

The optimal level of pollution control is where the damage caused by the marginal unit of pollution is equal to the marginal cost of avoiding it. If more abatement is undertaken, inefficiencies will arise since the total cost would mount. The economically optimal level of pollution is not zero, and the reason to this is the undervalued or overlooked, environmental assets and externalities arising from economic activities (Tietenberg, 2003). In Appendix 8 more on optimal pollution level is presented.

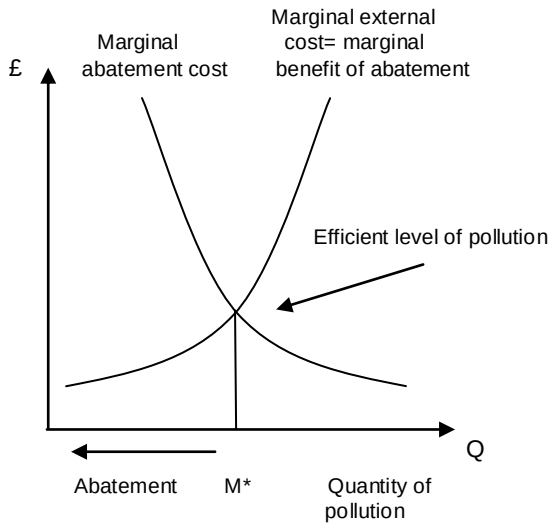

Figure 2.1 Efficient level of pollution
Source: Grafton et.al., 2004, p. 63

An externality exists when one agent's production or consumption decisions impact the utility or profit of another agent in an unintended manner and where no compensation or payment is made (Perman *et.al.,* 2003). Carbon dioxide and the damage it causes through climate change is a negative externality of actions like driving cars and heating our houses, i.e. an effect not fully included in economic models, which leads to reductions in our welfare. If the externalities are not controlled, a firm may produce too much of the good or service, causing more negative externalities. Since the price of the externalities is low, or zero, no incentives are given to the firm to reduce the production or to recycle or reuse the polluting substances

and society may face severe reductions in welfare. This is referred to as a market failure (Tietenberg, 2003).

Externalities are one of the sources of market failure and the main sources, according to Perman *et.al*. (2003), are presented in Table 2.5.

Sources of market failure
• Externalities
• Lack of appropriate markets
• Imperfect information
• Imperfect competition
• Incomplete property rights
• Public goods
• Agents are not maximisers

Table 2.5 Sources to market failure

By using economic models, where the sources of market failure are eliminated, an ideal situation is created where economic efficiency may be accomplished. Actual markets are not ideal since several sources of market failure are present. By comparing the ideal situation to the real world example, it is possible to identify and to recommend policies to correct them so the actual economy will perform better in relation to the objective of efficiency (Perman *et.al.,* 2003).

Due to the prevalence of externalities resources are being wasted and used in an unsustainable manner. Policies must attempt to minimise these inefficiencies by giving the correct incentives for change and optimal resource use. By fully internalising the externalities a policy may be cost-efficient, hence may succeed in giving correct incentives and result in a situation closer to the ideal economy (Tietenberg, 2003).

A policy is cost efficient if its objective is achieved at the lowest cost possible, thus wasteful expenditures are reduced and political backlash may be diminished. It is though generally considered impossible or very difficult to establish a set of tax rates that could guarantee specific environmental objectives, even though taxes may rectify some distortions in resource pricing. Emission trading is seen as the more reasonable method of achieving an environmental objective and at the same time being cost efficient, as the market forces will allocate permits and certify that costs are kept as low as possible (Tietenberg, 2003).

In addition to the issues regarding externalities and choice of policy, uncertainty is another factor strongly influencing decision-makers. Uncertainty is prevalent for both renewable and non renewable resource extraction and use, e.g. stock sizes, environmental impacts, health impacts and pay-offs from new products, which restricts long term planning and investment and hinder strong development in areas where development is requested (Perman *et.al*., 2003).

Transport issues are interrelated with all sectors in society and therefore Åkerman & Höjer (2006) emphasises that all policies in society must work in the same direction so for example agricultural, public procurement and tax policies are coordinated. Flexible and robust policies are requested as biofuel technologies are under development and no distinct solution has been presented (Åkerman & Höjer, 2006).

Azar *et. al*. (2003) advocates policies ensuring increased costs of emitting carbon dioxide via carbon taxes or cap and trade schemes and the inclusion of the transport sector in the CO_2 emission trade, as current carbon fees are not large enough to result in cost-efficient fuel changes. Subsidies should decrease over time and learning and scale effects should be encouraged in order to gain more efficiency improvements and cost reductions.

Johansson (2006) argues that optimal solutions are unattainable in the real world and instead promotes second-best solutions, such as taxation systems without tax exemptions or emission trading systems based on allocation through auctioning. The current Swedish system with significant tax reduction will result, according to Johansson (2006) in low environmental effects and high costs for businesses and create greater incentives for reducing production than for fuel conversion and energy efficiency improvements.

The transport system is one of the more complex and expensive infrastructural systems available and a change in fuel use and transport patterns will demand large efforts and potentially also involve high costs through extensive technological change, which is discussed in the following section.

2.6 Technological Change and Transition Theory

The technological change seen by the Western society for the past 50 years is the result of a union of science and technology. In the process of economic growth technical change contributes by permitting the substitution of knowledge for resources, aiding the substitution of less costly and more abundant resources for more expensive resources, releasing

limitations to growth caused by inelastic resource supplies and providing a new source of income. (Ruttan, 2001).

The transition of biomass to a modern energy source has slowly developed as more economic incentives and better technologies have been provided. Faaij (2006) presents the development stages of biomass utilisation, technological change and market development in Table 2.6.

Development stages of biomass utilisation
1. Utilisation of waste as a waste management solution
2. Local utilisation of excess resources from forests and agriculture, demanding some infrastructural changes
3. Regional scale development; larger conversion units provide economies of scale
4. National market development; increased market size and more complex logistics
5. Biomass becomes an internationally traded commodity regulated by legislation, taxes and subsidies

Table 2.6 Development stages of biomass utilisation

The diffusion of new technologies to the market place is not straightforward and a general distribution of adopters over time may look like Figure 2.2 illustrated on the next page.

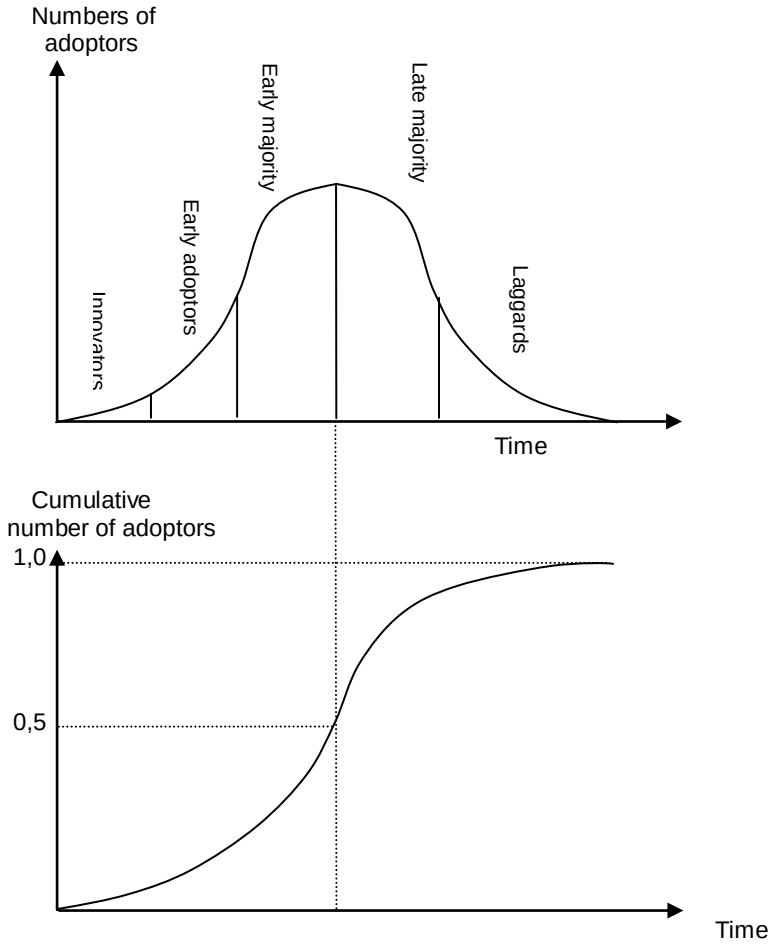

Figure 2.2 The process of diffusion of technological change

Source: Thirtle & Ruttan, 1987, p. 81

The s-shaped curve, in the lower graph, shows that there is resistance to technological change which results in delays of the technological diffusion. The resistance is explained by psychological, sociological and structural factors that hinder the development and rapid adoption of a new technology. (Azar *et. al.,* 2003). Another motivation for resistance is the economic interest of workers protecting their jobs, condition of employment and the industry protecting themselves against the happening of “creative destruction”, i.e. the substitution of older technologies due to technological competition (Ruttan, 2001). In order to augment diffusion rates, enhanced reliability and long term durability must be provided (Azar *et. al*., 2003).

In addition to that, technical change may also be seen as dehumanising the link between production and the workers and that increased specialisation may lead to deepening of income classes and increase inequality in society. Furthermore, technological progress may result in political domination when transferred from rich to poor countries and be a source of

war and conflict. Ultimately, technological change may contribute to the destruction of cultural values and result in degrading environmental externalities, such as pollution (Ruttan, 2001). All these factors are further contributing to the s-shaped diffusion curve presented in Figure 2.2.

Four main sources of technical change have been identified by Ruttan (2001); induced technical change, the evolutionary theory, path dependence and a general theory. Induced technological change is characterised by either a demand pull or supply push, as technologies available on the market create a demand for similar products or further developments of the initial product, or policies that stimulate production to certain level and creates a supply push towards that target level. Examples of demand pull and supply push policies are environmental standards and feed-in tariffs (Szarka, 2006). The evolutionary theory is driven by the search for better technologies by learning, which is achieved through local search for innovation, imitation of other firms' behaviour and the achievement of satisfying economic behaviour (Ruttan, 2001).

Unruh & Carrillo-Hermosilla (2006) question why technologies with potential to increase energy efficiency and substitute fossil fuels available today are not diffusing more rapidly and thereby provide the potential win-win situation. An explanation provided is carbon lock-in, which arises via the historical development path of industrialised countries. The path dependent process is driven by increasing returns to scale where small historical or chance proceedings provide a specific technology with early advantages which later results in the adoption of the technology which may have substandard long term potential (Ruttan, 2001).

Quasi-irreversibility or lock-in in physical technologies and social institutions may arise and creates market and policy barriers to alternative technologies (Könnölä *et. al.,* 2006) and is according to David (1985, cited by Ruttan, 2001) featured by interrelatedness, economies of scale and quasi-irreversibility of investment. Interrelatedness is characterised by the need for system compatibility, economies of scale is associated with decreasing user costs, and quasi-irreversibility by the specific skills needed and developed in order to manage a specific technology (Könnölä *et. al.,* 2006).

Road infrastructure is generally providing a negative lock-in situation regarding sustainable development while rail infrastructure and other public transport is providing a more positive, committing lock-in situation. In order to avoid premature negative lock-in situations Åkerman & Höjer (2006) promotes demonstration programmes rather than complete fuel switch.

Unruh & Carrillo-Hermosilla (2006) argue that carbon lock-in may be spreading globally and may constrain climate change mitigation options further, as many policy recommendations ignore risks of carbon lock-in. Reason provided for various lock-in situations are policies with path dependent features that due to relative ease of implementation, results in premature lock-in situation, as the easy path proved not to be the optimal transition path.

The fourth source of technological change provided by Ruttan (2001) is a general theory of institutional change, which may explain technological change more coherently as institutions are affected by changes in the physical, social and economic environment and energy policies are developed in accordance with how the institutions interpret the economic, social and physical environment. A new policy paradigm that reaches further than boosting production capacity and rather includes both institutional dynamics of innovation processes and the fostering of community engagement in executing processes will contribute to sustainable policy theory development (Szarka, 2006).

2.7 Conceptual Framework

In the light of the literature review, a conceptual framework was developed to facilitate analysis. The conceptual framework used for this project is based on the DPSIR framework, which is explained in more detail in Appendix 9. The DPSIR framework was chosen due to its suitability to illustrate causality, as different human induced activities affect the environment and the state of the environment is changed.

The framework shows that Drivers, Pressures, State, Impacts and Responses are all connected and interrelated. Policy makers, producers and consumers are representing society and they differ in their context, characteristics and behaviour. The Drivers to the environmental problems arising from the use of fossil fuels are created by humans, i.e. society, represented by the three groups identified in the conceptual framework. The need for transport of food, water, raw materials and other essential commodities is the main driver and, as we have seen in the previous chapter, increasing. New solutions are sought after and biofuel represent one of the many solutions to the use of fossil fuels.

The Pressure causing the environmental state to deteriorate is fossil fuel use that causes global warming and changes of land, soil, water and air quality. The deteriorating state of the environment leads to severe negative impacts on human health and ecosystems. Biodiversity is lost and other irreversible losses are visible. Society is affected by all these factors and consumers and producers put pressure on the policy makers which later result in

the introduction of new policies and regulations. The responses range from minimisation and mitigation of damage to adaptation to a changed environment. Regulations, economic instruments and voluntary agreements, on international as national levels, are utilised in order to fight off the negative outcomes of fossil fuel usage.

Within this thesis the main focus is on the responses as they consists of the policies implemented in order to facilitate the development towards a less carbon dependent economy, but other components of the DPSIR framework is also analysed. Of the Responses, further restrictions have been made due to time restrictions and field of study; only the economic instruments and, to a smaller degree, the voluntary agreements are analysed. Drivers and hinders to development are also of great importance and since a negative driver is a hinder, obstacles are discussed under driver headings in the findings. By considering the conceptual framework in Figure 2.3 on the following page and the research questions, presented again in the table below, together, the framework for the research is made more comprehensible.

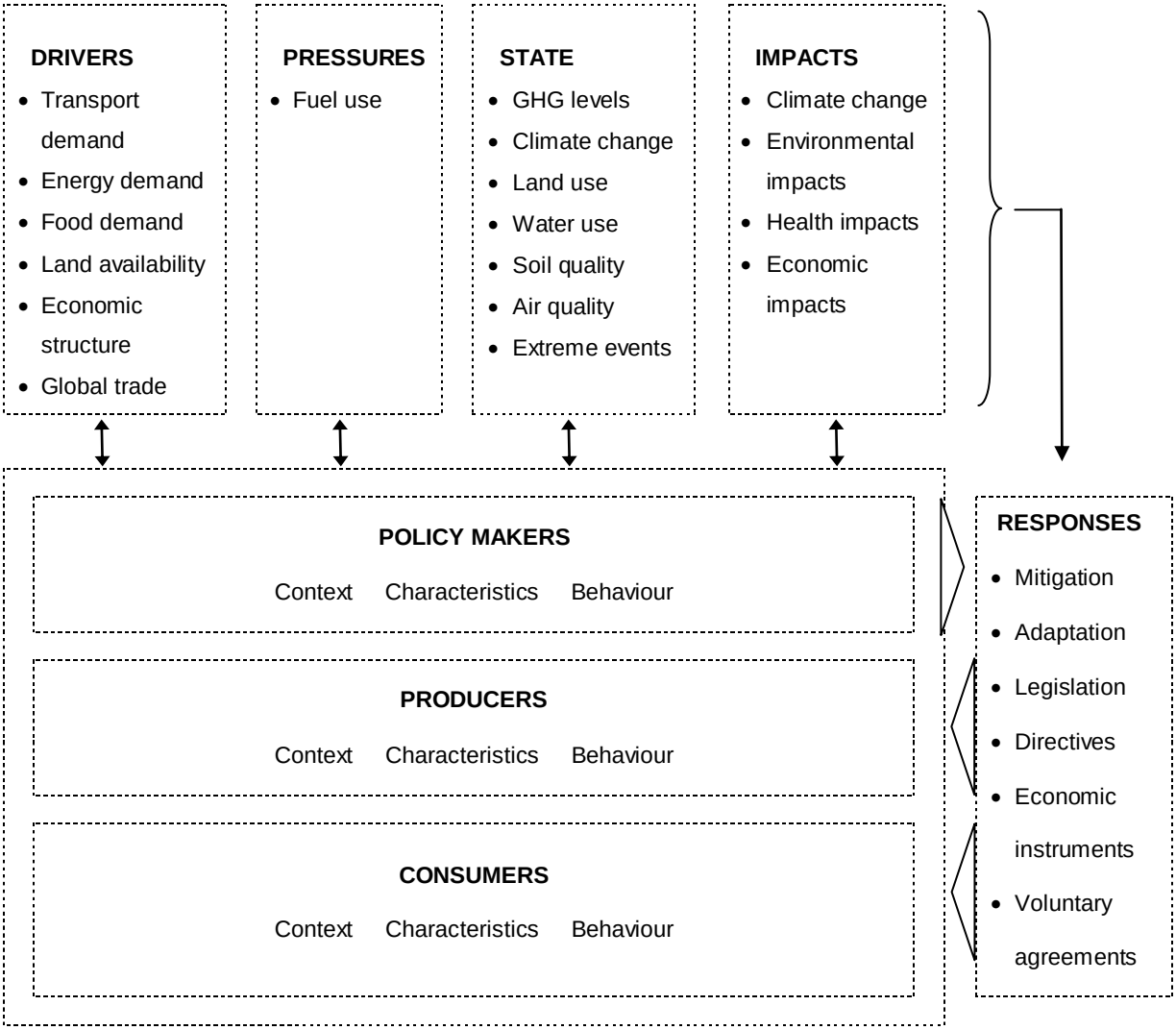

Figure 2.3 Conceptual framework

Review of literature presented theory which enabled a greater understanding of the research objectives and a set of research questions were developed to facilitate further analysis of the findings. For example the question "What are the main criterions for current biofuel policy?" was investigated in section 2.4 where Environmental Objectives are presented. "What are the reasons for the need of transport fuels other than fossil based fuels?" is considered in sections 2.2, 2.3 and 2.4. A table of all research questions developed is presented in the table below:

Background Questions	• What are the reasons for the need of transport fuels other than fossil based fuels? • What is the role of biofuels in the transition to stimulate oil independency?
Policy Questions	• What are the current policies regulating biofuel production and use in Sweden? • How is this policy developed and implemented? • What are the main criterion for current biofuel policy? Economic or environmental optimality? • What are the obstacles, drivers and challenges to increased production and use of biofuels?
Future Development Questions	• What lessons can be learned from the past and other nations? • How can biofuel policy be made more economically and environmentally efficient? • What should future biofuel policies regulate? • What are the likely developments for the biofuel market for the next 50 years?

Table. 2.7 Research questions.

2.8 Summary

Within this chapter issues of oil dependence, biofuel and technological potential, policy development, economic optimality and efficiency and technological change has been presented and outlined. The upcoming chapter is presenting the methodology used when conducting the research and will also explain how the research strategy was applied for this specific study.

Chapter 3

Research Methodology

3.1 Introduction

Throughout this chapter the methods utilized when conducting the research are presented. A research methodology is the theory or study of how research ought to be carried out and may moreover be regarded as the general principles that will guide the research, opposed to the method which is the particular approach to research, the tools used to gather data. The methodology is the overall approach to studying a topic where limitations, dilemmas and ethical choices must be considered (McIntyre, 2005; Dawson, 2002).

The study carried out under the scope of this thesis, policy controlling biofuel promotion and use, can be classified as “real world research” since the research is involving policies developed by people and situations from real life (Robson, 2002). The social scientist is committed to investigate the interactions between humans and society and the role played by social considerations in human behaviour (McIntyre, 2005).

This chapter is divided into two main parts;

- Research design – that outlines the purpose of the study, the research strategy, the type of data available, the data analysis methods and the quality of the research.
- Application of research design – that outlines how the data was collected, what difficulties arose during the data collection process and how the data was analysed.

3.2 Research Design

3.2.1 Purpose of the Study

According to Robson (2002) there are four classifications of purposes of enquiry; exploratory, descriptive, explanatory and emancipatory, of which the characteristics are further explained in Table 3.1.

Purpose of study	Characteristics
Exploratory	• To find out what is happening, particular in little understood situations. • To seek new insights. • To ask questions. • To assess phenomena in a new light. • To generate ideas and hypotheses for future research. • Almost exclusively of flexible design.
Descriptive	• To portray an accurate profile of persons, events or situations. • Requires extensive previous knowledge of the situation etc- to be researched or described, so that you know appropriate aspects on which to gather information. • May be of flexible and/or fixed design.
Explanatory	• Seeks an explanation of a situation or problem, traditionally but not necessarily in the form of causal relationship. • To explain patterns relating to the phenomenon being researched. • To identify relationships aspects of the phenomenon. • May be flexible and/or fixed design.
Emancipatory	• To create opportunities and the will to engage in social action. • Almost exclusively of flexible design.

Table 3.1 Classification of the purposes of enquiry

Source: Robson, 2002

A particular study may be concerned with more than one purpose but often one will prevail (Robson, 2002). In the case of this thesis the research is exploratory since attempts are made to find out on what grounds biofuel policy is developed and what targets the various policies may have, but also how and why biofuel policies are designed the way they are. By asking questions about current biofuel policies new insights may be acknowledged so ideas and hypotheses for future research can be developed and more efficient policy recommendations can be made and the phenomenon may be assessed in a new light.

3.2.2 Research Strategy

There are two major approaches of sociological inquiry; quantitative and qualitative research. Quantitative sociological research is research following the research models established by the natural scientists in order to discover the laws that govern social behaviour and is often presented in numbers which allow quantification. On the other hand, sociological research is concerned with human beings that think and feel which set them apart from the objects investigated by natural scientists. Therefore, according the German sociologist Max Weber, sociology must go beyond the natural science model and be an interpretative science, often referred to as qualitative research. Qualitative research is concerned with people's attitudes, motivations, experiences, beliefs, views, feelings and behaviour (McIntyre, 2005).

The research reported in this thesis is most suited to be of qualitative nature, in view of the fact that little or no statistical information will be generated and that the key informants' interpretations and thoughts of current policies and future policy development are of major interest for the analysis.

Qualitative research strategies are typically of flexible design where case studies, ethnographic studies and grounded theory studies are the three most common designs. Within the scope of a case study, attempts are made to gain detailed, intensive knowledge about a single case, or a number of related cases in a comparative study. An ethnographic study aims to interpret and explain how an organisation, community or group interact, develop and understand their lives and the world they live in. The grounded theory study endeavours to generate new theory from the object being studied (Robson, 2002). The flexible design of research strategy that will be employed during this particular study is the case study.

A case study is used to contribute to the creation of knowledge regarding individual, group, organisational, social and political phenomena. Case studies are commonly used among social, psychological, political science, business and economics and community planning researchers since there is a desire to gain understanding in a specific, often complex, social situation (Yin, 2003).

The focus of a case study should be on contemporary events, over which the investigator has no or restricted control, and generally, the form of research questions are of "how?" and "why?" character (Yin, 2003). As seen in Chapter 1, where the research questions for this thesis are outlined, the majority of the questions are of "how?" and "what?" nature.

The essence of a case study, as explained by Schramm (1971, quoted in Yin, 2003, p. 12), is…

> "…that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result."

Although, a case study may also be an investigation of the "…contemporary phenomenon within its real-life context…, especially when boundaries between phenomenon and context are not clearly evident." (Yin, 2003, p.13). In addition, a case study copes with situations where several variables of interest are analysed, where several sources of evidence is needed and theoretical propositions guide the data collection and analysis (Yin, 2003).

In order to structure and aid the research about to be carried out, a conceptual framework has been developed to facilitate the understanding of the research process and relationships between various factors. A conceptual framework is "the system of concepts, assumptions, expectations, beliefs, and theories that supports and informs your research" (Maxwell, 1996, quoted by Robson, 2002, p. 63) and the framework usually evolves during the progress of research (Robson, 2002). The conceptual framework developed for this study is illustrated in Figure 2.5 and a modified, final conceptual framework is presented in Figure 4.1.

3.2.3 Data Collection

When the purpose of the study and the research strategy has been determined, the method of collecting data must be established. The main methods of data collection used when conducting case studies are presented in Table 3.2 (Yin, 2003).

Data collection methods
• direct observation
• participant-observation
• Interviews
• Documentation
• archival records
• physical artefacts

Table 3.2 Data collection methods

The choice of method is affected by various constraints such as time limitation, budgetary limitations, business confidentiality and other ethical considerations (Robson, 2002).

By using interviews the researcher may gain understanding of events in where the researcher did not participate or had little knowledge about. Interviews are also suitable when attempting to describe social or political processes and how and why things change. Interviewing are often used by decision makers "…to shed new light on old problems." (Rubin & Rubin, 2005, p.3). In the light of these arguments the methods utilised for the data collection for this thesis was established to be interviews and documentary review.

3.2.3.1 Primary Data

Often a distinction is made between unstructured, semi-structured and structured interviews. A structured interview is seen as an oral version of questionnaires while less structured interviews allows for increasing degree of flexibility and expression of personal opinions. Semi-structured and unstructured interviews are often open-ended, i.e. allow for great variation in questions and answers. Interviews are often conducted face-to-face between two people but may also be in groups. Telephone interviews are becoming more common as it saves time and resources (Robson, 2002).

Face-to-face interviews have generally very high response rates and the interviewer may also observe the surrounding and nonverbal communication such as body language and facial expressions. Therefore, the semi-structured interview was established as appropriate data collection method for primary data in this study. Disadvantages of face-to-face interviews are extensive resource use and potential bias expressed by the interviewer through tone of voice, body language and question wording (Neuman, 2000).

3.2.3.2 Key Informants

To gain credibility for the research, the choice of interviewees is crucial. The interviewees should be knowledgeable, experienced, have first-hand knowledge about the research topic and the combined views attained from the interviews should present a balanced perspective (Rubin & Rubin, 2005).

3.2.3.3 Secondary Data

Secondary data or documents are another source where data may be collected from. Documents may be a book, a newspaper or magazine, a notice, a letter or even non-written artefacts like videos, television programmes, pictures, drawings or photographs. According to Robson (2002) advantages with secondary data is that they are unobtrusive and non-reactive, i.e. the researcher does not need to contact the person who produced the data and the data will not be changed because of the use of it.

3.2.4 Data Analysis

According to Yin (2003, p.109) data analysis…

> "…consists of examining, categorising, tabulating, testing, or otherwise recombining both quantitative and qualitative evidence to address the initial propositions of a study."

Miles and Huberman (1994) argue that successful analysis consist of three simultaneous flows of activities; data reduction, i.e. reducing data by creating summaries, abstracts, codes and writing memos, data display, i.e. display data in tables, figures, boxes, matrices and charts, and conclusion drawing and verification, i.e. noting patterns, regularities, irregularities, verifying facts and present evidence supporting your findings (Robson, 2002).

Codes and clusters are seen as "…tags or labels for assigning elements of meaning to the descriptive or inferential information complied during the study" (Miles & Huberman, 1994, p. 56), which was seen as an appropriate method together with written summaries of the interviews for reducing the data regarding this study.

3.2.5 Quality of Research

To assure the quality of the research, data must be reliable, valid and general in its nature. Reliability means dependability or consistency and several research methods, such as interviews, surveys and observations, are used in order to gain this reliability (Robson, 2002). A thing being valid is regarded as being "based on truth or reason" and "able to be accepted" (Cambridge Dictionary, 2006). Validity means truthful and refers to the bridge between a construct and the data. Qualitative researchers adhere to the principle of being truthful and giving a fair, honest and balanced account of the social attribute they are studying (Neuman, 2000). It is recognised there are limits to generalisability of case study research. However, this exploratory study will provide useful new insights and provide a basis for further research which can address the generalisability problem (Robson, 2002).

Summary of Research Design

- The purpose of the study is exploratory.
- The research strategy used is a case study.
- The type of data collected is qualitative.
- The data collection methods are face-to-face, semi-structured interviews and documentary review.
- The method used for data analysis is coding and clustering.
- Significant efforts have been made to present the data in a valid, reliable and general manner.

Table 3.3 Summary of Research Design

3.3 Application of Research Design

In this section the application of the research design is presented and motivated. The coding and clustering scheme, interview schedule, interview consent form and interview transcripts are attached in Appendix 10 to 13.

3.3.1 Data Collection

3.3.1.1 Primary Data

A semi-structured interview schedule, presented in Appendix 11, was prepared prior to the interviews in accordance with Robson's (2002) recommendations for a semi-structured interview schedule, i.e. introduction, warm-up, main body of interview, cool-off and closure. The questions were derived from the research questions developed from the literature review in Chapter 2. However, during the interviews additional questions were added in order to gain further insight and develop the research. The order of the questions was sometimes restructured during the interviews to facilitate a natural flow of questions related to the respondents' answers and to achieve as comprehensive understanding as possible. All interviews were recorded as it provides the opportunity to listen to what was said on later occasions and thereby facilitate analysis.

The criteria for the selection of respondents for the study were at least one of the following decisive factors:

- involvement in the biofuel industry,
- involvement in biofuel policy making processes,
- understanding of biofuel policy development and biofuel economy.

Early in the research process suitable key organisations and departments were identified in accordance with the criteria established above. Initially, electronic mails were sent out with a general enquiry for an interview to the person mentioned on the official web site or to a person that had been recommended to the researcher. The e-mail was polite and not especially forceful in its formulation but as only a few replies were received within the first week, an alternative approach was initiated.

The researcher phoned the identified department or organisation and presented her cause and announced interest for a face to face interview. As the personal contact, via phone, seemed to evoke interest from the key organisation's side, the response rate increased dramatically. In the cases where the researcher did not have a specific person in mind for the interview, the receptionists or secretaries managed to locate appropriate person within suitable department with substantial knowledge about the topic.

Eleven out of thirteen identified key informants agreed to meet for a shorter interview, estimated to last for 30 to 60 minutes. The visit to Chalmers in Gothenburg resulted in one additional respondent as respondent J joined in during the interview with respondent H and I. Finally, the following twelve respondents were to be interviewed:

Respondent	Organisation	Title/Department
A	The Swedish Bio Energy Association	Executive secretary
B	TallOil	Consultant
C	Nature Associates	Consultant
D	The Swedish Society for Nature Conservation	Handling officer
E	Swedish Environmental Protection Agency	Economist
F	The Swedish Road Administration	Engineer, Environmental Section
G	Swedish Parliament	Member of Parliament
H	Chalmers University of Technology	PhD/Researcher
I	Chalmers University of Technology Commission on Oil Independency	Professor, Sustainable Industrial Metabolism
J	Chalmers University of Technology	PhD/Researcher
K	The Swedish Biogas Association	Chairman, Head of Investigation
L	Ministry of Sustainable Development	Deputy Director, Division for Energy

Table 3.4 Key Informants

The interviews lasted from 20 minutes to 1 hour and 45 minutes and all twelve respondents seemed happy to answer the questions and also provided further information, such as internet links and power point presentations, booklets, information leaflets and annual reports in order to further deepen the understanding for their particular viewpoint.

3.3.1.2 Secondary Data

Secondary data used in the case study and the literature review of this study has been collected from a wide range of sources. Official documents such as European Directives and Swedish policy documents has been utilised as well as specialist literature and academic articles and journals. Internet sources and information leaflets has also been employed when needed. The literature review presented in Chapter 2 has contributed to the widening of the understanding and knowledge base for the complex issues of oil usage and related consequences, oil dependency and potential alternatives to fossil fuel reliance while the secondary findings presented in Chapter 4 were to be included in order to provide the reader with specific details of the current biofuel policies which will facilitate understanding of the discussion and conclusions drawn in Chapter 5.

3.3.2 Data Analysis

Within the scope of this study one interview was fully transcribed and is presented in Appendix 13. All interviews were coded using Miles and Huberman's (1994) recommendations for coding and clustering and are summarised in Chapter 4 under appropriate code related headings. The coding and clustering scheme was developed from primary and secondary data to facilitate the analysis process and is presented in Appendix 10.

The data was divided into five main macro-codes, drawn from the conceptual framework, that represent the drivers (Dri), pressures (Pre), state (Sta), impacts (Imp) and responses (Res) to oil usage and climate change actions. Since this study aims at identifying, and analysing, factors of improvements of biofuel policies, responses were then further grouped into three micro-codes, or clusters, where European (eur), economic (eco) and voluntary (vol) instruments are described in more detail. These micro-codes were divided into further codes so for example "Res-eur-bio" refers to a Response on a European level and specifically the Biofuel Directive.

3.4 Summary

Within this chapter the research methodology employed for this study has been described. In the following chapter, Chapter 4, the primary findings are discussed in relation to secondary findings in order to verify the content and strengthen the arguments.

Chapter 4

Case Study Findings

4.1 Introduction

Within this chapter the primary and secondary data collected using a case study methodology are presented. Findings from secondary data are summarised in section 4.2 while a fuller account of the findings is provided in Appendix 14. Section 4.3 is devoted to a summary and discussion of the findings from the primary data that was analysed using the method of coding and clustering (see Appendix 10) suggested by Miles and Huberman (1994). In Appendix 15 a complete account of the primary findings is available.

The reason Sweden was chosen for the case study was that Sweden is a clear forerunner of the development and implementation of alternative fuels, biofuels and clean vehicles (Kumlin & Axelsson, 2006). The use of biofuels in the transport sector has, during a few years, increased from 0.7% in 2002 to 2.7% in 2006. Every month the sales of clean vehicles set new records; e.g. in March 2006 the number of clean cars sold was 540% higher than in March 2005 and clean vehicles accounted for 15% of total sales (Landahl, 2006). 60% of the clean vehicles sold during 2005 were flexi-fuel cars, fuelled on ethanol (E85) and gasoline and the other 40% was bi-fuelled cars, usually utilising biogas and gasoline and electric hybrids. The development for clean vehicles has gone from being something very special to an ordinary alternative when purchasing a new car (Kumlin & Axelsson, 2006).

4.2 Findings from Secondary Data

On an international level Sweden is committed to follow ratified directive and agreements. The directives and agreements with greatest impact on Swedish biofuel development are the Kyoto Protocol, the Biofuel Directive, the Fuel Directive, the Emission Trading Scheme and the import tariff on ethanol products.

The Kyoto Protocol was ratified by Sweden in May 2002 and implemented the 16th February 2005. Sweden was, according to the protocol, allowed to increase greenhouse gas emissions by 4 percent but a national goal set up aims at reducing greenhouse gas emission by 4 percent, compared to baseline year 1990's GHG levels (Regeringskansliet, 2006d).

The Biofuel Directive was introduced in 2003 and the aim was to promote the use of biofuels instead of conventional transport fuels. The target by 2005 was 2 percent and future targets are 5.75 percent by 2010 and 20 percent by 2020 (Persson *et. al*., 2006). The Fuel Directive controls admixture levels of biofuels with conventional fuels and currently 5 percent admixtures are allowed for both ethanol and gasoline mixtures and biodiesel and diesel mixtures (Lexmon, 2006).

The 1st January 2005 the European Unions Emission Trading Scheme commenced operation. Approximately 45 percent of all carbon emissions within the EU are included in the trade scheme but the transport sector is so far exempt from the trade. The large number of vehicles adds significant complexity to the inclusion of the transport sector but it is expected to be included sometime in the future (Hasselknippe & Røine, 2006).

EU introduced new import regulations regarding import of ethanol from outside EU the 1st January 2006. Until 2006 ethanol was classified as an "agricultural product" and the Swedish importer paid 1.80 SEK per litre in import tax, and ethanol mixed with more than 20 percent gasoline was classified as "chemical products" and taxed 0.23 SEK per litre. According to the new regulations all ethanol is accountable for the higher tax level, regardless of admixture. As a result all non-European ethanol got more expensive and currently the Swedish ethanol is slightly cheaper than for example Brazilian ethanol. Brazilian ethanol supplied 80 percent of the Swedish ethanol market until the 1st January 2006 but currently no ethanol from Brazil is imported (Köhler, 2005b; Lindstedt, 2005).

On a national level, biofuel policy is driven by the Environmental Objectives (See section 2.4) and the various instruments used are primarily aimed at being effective. The characteristics of effective economic instruments managing environmental problems are:

- the environmental objective is reached rapidly,
- the instrument is cost efficient,
- the instrument stimulates technological development and makes it profitable to enhance processes and change consumption patterns,
- the instrument is straightforward and does not generate extensive administrative costs (Naturvårdsverket, 2005c).

The economic instruments available in Sweden today, regulating biofuel production and use are presented in Table 4.1.

Environmental Objective	A cost carried by affected agent	A cost relief or subsidy for affected agent
• Reduced climate impact	• Carbon tax • Energy tax • Green tax shift • Road tax for heavy vehicles • Emission trading	• Carbon differentiated vehicle tax • No tax on biofuels • Local climate investment programme, KLIMP
• Clean air	• Parking fees • Green classification of gasoline and diesel • Differentiated gasoline tax and diesel tax • Congestion charge	• Green classification of gasoline and diesel • Differentiated gasoline tax and diesel tax • Subsidised public transport • Free parking for green vehicles • No congestion charge for green vehicles
• A varied agricultural landscape		• Support for restoration and maintenance of “open landscapes” etc.
• A good built environment		• Local climate investment programme, KLIMP

Table 4.1 Economic Instruments
Source: Naturvårdsverket, 2005.

The carbon tax was introduced in 1991 and aimed at reducing carbon emissions from burning fossil fuels (Andersson, 2006). The energy tax is based on energy, environmental and fiscal grounds as the revenue is partly used for road maintenance (Larsson *et. al*., 2003). Tax level depends on fuel class which is illustrated in Table 4.2.

Fuel	Energy tax/litre	Carbon tax/litre	Total tax/litre
Class 1 gasoline	2.86 SEK	2.13 SEK	4.99 SEK/0.54€*
Class 2 gasoline	2.89 SEK	2.13 SEK	5.02 SEK/0.55€*
Class 1 diesel	0.74 SEK	2.62 SEK	3.36 SEK/0.36€*

* Exchange rate 2006-08-03; €1=9.21 SEK

Table 4.2. Energy taxes 2006
Source: Skatteverket, 2006a

Ethanol and biodiesel are exempt from the carbon tax as they are seen as carbon neutral and also from the energy tax, as a measure to encourage the introduction of biofuels and make them more competitive on the fuel market (Skatteverket, 2006b).

Other economic incentives encouraging biofuels are free parking in residential areas and general parking areas with rules varying from county to county (Miljöfordon, 2006a), and exemption from the congestion charge scheme tested in central Stockholm for the first 6 months of 2006 (Vägverket, 2005a). From the 1st October 2006 vehicle tax for new vehicles will be based on how much carbon dioxide and particulate matter the car emits rather than weight which was the old measure (Regeringskansliet, 2006f). Since 2002 companies purchasing clean vehicles for their employers will be charged lower vehicle taxes which further encourage use of biofuels (Landahl, 2006b).

Direct investment programmes, like Klimp, to support biofuel producers are other economic instruments utilised. The programmes contribute to the accomplishment of environmental targets by reducing GHG emissions, strengthen climate projects and distribute knowledge and increase awareness among the public (Green, 2006).

A hampering factor to increased biofuel use is lack of nationwide supply, which was partly managed in December 2005 when it was decided that all gas stations selling more than 3 000 m^3 fuel per year (approximately 60 percent of all gas stations in Sweden) must provide at least one kind of biofuel (Lexmon, 2006). The trend shows that ethanol is the preferred option, mainly as ethanol tanks are 10 times cheaper to install than biogas tanks (Landahl, 2006b).

Voluntary agreements have been initiated in order to further encourage biofuel production and use in Sweden. Various municipalities provide clean vehicle buyers with financial support either when purchasing the vehicle or when used, such as free biofuel for a limited time or specific amount (Miljöfordon, 2006c).

In December 2005 a Commission on Oil Independency was appointed by the Swedish Prime Minister with a task of proposing concrete measures to prepare Sweden for the transition to an increasingly fossil free and more sustainable development (Regeringskansliet, 2006g). One member of the commission was interviewed within this study and a summary of the report the commission presented can be viewed in Appendix 14.

4.3 Findings from Primary Data and Discussion

This chapter highlights the findings from the interviews conducted during June 2006 in Sweden. All quotations and references are from the key informants, which are presented in Table 3.4. The findings have been divided into five categories, Drivers-Pressure-State-

Impacts-Responses, in accordance to the main coding and clustering scheme (See Appendix 10) developed during the literature review and the interviews.

The key points raised under the five main categories, from the DPSIR framework, are summarised in a box at the end of each section. Responses have been further divided into ten subheadings in order to facilitate the understanding of the findings. The primary findings are discussed and reflected upon throughout the chapter.

4.3.1 Drivers

All respondents stated that the main drivers for production and use of biofuel are:

- increasing oil prices and shrinking fossil fuel reserves,
- the effects fossil fuels have on the environment and the climate,
- the accomplishment of energy autonomy.

This goes hand in hand with most acknowledge literature on the subject of climate change, for example Houghton (1994) who states that fossil fuel is not going to run out within the next 100 years but become increasingly expensive to extract and therefore scarce.

Other drivers identified during the interviews were:

- current successful technological and biofuel development,
- strong support from the Swedish Government,
- increased general awareness of potential impacts of climate change,
- excess amount of biomass and waste products suitable for biofuel production.

As presented by Ruttan (2001) the awareness of the problem has been highlighted, i.e. the importance of energy autonomy and clean technologies has been identified, and now attempts are made to set the stage for technological change, i.e. build infrastructure and acceptance, and slowly move on to the next stage of the technological change process; where insights are gained in the new area of research and enhanced technological solutions are presented, i.e. increase biofuel efficiency and reduce resource use.

No significant figure of potential production levels has been identified in the secondary data but the potential is seen as large (See for example Azar *et. al*., 2003; Åkerman & Höjer, 2006) and it is likely that a significant share, ~25 to 40 percent by 2025, of the car pool will be able to be based on biofuels in the future.

Additional drivers to successful biofuel development, according to respondent F, are the beneficial circumstances Sweden possesses; large forests and rich agricultural land, well developed car manufacturing and process industry.

It is expected that demand for biomass and biofuel will increase and respondent C argued that it may constrain further development and result in shortage of raw material, which gained support by respondent A, arguing that "the ceiling is reached soon" especially regarding generation 1 biofuels, such as ethanol from sugar beet. A demand for fuel in increasing, as showed by Åkerman & Höjer (2006) in section 2.2, it is likely that biomass demand will increase accordingly. Overestimated land availability issues was raised by respondents A, H and L who also argued that generation 1 may cover the EU target of 5.75 percent by 2010 but not more. An overview of the respondents views on future potential is presented in Table 4.3.

Respondent	Domestic potential
A	1st generation: 10-15 percent,
	2nd generation biofuels: 20-30 percent by year 2025
B	Large potentials, if regulations were removed
C	Increasing competition and decreasing potential
D	Extremely good potentials
E	100 percent if we want
F	Beneficial circumstances
G	Never self-sufficient
H	1st generation: never cover total need, would have to use all land
	3rd generation: could cover total demand
K	Biogas 40 to 60 TWh per year
L	"mind-boggling" potential

Table 4.3 Domestic potential.

Potential for biogas varied significantly; respondent K argued that 40 to 60 TWh can be produced every year while respondent L argued biogas has little potential on local market since problems of distribution, expensive vehicles and short driving range. The literature suggests potential of close to 72 PWh, but such extensive production is likely to affect several Environmental Objectives negatively.

Currently, biofuel is most energy efficiently used for heat and electricity generation, with 1:1 energy outputs or even better results according to respondent L. Despite energy losses when producing transport fuels, respondent E highlighted that biofuel for transport though provides

significant positive externalities not included in calculations and the danger in not developing an independent transport system.

Respondent K acknowledges energy efficiencies but stress that “It would be easier to use biomass for heat, but we can not drive on pellets or wood chips…” and biofuel for transportation is the next sector in line for energy improvements. Åkerman & Höjer (2006) confirms that the transport sector is responsible for 26 percent of all carbon emissions and should take responsibility for those emissions.

Another opinion was presented by respondent C who argued that the transport sector is not the obvious solution and total efficiency should be highlighted and ended the interview by stating “Once again, you should not say it is important to change fuels for the cars, because it is not!”. It has been showed by various references (Azar et. al., 2003; Cannell, 2003; Åkerman & Höjer, 2006) that marginal costs for reducing energy use is higher for the transport sector than heating and electricity generation sector.

Close to all respondents had optimistic expectations regarding the potential of biofuel but request fast development towards generation 2 and 3 biofuels (See Appendix 5). Respondent H argued that generation 1 is mainly kept alive by strong lobbying groups with private economical interests and respondent C argued that all biofuel support should involve large investments, administrative, monitoring or other external costs as it may lead to lock-in situations, which is supported in the literature by Johansson (2006), Perman *et. al*. (2003) and Tietenberg (2003).

Efficiency improvements were requested by respondent A and L, mainly in the form of more extensive use of by-products, combination of heat and electricity plants with biofuel plants in order to utilise all excess heat and steam. Other improvements promoted were crop improvements via either traditional plant breeding or gene technology measures. Despite large potential efficiency improvements respondent F advocated “careful scepticism” as no obvious path for development can be identified. As stated by Unruh & Carrillo-Hermosilla (2006) ease, and path dependent, implementation may results in premature lock-in situation, as the “easy” path may prove to be sub-optimal.

Most respondents still believe that fossil fuels will prevail in the transport sector for quite some time. Respondent H argued oil will most likely stay for another 100 years and cover approximately 30 to 40 percent of the fuel demand, but by 2200 the oil will be completely phased out. Moreover, respondent L expects oil to be used also in the future but not crude oil

as today, but tar sands and stone coal derived oil. Azar *et. al*. (2003) explained that psychological, sociological and structural factors may hinder development and rapid adoption of new technologies and enhanced reliability and long term durability must be guaranteed to increase diffusion rates.

Respondent B argued that the strong biofuel support provided by the Prime Minister and Minister of Sustainability drive the biofuel development ahead and may result in the 5.75 percent biofuel goal to be increased to 11 percent after the election in September 2006. Despite this, significant institutional limitations must be removed in order to allow for large expansion of biofuels. This may be underway as the Oil Commission, with significant governmental support, suggests major increase of biofuel use in the transport sector.

Brazilian ethanol was highlighted by all respondents as the most effective biofuel of generation 1 at present time. Respondent E and F declared it as "completely outstanding" regarding both growing the biomass and the process of producing ethanol. Large revenues can be expected for Brazil in the future, according to respondent A, if the strict agricultural policies within the EU would be removed. The import tariff on ethanol reduce pressure on the European market to improve energy efficiency and environmental impact in their production which result in worse life cycle results and ethanol with significantly negative carbon emission figures.

When making comparisons with the UK, respondent A, B and D highlighted the "natural handicap" of considerably less land available and respondent L argued that in general English people have larger psychological barriers to biofuel that need to be defeated before biomass will be accepted to a greater extent for both transport and heating purposes.

Major obstacles to wide-spread introduction of biofuel vehicles in Sweden, identified by all respondents, were lack of economic incentives when purchasing clean vehicles and lack of appropriate infrastructure, despite evidence of relatively extensive economic and voluntary support to biofuel buyers. Differentiated vehicle tax when purchasing a vehicle would make a difference, according to respondent D, and result in a clean vehicle fleet within 10-15 years according to respondent A. The differentiated vehicle tax implemented 1st October 2006 will affect new owners evenly throughout the year. A differentiated tax charged in the purchasing moment would create more visible incentives to choose a clean vehicle.

Another barrier to successful introduction of biofuels, according to respondents A and C, was the regulation forcing gas station owners to supply biofuel. The market powers should have

been left to act when the time was mature in order to prevent the creating of premature lock-in of potentially inferior technologies. According to David (1985, cited by Ruttan, 2001) lock-in is featured by interrelatedness, economies of scale and quasi-irreversibility of investment, where need for system compatibility, decreasing costs and specific skills and knowledge are blocking future technological change. As large investments was required this policy may result in lock-in as investments are partly irreversible.

Importance of correctly converted vehicles was emphasised by respondent F, since properly functioning engine and fuel result in much cleaner exhausts. As presented in section 2.2, Swedish vehicles are emitting 20 percent more carbon dioxide per kilometre in average than the average EU car. The reason to this difference is outlined by respondent H in Table 4.4 below.

Preferences of a Swedish vehicle buyer:
• a vehicle run on gasoline rather than diesel, due to propaganda against diesel vehicles in the past.
• a second hand vehicle, which often used to be company car and therefore often larger and more energy inefficient due to beneficial vehicle tax to companies.
• a Swedish vehicle, i.e. Saab or Volvo, who traditionally produce large, safe and thirsty cars.
• a vehicle that may pull a caravan during the summer holidays, a very popular hobby for many Swedish families.
• a vehicle that is stable during winter conditions with icy and slurry roads.
• a vehicle that is big enough to protect the passengers if hitting a large moose or other large animal.

Table 4.4 Preferences when purchasing a vehicle

The researcher must acknowledge some of these arguments as supporting domestic car manufacturing industry and safe vehicles, and price, are the main considerations when purchasing a vehicle. A summary of the main drivers is presented in Table 4.5.

Summary of Drivers

- Increasingly scarce fossil fuel resources.
- Increasingly unstable climate conditions.
- Biofuel technologies available and developing.
- Excess biomass available for biofuel production.
- Support from government and international bodies.
- Demand for increased energy autonomy.
- Large carbon emitting vehicle fleet.

Table 4.5 Summary of drivers

4.3.2 Pressures

According to respondent C 50 percent of all oil globally is utilised for transportation purposes. For OECD countries the oil used for transports account for 70 percent and the trend shows that global use will soon reach OECD levels of 70 percent while OECD countries will increase oil use in transport to 80 to 85 percent in the near future. This indicates increased dependence of oil in the transport sector, which may potentially create large problems in the case of abrupt changes in oil supply due to conflicts or heavily increased oil prices as discussed in Chapter 2.2.

Dependency on fossil fuels is a serious concern according to all respondents. Respondent G declares that it is dangerous to get stuck in any dependency situation regardless if it is fossil fuels or biofuel. This is supported by respondent H and J, who also argue that energy autonomy may not increase with increased levels of biofuels on the market. In order to avoid any dependency, respondent J declared that focus should be on efficiency improvements so less fuel is demanded and also change habits in order to reduce demand for transport in general. All technologies demanding large investments will present potential for future negative lock-in and should be avoided. Admixtures can be promoted as a superior solution as no major investments are required.

Respondent H advocates that the price development of fossil fuels and biofuels are very similar and increased demand will result in higher biofuel and fossil fuel prices and fuel demand is quite inelastic. If biofuels have inelastic prices there is a significant risk for lock-in as Ruttan (2001) presented in section 2.6. Respondent K disagreed on this point regarding biogas price development and claimed that prices would not follow the fossil fuel price development as the production is not directly affected by fluctuations in oil prices.

Current low fuel prices are, according to respondent H, encouraging high fuel usage levels throughout the economy and higher price level would, respondent J argues, force the transport sector to change to more efficient systems and reduce road transport and make Swedish biofuel economically competitive without subsidies and additional support.

Respondent J argued that the economy may not be as dependent on oil as expected. After the war in Iraq during the late 1990s the oil price peaked around $60 per barrel, which was expected to bring catastrophic outcomes but despite the high oil price the world experienced the highest economic growth for the last 30 years in 2004. The surprising economic growth was explained by respondent J as efficiency improvements and thereby decreased demand for oil.

Thus, the most important action for eliminating dependency situations, presented by respondents J, G and more, is efficiency improvements. Technological limits are present and therefore the transition must allow time for learning and continuous technological advancement.

Summary of Pressures

- Increasing fuel usage world wide.
- Locked in transport system, dependent on fossil fuels.
- Increasing fuel prices.
- Increasing demand for biofuels and subsequently, also growing dependency of biofuels.
- Solution to dependency situations is advancement in energy efficiency.

Table 4.6 Summary of pressures

4.3.3 State

Life cycle assessments estimating the environmental damage caused during a product's lifecycle is a measure of comparing products and processes. European ethanol, according to A, D, E, H and J, are sometimes estimated to perform 100 times worse than Brazilian ethanol regarding greenhouse gas emissions, even worse than conventional fuels, and is a clear example when the market fails in achieving sustainable biofuel production.

Use of artificial fertilisers eliminates the European ethanol's chances to positive life cycle estimates and respondent H explained that the main energy consuming processes are the

farm input phase, i.e. fertilisers and preparation of land, and when processing the raw material into ethanol. Brazilian values are motivated by successful co-operation of power and biofuel plants and extensive use of all by-products and should be learned from.

Biogas shows, according to respondent K, low or even negative carbon dioxide emission and especially the use of the by-products as natural fertilisers augment that performance. An additional side-effect of biogas production is that public environmental awareness increases as biogas facilities are smaller and often located close to residential areas so issues related to waste management and carbon emissions are brought closer to peoples' everyday life.

Respondent K consider biofuels as a "pure injection" to the Swedish economy due to employment opportunities, decreased import of biofuels and fertilisers, agricultural boost, increased energy autonomy, economic growth potential, cleaner exhausts and less noise and emissions in cities.

Summary of State

- Significantly better life cycle results for Brazilian ethanol than European.
- Highest energy input; fertilisers and biofuel processing.
- Enhanced air quality and waste management opportunities.
- Enhanced environmental awareness among the public.
- Better environmental consumers leading to better environmental choices.

Table 4.7 Summary of state

4.3.4 Impacts

Growing awareness among general public and decision makers will, according to respondent E, result in stricter regulations and increased transport costs. Global warming will affect economic, environmental and social aspects of life on earth but it is difficult to outline what aspect is protected the most. Respondents A, F and G claimed all environmental energy policies initially were based on environmental and energy autonomy issues and the more recent phenomenon climate change is acting as a catalyst in the development towards energy autonomy.

Respondent I argued that environmental concern is the major driver of energy regulation and policies but to add weight to the argument, economic profitability for the future is included as an objective. Respondents D and E alleged that the fiscal interests from the state is the main driving force for policy and always considered, which result in sub-optimal instruments due to

imperfect design. If sub-optimal choices are made, such as taxing different sectors differently and thereby creating differing marginal costs and benefits among the sectors, cost-effectiveness, as presented in section 2.5, cannot be achieved.

Politicians sometimes drive policy matters powerfully which according to respondent D often aims at the fulfilment of additional sub-targets and that the side effects may be more attractive than the actual policy target. Current instruments are, according to respondent D, "a hotbed of inconsistency", which is the outcome of various environmental, energy, fiscal and political objectives, which could be the result of politically popular policy advances. If this is correct, actions should be taken to reduce political logic from being the dominant decision-making power.

Respondent E alleged that depending on governmental department driving the design of a specific instrument different criteria are acknowledged. The Government do not necessarily pay attention to cost efficiency and other basic economic criteria but rather have public opinion and lobbying groups' interests in their mind while the Swedish Environmental Protection Agency has stricter objectives of cost efficiency to consider when designing an instrument. Respondent L argued that environmental and economic criteria are never weighted against each other but rather implemented if fit for purpose and expected to achieve the target set up.

Respondent H referred to a survey by the Swedish Energy Agency regarding what energy issue that called for the strongest support in society. In Sweden the climate issues were valued slightly higher than energy autonomy while in the rest of the EU energy autonomy got the strongest support. Respondent H also considered respondent J's statement that energy autonomy is not increased through the introduction of biofuels which thereby eradicates the argument for further development of biofuels in many countries.

Summary of Impacts

- Increased public awareness of potential climate change consequences; social, environmental and economical perspective.
- Great uncertainties regarding impacts still prevailing.
- Energy autonomy is the main target for energy policy and climate issues acts like catalyst in the transition towards oil independency.
- Political power decisive for environmental policy strategy.

Table 4.8 Summary of impacts

4.3.5 Responses

Since this thesis aims at finding more effective policies for aiding the development to a less carbon dependent economy, economic instruments are of great importance as efficiency is often measured in economic terms. Early during the interviews the respondents were asked what instrument they deemed to be the most important or effective instrument, i.e. achieving the objective of lowest cost, and why they believed this specific instrument functions so well.

Respondent A referred to carbon and energy taxes for heat and power fuels as “very strong, very useful and very good instruments” as the general and equal approach provided stability, long term commitment and simple guidelines for energy use. Respondents D and G considered all current economic instruments as relatively efficient, stable and competent in achieving the environmental objectives. Respondent H argued that still higher prices for polluting activities are needed for the price mechanism to force actors to change production and consumption patterns. By increasing price for pollution, negative externalities are internalised to greater extent and better cost efficiencies can be accomplished.

Emission trading was considered a reasonably efficient economic instrument by respondent A but difficulties establishing permit price and initial permit allocation were acknowledged. For example the electricity certificate system has contributed to increased share of renewable electricity and a similar solution could be applied to the transport sector. Lack of drivers for continuous enhancement was highlighted as the major drawback with this instrument.

Long term instruments were stressed by most respondents as vital, as they allows industry to plan and invest in new technologies and be assured they will support for a longer term. Respondent F accentuated that physical transport infrastructure is built to last more than 100 years and demands large investments with long pay back times and thereby potential lock-in situations.

Respondent G argued that “if everyone is fairly disappointed about a policy, then you have succeeded, but if someone is really happy, you have failed” and this was supported by respondent L who claimed that “fairness” is not considered explicitly when constructing instruments and if economic optimality is not achieved, it is merely a “natural consequence of the complex nature of a diverse issue”, as pollution abatement is costly and all sectors should be involved for attaining cost effectiveness, policies must affect the actors quite extensively.

Encouraging instruments was viewed by respondent H as central, as it encourages individual solutions and promotes innovation. As it is unclear whether biofuels are the optimal substitute for fossil fuels policies must be general and flexible so other technologies can co-develop. Hence, saving a litre of fuel through more efficient systems is preferred to replacing it with green alternatives.

4.3.5.1 Economic Instruments in Europe

Respondent C claimed that the Kyoto Protocol creates inefficient economic incentives that in the long run will result in marginal costs for abatement to increase and expensive climate policies, due to restrictions and delimitations to certain sectors and areas. By forcing the transport sector back to 1990s levels of emissions, the marginal cost for abatement in that sector will exceed the marginal cost in other sector and economic optimality can not be established.

The introduction of the Biofuel Directive aided successful introduction of biofuels in Sweden according to respondent B as the directive altered the fuel scene and provided necessary conditions for the biofuel market. Respondent D proclaimed that fuel substitution is not resulting in decreased levels of carbon emissions simply shifting the source and that “the best becomes the good’s enemy”, i.e. it is wrong to force in biofuels and give tax reductions as carbon emissions persists. Also the Energy Tax Directive present issues of optimality as other policies are needed to complement the directive to, according to respondent C, “mend the pieces together” and assure development in the correct direction.

4.3.5.2 Biofuel Potential

Admixtures of ethanol and gasoline were pointed out by several respondents as a great means of introducing large quantities of ethanol in the transport sector. Respondent C stressed the possibility to change admixture levels according to the world price of biofuel and large capital investments are not needed as current vehicle fleet, infrastructure and distribution system can be utilised.

EU are currently allowing up to 5 percent biofuel admixtures based on engine starting properties, risk for corrosion, increased pressure issues and seasonal temperature changes. In addition, vehicle insurances from car manufacturers only cover the fuel the vehicle was made for and admixtures alter fuel properties. Ethanol admixtures up to 10 percent are soon expected according to respondents A and J. Respondent E warned that increased

admixtures may result in removal of biofuel exemptions from energy and carbon tax large revenue losses will follow.

4.3.5.3 Ethanol Import Tariff

All respondents but one argued that the import tariff should be removed as soon as possible. The tariff is, according to respondents B, E, F, H and J hindering long term development of the international ethanol market. At the same time the tariff protects domestic businesses and a removal would, according to respondent B, result in increased competition and reduced profits. Respondent D claimed the tariff adds inconsistencies to the fuel policy system as ethanol is made more expensive to import as well as it is exempt from all energy taxes. Respondent D viewed the situation as “absurd” and “illogical” as the Government’s primary objectives are to promote renewables and substitute oil and other governmental instances block this development by making import expensive and force in EU raw materials.

In contrast to the other respondents, respondent K argued that it was irritating that we used to be able to import cheap Brazilian ethanol when we could produce it ourselves. The reason for the import tariff not is a national revenue interest, as 75 percent of the revenues go to the EU and the remaining 25 percent go to the importing country, according to respondent E. Respondent E presented control of trade as the only objective of the tariff with strong agricultural lobbying groups within the EU driving the issue in order to protect and build the ethanol market within the EU. An option, according to respondent C, may be to utilise a flexible tariff on non European biofuel if significant environmental damage is occurring where the biofuel is produced. The removal of the tariff could achieve greater “fairness” as developing countries seldom implement import tariffs for European commodities but are strongly affected by European import tariffs.

The main target should be, as stated by respondent D, to use as little fuel as possible, i.e. it is never environmentally beneficial to burn rape or other biomass products, which according to respondent J, will be costly but something we must be prepared to pay for if more stringent future environmental objectives are to be met. As European ethanol show much worse life cycle results, that ethanol is not contributing to improved carbon emissions, and for example Brazilian ethanol, which is highly energy efficient, should be encouraged and Europe should opt for the most energy effective option rather than focusing on sector protection.

4.3.5.4 The Carbon Tax

The current carbon tax on conventional fuels is according to respondent E too low and external costs are not internalised fully since many sectors and countries are not included in international agreements on carbon taxes. As a result marginal costs cannot equal marginal benefits and cost efficiency is not achieved. If negative externalities are not fully included, pollution levels will stay positive and carbon emissions will not be reduced, as seen in Figure 2.1.

According to respondent D wrong economic signals are transmitted to the public and individuals in the production process when, for example, biofuel producers drive on conventional fuels instead of biofuels. Since the carbon tax affects everyone similarly, as respondent H claimed, stable price signals are provided and promoting even change. A tax would have to be equal for all actors and also affect all sectors, businesses and countries similarly in order to attain complete cost efficiency as explained in section 2.5.

By raising carbon taxes a faster transition away from fossil fuels could be realised, according to respondent J and H. The price mechanism and the "invisible hand" would force out fossil fuels and biofuels would gain market shares according to respondent A. Unfortunately, raised carbon tax does not reward thriftiness as respondent J would have preferred. In addition, respondent D argued that it is politically dangerous to fiddle around with taxes so often inflation adjustments are carried out. Since biofuels are excluded from the carbon tax, the tax is seen as a temporary device for attracting more biofuel to the market. Some alternatives to the carbon tax provided by the respondents are presented in Table 4.9.

Instruments superior to carbon tax:

- Respondent D – National bubble, i.e. fuel quantities regulated by providing permits for selling fuel. Number of permits should be reduced every year. Same outcome as carbon tax but not inflict on state revenues.
  – Kilometre tax for private and heavy vehicles. Uncertain if EU's Tax Directive would allow it.

Instruments inferior to carbon tax:

- Respondent A – Certification system, provide unstable price levels and unclear incentives.
  – Stop-and-go policies, i.e. direct investments. Cannot guarantee continuous, long term support.

Table 4.9 Alternatives to carbon tax.

4.3.5.5 The Energy Tax

Biofuels exempted from the energy tax is seen as a very short term incentive for biofuelled vehicles by respondent A. Revenues from the energy tax are covering road maintenance and as road wear is as significant for clean vehicles as conventional vehicles, biofuel cannot be exempt for ever. A preferable instrument would be a state guarantee to always provide biofuels at lower prices than conventional fuels. Respondent C argued that the carbon and energy tax exemption merely distort the outcome of the climate policy and make it tremendously expensive. As clean vehicles also need good roads and infrastructural networks they should be obliged for energy tax. A potential solution is to have a road wear/carbon differentiated tax so biofuels are paying for their share of emissions and road wear. The same argument can be used when comparing E85 and admixtures of ethanol, as admixtures is diffused easier and do not demand large investments.

4.3.5.6 Biofuel Certification

A topical matter in biofuel circles is biofuel certification used to guarantee good production conditions, assure sustainable land use and maintained food production, protect valuable rain forests, sensitive habitats and biodiversity. Impartial institutions would be needed, according to respondent A, and the certification must not lead to protectionism or discriminating behaviour. According to respondent A, C, D and L not only certain biofuel products should be certified, as other agricultural production may be forced out in threatened areas and concealed environmental damage for the outside world.

Obligatory certification may lead to problems with the World Trade Organisation, respondent D claimed, as the certification would hinder free trade to take place. Voluntary agreements would provide a better alternative as independent governments could demand the certification for official procurements and thus influence the rest of the nation.

The goal of a biofuel certification system would, according to respondent D, not be to find a optimal product but to find an optimal regulation level in order to get as large a market share as possible and thus have the greatest impact achievable on global biofuel production levels. Respondent D argued that if 10 percent of the total market is certified, i.e. “green”, it is better than if 2 percent of the market goes 100 percent better.

4.3.5.7 Green certificates

No obvious answers were provided to this issue by the respondents. Green certificates may reduce the state revenue losses if replacing the carbon tax exemption, but was seen by all respondents as a short term, unsustainable incentive for biofuel. Respondent A dislikes the idea of having a trade system over certificates as price will fluctuate and a "fundamental insecurity is inherited" within the policy. Respondent A argued that certificates are popular in Sweden due to high tax levels and the Ministry of Finance prefer policies not affecting the state budget.

Potential market size for certificate seem to be very small, expressed by respondent J, as around three companies would actively trade the certificates. Large administrative costs for brokers would be demanded and it would be environmentally and economically preferable to have compulsory admixtures of 10 percent instead. In section 2.5 sources of market failure were presented and lack of appropriate markets was highlighted as one source. Large administrative costs and small potential market would present issues that could result in market failure and problems achieving cost efficiency.

Responsibility of quota duty was another issue raised by respondents E and J who wondered who should be responsible for buying the certificates and what would be done about foreign biofuels? Respondent G advised that green tax shift might be preferable or to include the transport sector in the emission trading scheme or create a "national bubble", as presented by respondent D earlier, since the transport sector is very complex and restricted by various, inconsistent policies.

4.3.5.8 Biofuel Supply

The introduction of biofuel tanks on all gas stations selling more than 3 000 m^3 fuel, to create substance in the biofuel market, was according to respondents C, K and L driven by individual politicians and "political logic" and resulted in a sub-optimal lock-in situation, demanding large investments, where ethanol got market advantage without showing significant proof of being superior in the long run.

A preferred instrument promoted by respondent would be the introduction of a fund where gas station owners could apply for funds to cover 50 to 80 percent of a biofuel tank. The fund would not have forced anyone into something and it would not have made such an impact on the gas market as the biofuel supply policy did. The driver behind the policy was likely to be

more good will than reflection but had unfortunate consequences as it indirectly gave stronger support to ethanol.

Some respondents, such as respondent G, accepted this policy as a first measure towards a complete supply of various biofuels in the future and argued that one has to start somewhere. Compensation later given to the biogas industry to increase equal opportunities for the two biofuels merely adds to the distortion from optimal policy options according to respondent C. Respondent J argued that it is close to impossible to provide policies that are completely fair and treat all sectors and businesses alike. Often the technology or business that will survive has some kind of first mover advantage or even "first push advantage" as in the case of ethanol and biogas.

4.3.5.9 Investment Programmes

Respondent A warned for stop and go policies, i.e. policies that provide incentives for a shorter time period and then stop. Also EU advises against this kind of support as it is constrained by time and increases the rate of insecurity for the affected companies as application formulations and missed dates can ruin a business. The introduction of investment programmes, such as Klimp or the Oil Conversion Support, may give the idea of taking action for the industry but may be a means of building political support and is possibly based in "political logic" rather than genuine interest for the industry. More general support to all companies fulfilling some specific criterion was promoted as an alternative that would provide more secure support.

Respondent K was of another opinion and argued that direct investments showed significant results and pushed the biofuel development ahead. Other direct investment examples provided by respondent K are funds granted to biogas buyers which is vital for successful introduction of biofuel on the market.

4.3.5.10 Research and development

It was widely accepted that the state must provide funds for research and development in order to expand the biofuel potentials within Sweden. Respondent J argued that funds should not go to basic research as there is no reason to compare fuels at an early stage as everything may change with time. Instead demonstration projects should be supported where several different technologies and raw materials are tested and compared.

Respondents A, C, E, J and K agreed that technologies must be put into practice and tested and learned from. By using a technology learning-by-doing effects may occur and potential cost reduction areas can be identified. Therefore, respondent E argued that all technologies should have one major facility built so that specific technology could be developed to perfection and thereafter introduced on the marketplace. Respondent A argued that research is for those who prefer things to be done "later" and recommend available technologies to be tested on the market in order to learn from mistakes and prepare the market in order to gain larger market shares later on. Also respondent C claimed it is better to learn along the way and make sure the market is mature enough for the new technology.

Sending out "the right signals" was highlighted by respondents C, D, E, H and K, where, the small nation, Sweden is a forerunner and leading the way into this new technological era. According to respondent E Sweden is impacting on the European development to a large extent by promoting flexi-fuelled clean vehicle technology and vehicles. Nevertheless, respondent H questioned whether Sweden "has to take responsibility" for all biofuel development and perhaps rather focus on a few areas with highest potential, but again, according to respondent E, Sweden is setting high standards for the EU, and maybe even for the world, to follow.

According to respondent C the 2nd and 3rd generation of biofuels should be introduced in research and development discussions, as they are needed in order to fulfil international agreements such as the Kyoto Protocol. Respondent D seemed quite confident that development will come because all you need it to do is to "give the engineers some money and some time and you will have a solution". Since significant uncertainty is prevailing regarding climate change and potential outcomes, see Appendix 1, time should be viewed as fairly limited so preventive and adapting measures are encouraged today.

Other opportunities, except oil independency and cleaner fuels, that may arise from research and development on biofuels are other technologies developed along side the original research, that could be exported and bring more profits in to Sweden. Respondent K promotes diversity in technologies and equal opportunities to development and desires a technological environment where we should "let all flowers blossom and let them blossom together".

Summary of Responses

- Current economic instruments are satisfactorily competent in reaching the environmental and economic objectives.
- Instruments with long term, general targets are of most significance.
- Economic optimality not achieved is merely a natural consequence of the complexity surrounding the problem.
- Admixtures of biofuels with conventional fuels have the potential to make large contribution to quantity biofuel being sold.
- European import tariff, driven by trade control and protectionism, hinders global development of the ethanol market.
- Increasing the carbon tax would lead to faster transition towards a carbon independent economy and externalities would be internalised to larger extent.
- Voluntary biofuel certificates could result in enhanced, more sustainable biofuel market.
- Green certificates may provide uncertain price levels, large administrative costs and limited market power.
- Politically implemented policies may result in lock-in situations and extended support to “first movers”.
- Vast complications to overcome in order to provide technologically neutral policies.
- Direct investments may create stop-and-go policies which can lead to financial insecurity.
- Research and development should focus on demonstration projects where learning-by-doing, cost reductions and market preparations can be executed. Being a sound role model and exporting technologies are other advantages arising from R&D.
- Improved fuel efficiency more important than replacing fossil fuels.

Table 4.10 Summary of Responses

4. 4 Summary

In this chapter the findings from the case study have been presented. A summary of the secondary and primary findings were provided and discussed. A complete account of the findings can be found in Appendix 14 and 15. The findings have resulted in an amended conceptual framework, presented in the next section, that will be used when drawing conclusions and making recommendations for effective policy strategies in the final chapter.

4.5 Revised Conceptual Framework

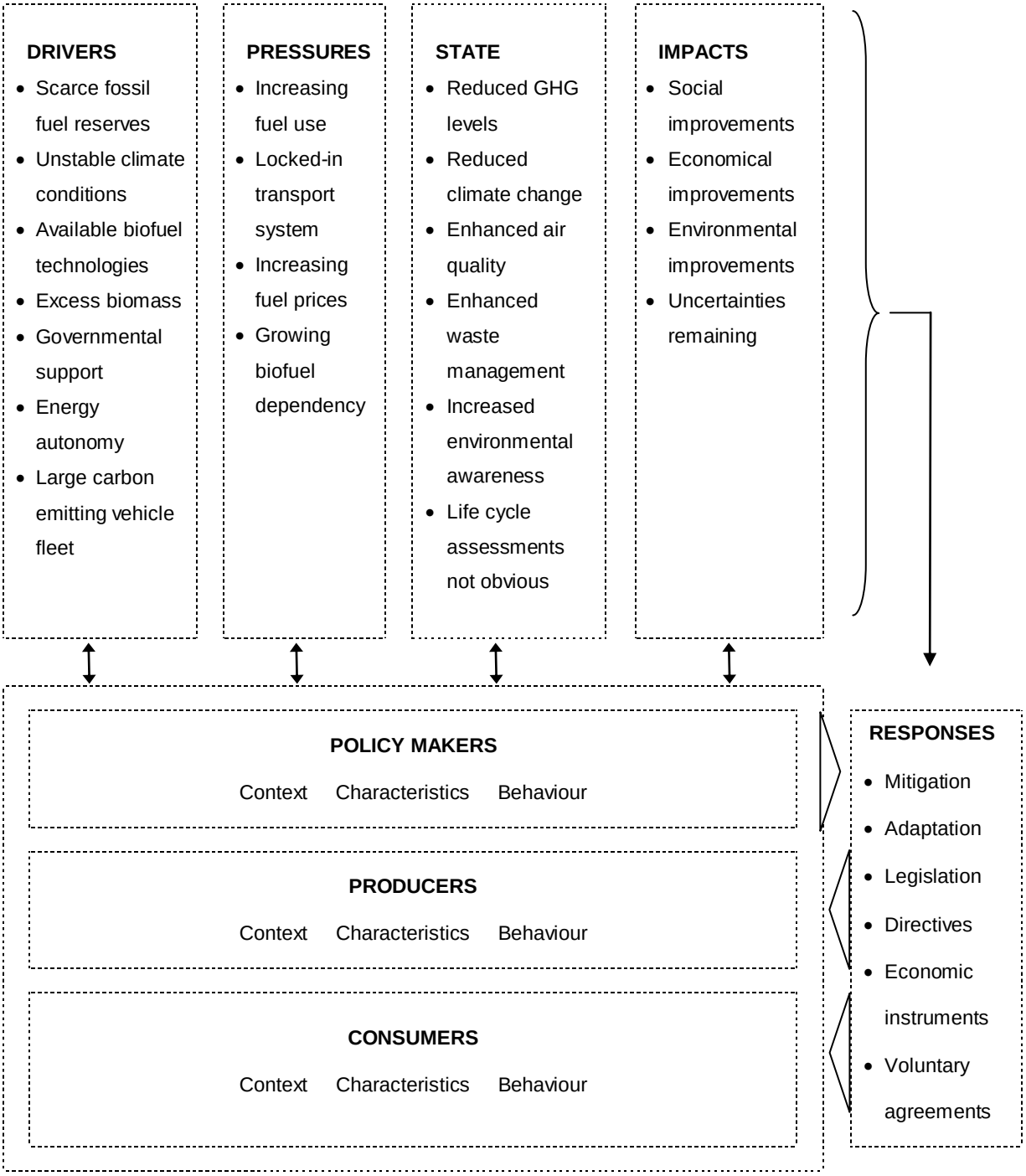

Figure 4.1 Conceptual framework, revised version

In the revised version of the conceptual framework the respondents views of Drivers, Pressures, State, Impacts and Responses has been included and is therefore a more balanced account of the DPSIR factors compared to the initial framework presented in section 2.8.

Chapter 5
Conclusion

5.1 Introduction

In this chapter conclusions and recommendations drawn from the findings and discussion are presented in section 5.2. In section 5.3 the aim, objectives and research questions are considered again in order to evaluate whether this study has achieved the intended targets. Limitations to the study and further research areas are identified in section 5.4 and 5.5.

5.2 Conclusions and Policy Recommendations

Within the scope of this case study, biofuels have been identified as one of the key options to mitigate greenhouse gas emissions and simultaneously substitute fossil fuels. The scale at which biofuels are being used has developed from waste management activities to regional, national and international markets with increasing cross-border trade-flows and national policies have proved to be vital for the success of the development.

Biofuel policies in Sweden are intertwined with several sectors; energy, transport, agriculture, food processing, waste management, paper and pulp and building materials, and thereby have potential to generate multiple benefits apart from energy generation. Consequently, there is a great need for policies to work over all sectors, in the same direction.

Many different biofuel options are available on the Swedish market and many more are under development, but still no clear winner has emerged so far. The technological change is ecologically driven, i.e. the technological change leads to efficiency improvements so per capita energy consumption can be reduced. Policies also drive energy prices up and provide further incentives for energy saving and more efficiency improvements.

Due to the significant carbon lock-in situation and reliance on fossil fuel the Swedish transport sector faces, which was identified within the scope of this study, fossil fuels are likely to stay for a considerable time, attributable to higher marginal cost per unit energy saved, compared to the heating and electricity generation sectors. Technological change takes time and efforts due to high inertia and persistent social, institutional and economical resistance.

The problems related to the development of biofuels are the potential for a new dependency situation and minute environmental improvements, for example life cycle results from European ethanol. Increased fuel prices are likely to affect also the biofuel prices, which must be adjusted to in order to provide future incentive for biofuel production. The only significant solution that can concluded from this case study is energy efficiency improvements, as total fuel use will be reduced and result in less total fuel dependency and improved environmental conditions. Since Sweden has a large, comparatively carbon intense vehicle fleet, significant improvements can be achieved in 10 to 15 years time with quite small transitional efforts.

Growing environmental awareness among the public in Sweden will boost the introduction of environmentally superior vehicles and transport patterns, but significant efforts must be realized as behavioural changes are slow and restricted by social and physical constructs. More aware consumers will result in environmentally, socially and economically better choices and contribute to a more sustainable economy and transport system.

Political power has proved to strongly influence the Swedish biofuel policy development and resulting in varying environmental and economic outcomes. By forcing gas stations to provide biofuel, large investment costs burdened the owners, while the availability of biofuel increased significantly. As the regulation proved to be far from technologically neutral, since ethanol was preferred by gas station owners due to lower required investment costs, compensation had to be made to affected biofuel producers, such as the biogas industry, and as a result ethanol may gain market shares due to a “first mover/push advantage” and low cost efficiency is attained.

A system where policies are used to compensate for earlier policies will never be economically efficient as the economic incentives will differ and different sectors and industries face different marginal costs for abatement. There is also a significant risk that politically driven policies will promote one specific technology and result in technological lock-in or at least quasi-irreversible structures which should be avoided when the future of a specific biofuel technology is unclear.

Energy autonomy has been put forward as the major governmental target in Sweden while issues of climate change are acting as a catalyst for the transition towards a less oil dependent economy. Sweden has a relatively small share of fossil fuelled energy in total and the transport sector is the main fossil fuel user and therefore there is a great urge to change that state. Current responses to introduce more biofuel on the market are fairly efficient from

both environmental and economic perspectives, but large improvements must be accomplished in order to provide better economic efficiency and cost effective development.

The instruments must be more general, with no or very few exemptions, and long term, in order to provide low risks when investing in expensive infrastructure and technology. More general policies, covering all sectors, including the transport sector, will result in even marginal costs that provide higher cost efficiency and smaller economic losses. Economic optimality is not achieved today due to large complexity regarding regulatory and economic incentives and a variety of instruments that affect different actors differently and not always in a fair balanced manner.

Instruments with integrated flexibility and robustness are also essential so successful technological change can take place without resulting in lock-in situations and restrict future technologies to diffuse effectively. Based on the literature review and the interviews conducted for this study, recommendations are to focus on general instruments like the carbon and energy tax and increase those taxes for all fuels and charge the tax depending on carbon emissions regardless if the fuel is from a renewable or non renewable source.

A general tax would be able to incorporate negative externalities to a larger extent and more cost efficient solutions could be realized. General economic policies also provide incentives for a larger variety of responses such as energy efficiency improvements, fuel substitution and reduced carbon consumption. In order to increase cost effectiveness a supra-national approach is requested as the greenhouse emissions are transboundary pollutions and affects the global society regardless of where it was emitted.

Independently functioning markets where the market mechanisms are allowed to react on prices and fuel demand and supply is also crucial, as more optimal, long term technological solutions, that prove economic profitability will endure. Fewer governmental interventions also reduce the risk for skewed development and provide similar conditions for all biofuel technologies. Instruments like the ethanol import tariff, hinder the market to develop independently and skewed support delays efficient technological development and the biofuel market cannot reach an economically or environmentally optimal level.

The recommendation regarding research and development is to focus most efforts on demonstration projects and pilot plants where learning-by-doing effects can arise, cost reductions can be identified and the market can be prepared for the new technology. It is also of importance to push the development of the 2nd and 3rd generation of biofuels in order to

gain competitive advantage in the future. Technological flexibility, e.g. flexi-fuelled vehicles, is also requested as biofuel prices are prone to fluctuate depending on supply and demand and potential increase in biofuel dependency.

In addition to that, expansion of public transportation systems, which can provide positive, encouraging lock-in situations, should be promoted. Other measures in reducing fuel dependency are the encouragement of telecommuting, carpooling, small, cleaner urban vehicles, improved bike and walking paths and to raise the public's awareness and get attention to these alternatives and successfully demonstrate and diffuse them.

The main finding derived for this study is that fuel substitution is important, but not as important as improved fuel efficiency. The main objective of all energy policies should be to create incentives for fuel savings rather than fuel substitution.

5.3 Review of Aim, Objectives and Research Questions

The aim, objectives and the research questions were presented in Chapter 1, where also the research problem and the scope of the research were outlined. The aim of this study was to recommend effective policy to promote production and use of biofuels in order to aid the transition towards a less carbon dependent transport sector in Sweden, which was executed in the previous section.

The three main objectives acknowledged for this research project were the identification of:

1. obstacles and challenges to the production and use of biofuels.
2. economic barriers and drivers to an oil independent economy.
3. efficient policies that aid the transition to a less carbon dependent economy.

The specific sections where the three objectives were considered are presented in Table 5.1.

Sections related to research objectives	
Objective 1	Sections 2.3 and 2.4
	Appendix 5
Objective 2	Sections 2.2, 2.3, 2.4, 2.5, 2.6, 4.2 and 4.3
	Appendix 7 and 8
Objective 3	Section 2.5, 4.2 and 4.3
	Appendix 7, 8 , 14 and 15

Table 5.1 Sections related to research objectives.

The research questions presented in section 1.3 have been considered throughout the study and any limitations in obtaining appropriate answers are outlined in the following section.

5.4 Limitations of Research

The aim and objectives have been answered with the researcher's total commitment and will to provide a balanced, valid and reliable account of the research problem. Major limitations to the fulfilment of the aim, objectives and research questions comprise of time and human resource restrictions, such as personal interpretations provided by the respondents regarding concept, policies and impacts and other issues regarding personal opinions and values.

The complexity inherent in the climate change and fossil fuel issues is also restricting a complete account for these factors. Most questions are strongly interlinked and cannot be understood independently and therefore a wide variety of policies have been discussed and analysed in order to compare and contrast the various advantages and disadvantages they bring.

In the case the same or similar research would be carried out the topic studied would be restricted further, by eliminating some research questions and defining one or two policies that would be thoroughly examined. The numbers of policy documents and additional literature seemed overwhelming some times, which could have been prevented if planned for more carefully.

5.5 Recommended Research Areas

As the topic provides numerous inconsistencies and uncertainties, various future research areas could be recommended. The main question that came up during the research was how to reduce and transform the amount of policies available today in order to provide a more transparent and comprehensible policy framework for the industry and consumers to understand and follow. Current policies do not offer an easily understandable structure and new actors have major difficulties to enter the market in a fair, competitive manner.

Additional research areas are provided in Table 5.2.

Recommended research areas

- Making biofuel policies more consistent and transparent.
- The achievement of technological neutrality.
- Achieving economically efficient compensation.
- Change of human transport behaviour and habits.
- Successful knowledge transfer without losing competitive advantage.
- Fuel and vehicle efficiency improvements.
- Finding sustainable, global carbon agreement.
- The elimination of “political logic” in decision making processes.
- The encouragement of innovations.

Table 5.2 Recommended research areas

References

Andersson, V (2006). Handledning för punktskatter. Skatteverket. [Accessed 2006-07-02] http://www.skatteverket.se/download/18.3a2a542410ab40a421c80002832/50409.pdf

Azar, C., Lindgren, K. & Andersson, B. A. (2003). Global energy scenarios meeting stringent CO_2 constraints – cost-effective fuel choices in the transportation sector. *Energy Policy*, vol. 31, p. 961-976.

Björsell, M. (2005). Miljöklassade bränslen och alkylatbensin. [Accessed 2006-07-10] http://www.naturvardsverket.se/index.php3?main=/dokument/teknik/trafik/trafikdok/mkbensin.htm

Bellis, M. (2006). The History of the Automobile. New York Times Company, About Inc. [Accessed 2006-07-10] http://inventors.about.com/library/weekly/aacarssteama.htm

Boyle, G. (2004). *Renewable Energy – Power for a sustainable future*, 2nd edition. Oxford University Press, Milton Keynes.

Brundtland Report (1987). Development and International Economic Co-operation: Environment. Report of the World Commission on Environment and Development. United Nations, General Assembly. [Accessed 2006-05-28] http://www.are.admin.ch/imperia/md/content/are/nachhaltigeentwicklung/brundtland_bericht.pdf

Burgess, A., Comparet, M., Davies, U., Doyle, M., Gilbert, A., Heine, C., Howard, C., Jones, S., McKelvey, D., Potter, K. & Wright, S. (2006). *World in Figures*, pocket, 2006 edition. The Economist. Profile Books Ltd., London.

Cannell, M. G. R. (2003). Carbon sequestration and biomass energy offset: theoretical, potential and potential and achievable capacities globally, in Europe and the UK. *Biomass and Bioenergy*, vol. 24, p. 97-116.

Change (2006). Klimatförändringar – Vanliga frågor och svar. Europeiska Kommissionen. [Accessed 2006-08-07] http://www.edelmaninteractive.co.uk/climatechange/ccqanda_sv.htm

Christian Aid (2006). Climate of Poverty: Facts, fears and hope. [Accessed 2006-07-09] http://www.christianaid.org.uk/indepth/605caweek/caw06final.pdf

Clery, P. (2001). Liquid Biofuels in the UK – Production, Infrastructure and Fuel Use Issues. *Refocus*, July/August, 2001. [Accessed 2006-05-22] www.re-focus.net

Dalenbäck, J-O. (2002). Energy in Sweden – Leading the way to a sustainable future? *Refocus*, September/October, 2002. [Accessed 2006-04-27] www.re-focus.net

Dawson, C. (2002). *Practical Research Methods – A used-friendly guide to mastering research techniques and projects*. How to Books Ltd, Oxford.

DTI, Department of Trade and Industry (2005). Renewable Energy. News and events. [Accessed 2006-07-10] http://www.consumer.gov.uk/renewables/renew_5.1.1.3.htm

Engström, A., Hadenius, A. & Hårsman, B. (2003). Intressekonflikter och tidsåtgång – En genomgång av åtgärder för att uppfylla miljökvalitetsnormen för kvävedioxid. Report 5310, April 2003, Naturvårdsverket. [Accessed 2006-08-06] http://www.naturvardsverket.se/bokhandeln/pdf/620-5310-8.pdf

Environment Agency (2006). Business and Industry – Negotiated or voluntary agreements. [Accessed 2006-02-01] http://www.environmentagency.gov.uk/business/444217/590750/590850/?version=1&lang=_e

European Commission (2006). Freedom, Justice and Home Affairs - Candidate and acceding countries have to adopt and implement EU legislation on justice and home affairs. [Accessed 2006-06-28] http://ec.europa.eu/justice_home/fsj/enlargement/acquis/wai/fsj_enlarge_acquis_en.htm

Faaij, A. P. C. (2006). Bio-energy in Europe: changing technology choices. *Energy Policy*, vol. 34, p. 322-342.

Faure, M. & Skogh, G. (2003). *The Economic Analysis of Environmental Policy and Law – An Introduction.* Edward Elgar Publishing Limited, Cheltenham.

Forsurning (2006). Växthusgaserna. Internationella försurningssekretariatet. [Accessed 2006-08-07] http://www.acidrain.org/forsurning/tema_climat_gaser.asp

Fridell, M. (2004). Så arbetar regeringen, Regeringskansliet. [Accessed 2006-07-02] http://www.regeringen.se/content/1/c6/01/44/01/2cc16dfb.pdf

Grafton, R. Q., Adamowicz, W., Dupont, D., Nelson, H., Hill., R. J. & Renzetti, S. (2004). *The Economics of the Environment and Natural Resources*. Blackwell Publishing Ltd., Malden.

Green, A. (2006). Klimatinvesteringsprogram (Klimp), Naturvårdsverket. [Accessed 2006-08-06] http://www.naturvardsverket.se/index.php3?main=/dokument/hallbar/invprog/klimp/klimp.htm

Hamelinck, C. N. & Faaij, A. P. C. (2002). Future prospects for production of methanol and hydrogen from biomass. *Journal of Power Sources*, vol. 111, p. 1-22.

Hamelinck, C. N. & Faaij, A. P. C. (2006). Outlook for advanced biofuels. *Energy Policy*, Article in press.

Hardy, J. T. (2003). *Climate Change – Causes, Effects, and Solutions*. John Wiley & Sons Ltd., West Sussex.

Hasselknippe, H. & Røine, K. (2006). Point Carbon: Carbon 2006 – Towards a truly global market. [Accessed 2006-08-01] http://www.pointcarbon.com/wimages/Carbon_2006_final_print.pdf

Hawke, N. (2002). *Environmental Policy: Implementation and Enforcement*. Ashgate Publishing Company, Burlington.

Helm, D. (1991). *Economic Policy – Towards the Environment*. Blackwell Publishers, Oxford.

Houghton, J. (1994). *Global Warming – The Complete Briefing – An investigation of the evidence, the implications and the way forward*. Lion Publishing plc., Oxford.

Houghton, J. (2006). Global Pollution and Climate Change, The John Ray Initiative. [Accessed 2006-08-06] http://www.jri.org.uk/brief/climatechange.htm

Hyllenius, P., Ljungberg, C. & Smidfeldt Rosqvist, L. (2004). Sumo – System för utveckling av mobilitetsprojektet. Baserad på MOST-MET, Vägverket. [Accessed 2006-08-06] http://www.vv.se/filer/publikationer/publ_2004_98.pdf

Ingelström, A (2000). Vägverkets verksamhet. 2.1 Vägverkets ansvar, uppgifter och mål. Publikation 1997:4, utgåva 3, april 2000. [Accessed 2006-08-07] http://www.vv.se/filer/506/Rapp21.pdf

Jacobsen, H. & Kristoffersen, M. (2002). *Case studies on waste minimisation practices in Europe*, European Topic Centre on Waste.

Jacobson, K. & Sjödin, J. E. (2006). Klimatinvesteringsprogram, Energimyndigheten. [Accessed 2006-08-04] http://www.stem.se/WEB/STEMEx01Swe.nsf/F_PreGen01?ReadForm&MenuSelect=148B54351DAA6124C1256DDB00485D7C

Jennishce, U (2006). Klimat i förändring – Utsläppshandel. [Accessed 2006-07-28] http://www.naturvardsverket.se/index.php3?main=/dokument/hallbar/klimat/utslappshandel/utslappshand/referens.htm

Johansson, B. (2006). Climate policy instruments and industry – effects and potential responses in the Swedish context. *Energy Policy*, vol. 34, p. 2344-2360.

Klooster, J. & Kampman, B. (2006). Dealing with transport emissions – An emission trading system for the transport sector, a viable solution. Swedish Environmental Protection Agency, Report 5550, March 2006. [Accessed 2006-07-16] http://www.naturvardsverket.se/bokhandeln/pdf/620-5550-X.pdf

Korsfeldt, T. & Palmberger, B. (2003). *Växande energi, Bioenergin i Sverige – en marknad i utveckling*. Statens Energimyndighet, Energimyndighetens förlag, Eskilstuna.

Kumlin, A-S & Axelsson, U. (2006). Miljöbilar i Region Skåne – Utvecklingen inom området. [Accessed 2006-07-06] http://www.miljo.skane.se/sv/d/bilagor/U1748%20Milj%C3%B6bilar%20i%20Region%20Sk%C3%A5ne%20-maj%202006.pdf

Kågeson, P. (2006). Presentation at Ångpanneföreningen, personal communication. 2006-06-16. Stockholm.

Könnölä, T, Unruh, G. C. & Carrillo-Hermosilla, J. (2006). Prospective Voluntary Agreement: Escaping Carbon Lock-in. [Accessed 2006-05-26] http://www.euro-environment.dk/media/paper_totti_k_nn_l_.doc

Landahl, G. (2006a). Miljöbilar i Stockholm – Nyhetsbrev 2, 2006, Ordförrådet AB. [Accessed 2006-08-06] http://www.miljobilar.stockholm.se/upload/3723/2_06_4.pdf

Landahl, G. (2006b). Exporterar svensk etanolerfarenhet. Nyhetsbrev 1, 2006, Ordförrådet AB. [Accessed 2006-08-06] http://www.miljobilar.stockholm.se/upload/3713/1_2006.pdf

Larsson, E., Husblad, R., Kärrmarck, U. & Hijino, E. (2003). Ekonomiska styrmedel inom energiområdet – en faktarapport inom IVA-projektet Energiframsyn Sverige i Europa. [Accessed 2006-08-02] http://www.stem.se/web/biblshop.nsf/FilAtkomst/StyrmIVA.pdf/$FILE/StyrmIVA.pdf?OpenElement

Lexmon, Å (2006). Sweden, Oilseeds and Products. Nordic/Baltic Biofuels Report. GAIN report. USDA Foreign Agricultural Service. Report number: SW6012. [Accessed 2006-07-29] http://www.fas.usda.gov/gainfiles/200604/146187357.pdf

Lindstedt, J. (2005). BAFF – BioAlcohol Fuel Foundation. Inhemsk produktion kontra import. Nr. 6, 2005. [Accessed 2006-08-06] http://www.novator.se/bioenergy/BE0506/30.pdf

McIntyre, L. J. (2005). *Need to Know – Social Science Research Methods*. McGraw-Hill, New York.

Melander, L. (2005). Pressmeddelande – Försök med trängselskatt i Stockholm startar på tisdag, Vägverket. [Accessed 2006-07-18] http://www.vv.se/templates/Press release____14737.aspx

Miles, M. B. & Huberman, A. M. (1994). *An Expanded Sourcebook – Qualitative Data Analysis,* 2nd edition. Sage Publications, London.

Miljöfordon (2006a). Förmåner - Fri parkering. [Accessed 2006-08-06] http://www.miljofordon.com

Miljöfordon (2006b). Större bensinstationer måste sälja etanol eller biogas, Pressmeddelande. [Accessed 2006-08-06] http://www.miljofordon.se/nyheter/main.asp?iNewsID=554&iMenuID=413&iParentMenuID=&iLanguageID=1

Miljöfordon (2006c). Bidrag till inköp. [Accessed 2006-08-07] http://www.miljofordon.se/fakta/index.asp?sTemplate=main.asp&iMenuID=575&iParentMenuID=406

Naturvårdsverket (2003). Koldioxidskatt. [Accessed 2006-06-02]. http://www.naturvardsverket.se/index.php3?main=/dokument/hallbar/styrmedel/styrdok/lankar.htm

Naturvårdsverket (2005a). Handbok för miljöövervakning – DPSIR-modellen. [Accessed 2006- 08-02] http://www.naturvardsverket.se/index.php3?main=/dokument/mo/hbmo/del1/grund/dpsir.htm

Naturvårdsverket (2005b). Ekonomiska styrmedel för att uppnå miljömål. Ekonomiska styrmedel, Miljöskatter och miljöavgifter. [Accessed 2006-06-02] http://www.naturvardsverket.se/dokument/hallbar/styrmedel/styrdok/styrmedel-miljomal.pdf

Naturvårdsverket (2005b). Ekonomiska styrmedel - Ekonomiska styrmedel och miljömål. [Accessed 2006-06-02] http://www.naturvardsverket.se/index.php3?main=/dokument/hallbar/styrmedel/styrdok/lankar.htm

Naturvårdsverket (2005c). Ekonomiska styrmedel för miljöns skull. [Accessed 2006-07-12] http://www.naturvardsverket.se/bokhandeln/pdf/620-8215-9.pdf

Naylor, D., Ihse, M., Sjödahl, M., Norell., B., Ihse, M., Sehlstedt, Å., Elmhag, J., Adolfsson, M. & Vävare, S. (2005). Odlingslandskap I förändring – En uppförljning av Lim:s referensområden. Naturvårdsverket, Jordbruksverket & Riksantikvarieämbetet. Report 5420, April 2005. [Accessed 2006-08-06] http://www.naturvardsverket.se/bokhandeln/pdf/620-5420-1.pdf

Neuman, W. L. (2000). *Social Research Methods – Qualitative and Quantitative Approaches*, 4th edition. Allyn & Bacon, Needham Heights.

Nordin, T. % Tamm, E. (2005). Svenska Petroleum Institutet. Remiss: Förslag till lag om skyldighet att tillhandahålla förnybara fordonsbränslen, M2005/2459/Mk. [Accessed 2006-06-17] http://www.spi.se/fprw/files/Remissvar%20Lagkrav%20om%20%20pumpar,%202005-05-09,%20web.pdf

Perman, R., Ma, Y., McGilvray, J. & Common, M. (2003). *Natural Resource and Environmental Economics,* 3rd edition. Pearson Education Limited, London.

Persson, G (2006a). På väg mot ett oljefritt Sverige, Kommissionen mot oljeberoende. June, 2006. [Accessed 2006-06-21] http://www.regeringen.se/content/1/c6/06/62/80/bf5c673c.pdf

Persson, G. (2006b). Making Sweden an OIL-FREE Society. The Commission on Oil Independency, Report, June 2006. [Accessed 2006-06-21] http:// www.sweden.gov.se/content/1/c6/06/70/96/7f04f437.pdf

Pollock, D. S. G. (2006). Environmental Economics – The Atmosphere. [Accessed 2006-06-30] http://www.qmw.ac.uk/~ugte133/courses/environs/5warming.pdf

Read, P. (1994). *Responding to Global Warming*. Zed Books Ltd, London.

Regeringskansliet (2004a). Sweden's Environmental Policy – A Brief Overview. The Swedish Ministry of Environment. [Accessed 2006-07-02] http://www.sweden.gov.se/content /1/c6/02/58/00/e07c2088.pdf

Regeringskansliet (2004b). The Swedish model of government administration - three levels. [Accessed 2006-06-16] http://www.sweden.gov.se/sb/d/2858;jsessionid=attUeFZ_e7d8

Regeringskansliet (2005). Sveriges rapport om påvisbara framsteg – i enlighet med Kyotoprotokollet. Ds. 2005:57, Naturvårdsverket. [Accessed 2006-08-06] http://www.naturvardsverket.se/dokument/klimat/pdf/pf_sv.pdf

Regeringskansliet (2006a). Regeringskansliet med departementen. [Accessed 2006-06-17] http://www.regeringen.se/sb/d/385

Regeringskansliet (2006b). Miljö- och Samhällsbyggnadsdepartementens ansvarsområden. [Accessed 2006-06-17] http://www.regeringen.se/sb/d/4455

Regeringskansliet (2006c). Miljökvalitetsmålen – utgångspunkt för miljöpolitiken. [Accessed 2006-06-20] http://www.regeringen.se/sb/d/2055

Regeringskansliet (2006d). Klimatförändringarna. [Accessed 2006-06-20] http://www.sweden.gov.se/sb/d/2985

Regeringskansliet (2006e). Miljöanpassade fordon. [Accessed 2006-06-20] http://www.sweden.gov.se/sb/d/4264

Regeringskansliet (2006f). Nya fordonskatter för personbilar. [Accessed 2006-08-06] http://www.regeringen.se/sb/d/6495/a/59987

Regeringskansliet (2006g). The Commission on Oil Independency. [Accessed 2006-05-27] http://www.sweden.gov.se/sb/d/2058/a/57732

Regeringskansliet (2006h). Så styrs Sverige. [Accessed 2006-08-01] http://www.regeringen .se/sb/d/109

Reijnders, L. (2006). Conditions for the sustainability of biomass based fuel use. *Energy Policy*, vol. 34, p. 863-876.

Rekacewicz, P (2002). The DPSIR Framework, UNEP/GRID-Arendal, United Nations Environment Programme, GRID/Arendal, Maps and Graphics. [Accessed 2006-05-02] http://maps.grida.no/go/graphic/the_dpsir_framework#metainfo

Robson, C. (2002). *Real World Research*, 2nd edition. Blackwell Publishing, Oxford.

Rubin, H. J. & Rubin, I. S. (2005). *Qualitative Interviewing – The Art of Hearing Data*, 2nd edition. Sage Publications, Inc.

Ruttan, V. W. (2001). *Technology, Growth, and Development – An Induced Innovation Perspective*. Oxford University Press, Oxford.

Ryan, L., Convery, F. & Ferreira, S. (2006). Stimulating the use of biofuels in the European Union: Implications for climate change policy. *Energy Policy*, Article in press.

Sahlin, M (2006). Speech given by the Minister of Sustainable Development at the Beyond Peak Oil Conference in Washington DC, May 2006. [Accessed 2006-08-02] http://www.regeringen.se/sb/d/6791/a/63715

Szarka, J. (2006). Wind power, policy learning and paradigm change. *Energy Policy*, vol. 34, p. 3041-3048.

Shah, R. (2000). *International Frameworks of Environmental Statistics and Indicators*. United Nations Statistics Division, Inception Workshop on the Institutional Strengthening and Collection of Environment Statistics, 25-28 April 2000, Samarkand, Uzbekistan. [Accessed 2006-05-02] http://www.unescap.org/Stat/envstat/stwes-015.pdf

Skatteverket (2006a). Ändrade skattesatser på bränslen. Energi-, koldioxid- och svavelskatt. Skattesatser 2006. [Accessed 2006-08-03] http://www.skatteverket.se/download/18.59bd2f7d107d387b4ec800019/skattesatser_jan2006.pdf

Skatteverket (2006b). Ändringar i miljöklassningen av bränslen. [Accessed 2006-07-27] http://www.skatteverket.se/skatter/punktskatter/infoenergikoldioxid/andringarimiljoklassningenavbranslen.4.e03bc7b10bcce611828000155.html

Skatteverket (2006c). Vägavgift för svenska tunga fordon. [Accessed 2006-08-04] http://www.skatteverket.se/skatter/vagavgifter/vagavgifter.4.18e1b10334ebe8bc8000899.html

Skatteverket (2006d). Miljöbilar, förmånsvärde, Justering av förmånsrätt. [Accessed 2006-08-04] http://www.skatteverket.se/infotext/arbetsgivare/miljobilar.4.18e1b10334ebe8bc8000111.html

SPI – Svenska Petroleum Institutet (2006). Diesel per miljöklass. [Accessed 2006-07-09] http://www.spi.se/statistik.asp?art=61

SNF – Svenska Naturskyddsföreningen – The Swedish Society for Nature Conservation (2006). Så här arbetar SNF. [Accessed 2006-08-07] http://www.snf.se/snf/snf-merinfo.htm

SVEBIO (2006). Biodrivmedel. [Accessed 2006-07-21] http://www.svebio.se/?p=816&m=548

Sveriges Miljömål (2006). Environmental Objectives Portal. [Accessed 2006-06-24] http://www.miljomal.nu/english/english.php

Thirtle, C. G. & Ruttan, V. W. (1987). *The Role of Demand and Supply in the Generation and Diffusion of Technical Change*. Harwood Academic Publishers, London.

Tietenberg, T. (2003). *Environmental and Natural Resource Economics*, 6th edition. Pearson Education Inc., New York.

Unruh, G. C. & Carrillo-Hermosilla, J. (2006). Globalizing carbon lock-in. *Energy Policy*, vol. 34, p. 1185-1197.

Vägverket (2005b). Trängselskatt – Undantag från trängselskatt. [Accessed 2006-08-04] http://www.vv.se/templates/page3____14071.aspx

Vägverket (2005b). Trängselskatt – Vägverkets ansvar. [Accessed 2006-08-04] http://www.vv.se/templates/page3____10915.aspx

Weart, S. R. (2003). *The Discovery of Global Warming*. Harvard University Press, Cambridge.

Yin, R. K. (2003). *Case study research – Design and Methods*, 3rd edition. Sage Publications Inc., London.

Åkerman, J. & Höjer, M. (2006). How much transport can the climate stand? – Sweden on a sustainable path in 2050. *Energy Policy*, vol. 34, p. 1944-1957.

Bibliography

Ahlvik, P. & Brandberg, Å. (2001). Well-to-wheel efficiency – For alternative fuels from natural gas or biomass. A report for the Swedish National Road Administration. Ecotraffic ERD^3 AB.

Berg, S. (2003). Harvesting technology and market forces affecting the production of forest fuels from Swedish forestry. *Biomass & Bioenergy*, vol. 24, p. 381-388.

Boeshertz, D. (2002). The promotion of biofuels in the European Community internal market; recent developments. Eur. J. Lipid Sci. Technol., vol. 104, p. 363-368.

Biogas West (2006). Fueling the future – Production, distribution and use of biomethane as vehicle fuel. Business Region Göteborg.

Defra (2003). The facts on biodiesel and bioethanol. Renewable biofuels for transport.

Edin, K-A. (1997). The future of biofuels – a comment on the paper by Herman Vollebergh. *Energy Policy*, vol. 25, no.6, p. 623-627.

Feehan, J. & Petersen, J-E. (2004). Biomass and Agriculture: Sustainability, Market and Policies. A Framwork for Evaluating the Environmental Impact of Biofuel Use. European Environment Agency, EEA, OECD Publication Serivce, Paris.

Forsberg, G. (2000). Biomass energy transport. Analysis of bioenergy transport chains using life cycle inventory method. *Biomass & Bioenergy*, vol. 19, p. 17-30.

Fredriksson, C. & Svensson, R. (2006). Biogas i Sverige – 1996-2006. 10-årsjubileum för biogas till fordon.Högskolan Väst, Trollhättans Stad och SBGF.

Garrod, G. & Willis, K. G. (1999). *Economic Valuation of the Environment – Methods and Case Studies*. Edward Elgar Publishing Limited, Cheltenham.

Giupponi, C. (2006). From the DPSIR reporting framework to a system for a dynamic and integrated decision making process. MULINO Conference on “European policy and tools for sustainable water management, 21-23 November, Venice.

Hansen, A. C., Zhang, Q. & Lyne, P. W. L. (2005). Ethanol-diesel fuel blends – a review. *Bioresource Technology*, vol. 96, p. 277-285.

Hanson, D., Laitner, J. A. S. (2004). An integrated analysis of policies that increase investments in advanced energy-efficient/low-carbon technologies. *Energy Economics*, vol. 26, p. 739-755.

Hansson, J., Jonasson, K., Grahn, M., Nerndes, G. & Sandén, B. (2006). Remissyttrande på slutbetänkandet från utredningen am förnybara fordonsbränslen: Introduktion av förnybara fordonsbränslen – SOU 2004:133. Institutionen för Energi och Miljö, Chalmers Tekniska Högskola.

Honkasalo, N., Rodhe, H. & Dalhammar, C. (2005). Environmental permitting as a driver for eco-efficiency in the dairy industry: A closer look at the IPPC directive. *Journal of Cleaner Production*, vol. 13, p. 1049-1060.

Ignaciuk, A., Vöhringer, F., Ruijs, A., & van Ierland, E. C. (2006). Competition between biomass and food production in the presence of energy policies: a partial equilibrium analysis. *Energy Policy*, article in press.

Koroneos, C., Spachos, T., & Moussiopoulos. (2003). Exergy analysis of renewable erngy sources. *Renewable Energy*, vol. 28, p. 295-310.

Körbitz, W. (1999). Biodiesel production in Europe and North America, an encouraging prospect. *Renewable Energy*, vol. 16, p. 1078-1083.

Lynas, M. (X). *High tide – How Climate Change is Engulfing our Planet*. Harper Perennial, London.

Malça, J. & Freire, F. (2006). Renewability and life-cycle energy efficiency of bioethanol and bio-ethyl tertiary butyl ether (bioETBE): Assessing the implications of allocation. *Energy*, article in press.

Mankiw, N. G. (1998). *Principles of Economics*. The Dryden Press, Orlando.

Piel, W. J. (2001). Transportation fuels of the future? *Fuel Processing Technology*, vol. 71, p. 167-179.

Radetzki, M. (1997). The economics of biomass in industrialized countries: an overview. *Energy Policy*, vol. 25, p. 545-554.

Read, P. (1997). Food, fuel, fibre and faces to feed. Simulation studies of land use change for sustainable development in the 21st century. *Ecological Economics*, vol. 23, p. 81-93.

Scheer, H. (2005). *The Solar Economy – Renewable Energy for a Sustainable Global Future*. Earthscan, London.

SOU 2004:133 (2005). Introduktion av förnybara fordonsbränslen. Miljö och Samhällsbyggnadsdepartementet.

Stadler, M., Kranzl, L., Huber, C., Haas, R. & Tsisliaridou, E. (2006). Policy strategies and paths to promote sustainable energy systems – The dynamic In*vert* simulation tool. *Energy Policy*, article in press.

Statens Energimyndighet (2005). Kostnadseffektiva styrmedel i den svenska klimat- och energi-politiken? Metodologiska frågeställningar och empiriska tillämpningar. ER 2005:30. Energimyndighetens förlag.

Svenska Naturskyddsföreningen (2005). Yttrande över "Introduktion av förnybara fordonsbränslen" (SOU 2004:133). Swedish Society for Nature Conservation.

Sørensen, B. (2000). *Renewable Energy – Its physics, engineering, environmental impacts, economics and planning,* 2nd edition. Academic Press, London.

Tekniska Verken (2001). Biogas in Trollhättan. A powerful and an environmentally friendly fuel system. Trollhättans kommun, Rydins Tryckeri AB.

Tzilivakis, J., Jaggard, K., Lewis, K. A., May, M. & Warner, D. J. (2005). Environmental impact and economic assessment for UK sugar beat production systems. *Agriculture Ecosystems & Environment*, vol. 107, p. 341-358.

Ulgiati, S. (2001). A Comprehensive Energy and Economic Assessment of Biofuels: When "Green" Is Not Enough. *Critical Reviews in Plant Science*, vol. 20 (1), p. 71-106.

van Kooten, G. C. & Bulte, E. H. (2000). *The Economics of Nature – Managing Biological Assests*. Blackwell Publishers Inc., Oxford.

Venturi, P. & Venturi, G. (2003). Analysis of energy comparison for crops in European agricultural systems. *Biomass & Bioenergy*, vol. 25, p. 235-255.

Williams, J. B. (2002). Production of biodiesel in Europe – the markets. Eur. J. Lipid Sci. Technol., vol. 104, p. 361-362.

Yin, R. K. (2003). *Applications of Case Study Research*, 2nd edition. Sage Publications, Inc., London.

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