Consequences of a high oil price

A scenario picturing the effects on society with an oil price at $300/barrel in the year 2015

Master Thesis in Production Management

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Abstract

Background Since 2001 there has been an increase in oil price and unlike other times there is nothing indicating a major persistent decline. As oil is a limited resource and since current production capacity can not fully meet the growing demand the price on oil is kept high. A high oil price will not only result in higher price on fuel and thereby a higher cost of transport. It will also affect areas such as electricity, heating and oil based products. These and other indirect effects will have an impact on the private individual, companies as well as on the society as a whole. Since the products of the Volvo Group are linked to oil it is necessary for the company to have a good insight in the effects both concerning specific products as well as on a more aggregated level.

Objective The objective of this master thesis was to develop a scenario based on collected and interpreted information on how a high oil price can affect the society in 2015. In order to exemplify a high oil price the fictive price of $300/barrel was used. The price was predicted to have a steady climb from today's price of about $60/barrel up to $300/barrel.

Method Since the purpose of this master thesis was to create a scenario for 2015, a predictive approach was chosen. A qualitative scenario technique has been used since it intends to clarify connections, identify key players, insecurities and potential questions which were the intent of this master thesis. A qualitative scenario technique was also appropriate as it generates descriptions on possible future developments and not predictions of the exact development.

Conclusions *The final conclusions of this thesis are expressed in a scenario:*

The oil price will have a steady increase from 2006 until it reaches the level of $300 per barrel in 2015. The decreased availability of oil will push forward an increased use of foremost natural gas and coal. However, the correlation in price between oil and natural gas will come to push even the gas prices upwards. Renewable resources of energy will also increase in importance, but due to limited production capacity these resources will not be able to reach their full potential by 2015. Still the intensified use of biomass will trigger a competition for land, and together with higher production costs, this causes an increased price on food and other bio-based commodities. The increased need for natural gas and coal limits the desired reduction in greenhouse gases.

Even though there are investments made in alternative solutions the sharp increase in oil price will make it impossible to fill the gap entirely between production and demand. The resulting increase in costs for fuel, chemical feedstock as well as heat and electricity causes a decline in consumption. This leads to reduced economic activity and negative GDP development. The effect hits countries who are large importers of foremost oil but also of natural gas the hardest. The necessity for the public and the industry to invest in both alternative sources to oil as well as increased efficiency keeps up a certain level of economic activity. Before this gap between production and demand is closed once again there will be an economically unstable transition period.

Key words: Scenario, scenario model, oil, oil price, consequences, transport, non-energy use, heat and electricity, alternatives, efficiency, GDP, inflation.

Sammanfattning

Bakgrund Sedan 2001 har det varit en ökning av råoljepriset och till skillnad från tidigare finns det ingenting som tyder på en kraftig nedgång. Då råolja är en begränsad resurs och eftersom den nuvarande produktionskapaciteten inte fullt ut kan möta den växande efterfrågan kommer priset på råolja att förbli högt. Ett högt pris på råolja kommer inte bara resultera i ett högre pris på transportbränsle och därigenom ett högre pris på transporter. Det kommer även att påverka områden så som el, värme och oljebaserade produkter. Dessa och andra indirekta effekter kommer att ha en stor påverkan på den privata individen, företag samt samhället i stort. Då Volvo Groups produkter är nära kopplade till olja är det essentiellt för företaget att ha en god insikt i de effekter som påverkar både specifika produkter men även påverkan på en mer aggregerad nivå.

Syfte Syftet med detta examensarbete var att ta fram ett scenario baserat på insamlad och tolkad information angående hur ett högt oljepris kan komma att påverka samhället år 2015. För att kunna exemplifiera ett högt oljepris har det fiktiva priset på $300/fat använts. Råoljepriset predikteras ha en linjär uppgång från nuvarande $60/fat till $300/fat år 2015.

Metod Då syftet med det här examensarbetet var att skapa ett scenario för 2015 har en prediktiv ansats används. En kvalitativ scenarioteknik har nyttjats då intentionen med detta arbete var att klargöra kopplingar, identifiera nyckelaktörer, osäkerheter och potentiella frågor. En kvalitativ scenarioteknik var även lämplig då den genererar beskrivningar av möjliga framtida utvecklingar och inte en förutsägelse av exakta utvecklingar.

Slutsats *Slutsatsen i detta arbete har uttryckts i ett scenario:*

Efter att ha varit i en jämn stigning sedan 2006 når priset på råolja nivån $300/fat i år 2015. Den minskade tillgängligheten på olja resulterar i ett ökat användande av framförallt naturgas och kol vilket minskar möjligheten till den önskade reduktionen av växthusgaser. Den nära korrelationen mellan olje- och naturgaspriset har resulterat i att även naturgaspriset har ökat som en följd av det ökade oljepriset. Förnyelsebara energikällor har även de ökat i betydelse men till följd av begränsningar i tillgänglig produktionskapacitet kommer dessa källor inte hinna nå sin fulla potential vid år 2015. Trots detta har det ökade utnyttjandet av biomassa skapat konkurrens om odlingsbar mark. Detta leder till ökade kostnader för livsmedel samt andra biobaserade produkter.

Även om kraftiga investeringar görs i utbyggnad av alternativa lösningar kommer det vara omöjligt att täcka det ökande gapet mellan utbud och efterfrågan. Den resulterande ökningen i kostnader för bränsle, processråvara samt el och värme leder till en minskning i konsumtion utöver basbehoven. Denna minskning leder till en reduktion i den ekonomiska aktiviteten och en negativ BNP utveckling. Följderna av det ökade råoljepriset slår hårdast på länder som i stor utsträckning konsumerar importerad olja och naturgas. Behovet av att både privatpersoner och industrin investerar i alternativa resurser samt ökad effektivisering leder till att en viss ekonomisk aktivitet uppehålls. Trots detta uppstår en ekonomiskt osäker övergångsperiod innan gapet mellan utbud och efterfrågan på energi slutits.

Nyckelord: Scenario, scenario modell, olja, oljepris, konsekvenser, transport, icke-energi användande, värme och el, alternativ, effektivitet, BNP, inflation.

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Abbreviations

ACC	**-**	American Chemistry Council
ACEEE	**-**	American Council for an Energy-Efficient Economy
BTL	**-**	Biomass-To-Liquid
BTU	**-**	British Thermal Unit, 1.054-1.060 joules
CAP	**-**	Common Agricultural Policy (EU)
CCS	**-**	Carbon Capture & Storage
CDM	**-**	Clean Development Mechanism
CNG	**-**	Compressed Natural Gas
CPI	**-**	Consumer Price Index
CTL	**-**	Coal-To-Liquid
DME	**-**	Di-methyl Ether
EIA	**-**	Energy Information Agency
EU25	**-**	25 countries in the European Union after the expansion of 1 May 2004; *Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom.*
EU15	**-**	15 countries in the European Union before the expansion on 1 May 2004; *Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom*
FTD	**-**	Fischer-Tropsch Diesel
GDP	**-**	Gross Domestic Product
GHG	**-**	Green House Gases
GTL	**-**	Gas-To-Liquid
Ha	**-**	Hectare
IEA	**-**	International Energy Agency
IMF	**-**	International Monetary Found
JI	**-**	Joint Implementation
LNG	**-**	Liquefied Natural Gas
NGV	**-**	Natural gas for vehicles
OECD	**-**	Organisation for Economic Co-operation and Development; *Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States*
OPEC	**-**	Organization of the Petroleum Exporting Countries
pkm	**-**	person-kilometre
RME	**-**	Rape-methyl Ether
SME	**-**	Sunflower-methyl Ether
toe	-	ton oil equivalent
VAT	**-**	Value Added Tax

1 Introduction

In this chapter the foundation of this master thesis is given. This foundation starts with a short presentation of the Volvo Group and Volvo Powertrain initiator of this thesis question and where this master thesis was conducted. Background, purpose, problem analysis and delimitations for the master thesis are then presented and then the thesis structure is shown.

As it is important to understand the background of a study, this initial chapter presents the foundation of the master thesis. The presentation of the Volvo Group and Volvo Powertrain gives a better understanding of the context of the master thesis. The background for the master thesis is described to demonstrate the relevance of the researched problem and the purpose of the master thesis gives a clear definition of what should be accomplished with researching the topic. The problem analysis and the defining of delimitations help to further structure the topic. At last a presentation concerning the content of the different chapters is included to get an overview of the master thesis.

1.1 Company Presentation[1]

The vision of the Volvo Group is to “be valued as the world’s leading supplier of commercial transport solutions”. Today the Volvo Group is already the leading manufacturer in the world with regard to heavy commercial vehicles and diesel engines.

Volvo was incorporated as a subsidiary of AB SKF in 1915. The founders, Assar Gabrielsson and Gustaf Larson, decided in 1924 to start the construction of a car that could withstand the rough Swedish roads and cold temperatures. The emphasis on durability and quality has been a trade mark for Volvo ever since. At 10 am April 14th 1927 the first series-manufactured Volvo car was driven through the gates of the factory and the company Volvo was officially born. Series-manufacturing of the first trucks took off in 1928 and as it was an immediate success, it became an important contribution to the company. The durability and quality that was the emphasis of Volvo was later accompanied with another important aspect: environmental concern. In 1995 Volvo Trucks introduced the ECT, Environmental Concept Truck. This environmental concept attracted a great deal of attention. In the year 1999 Volvo Cars, the “crown jewel” of the Volvo Group was sold to Ford Motor Company for € 5,5 billion[2] and an attempt to take over Scania was stopped by the EU commission the same year. When the attempt with Scania was stopped Volvo started to consider other companies, and in January 2001 Volvo AB acquired Renault Trucks and its subsidiary Mack Trucks. Volvo Global Trucks was now formed. As a result a complete renewal of the product program was carried out during 2001. Today the Volvo Group strives to offer global transport solutions to customers with high demands. The objective is to offer the customer the best solution for their services and thereby strengthen their efficiency and competitiveness. The company has approximately 82,000 employees, runs production in 25 countries and operates on more than 185 markets. The Volvo Group consists of eight business areas as well as five business units as presented in Figure 1.1.

[1] *A Global Group*, 2006-08-30
[2] 1 SEK = € 0,11, 2006-12-01

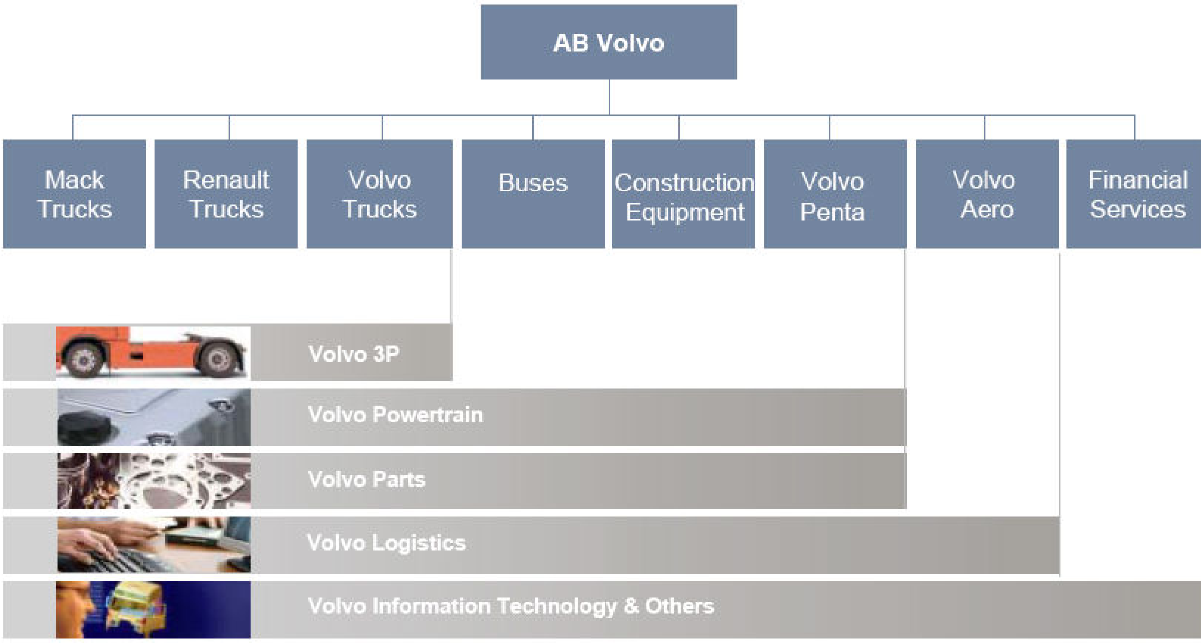

Figure 1.1: Organisational chart of Volvo AB.[3]

Within the Volvo Group it is said that their products and operations shall have the lowest possible adverse impact on the environment. As the Volvo Group strive to be ranked as a leader in environmental care they are working to improve energy efficiency and to reduce emissions. In order to achieve the goal of being an environmental leader the Volvo Group work with continuous improvements, technical developments and efficient resource utilization. The developments in recent years, with increasingly stringent emission regulations and more expensive fossil fuels, have forced the Volvo Group to increase their development resources for optimization of engines and drivelines. There has also been engagement in supplementary fuels and alternative drivelines.

Volvo Powertrain

Volvo Powertrain is the Volvo Group Strategic Centre for powertrain issues. Their vision is to supply the Volvo Group with powertrain systems and components such as engines, transmissions and driven axles. These products are to be world class with regard to performance, product cost, operating cost, customer adaptation and the key values: quality, security and environmental concern. Volvo Powertrain works a lot with fuel efficiency and hybrid technology. The products are to be supplied to the Group business areas': Mack Trucks, Renault Trucks, Volvo Trucks, Buses, Construction Equipment as well as Volvo Penta. Volvo Powertrain operates in Sweden, France and North and South America.

The environmental plan is important to Volvo Powertrain. In their production there should be a 45% decrease in energy use in the next five years. During the same period 15% of the heating should originate from non-fossil fuels. The expected high oil price pushes the development of fuel efficient products and solutions for alternative fuels forward.

[3] *Volvo OH presentation*. 2006-08-30

1.2 Background of the Thesis

The products of the Volvo Group are often fuelled with diesel or other carbon related fuels. This causes both the Volvo Group and their customers to be influenced by a change in the oil price. Liquid fuels for transports is one of the areas predicted to be the most difficult to substitute with other products if the price on oil increases. The fact that the products of the Volvo Group are mostly constructed in metal and plastics will also further affect the company since a raise in the oil price might affect these areas as well. Since the products of the Volvo Group are affected by the oil price, it is crucial for the Volvo Group to develop strategies that take the future development of the oil price into consideration. During the past five years there has been an increase in the oil price and as opposed to the oil crisis in the seventies there is nothing indicating a decline this time. As oil is a limited resource and since current production capacity can not fully meet the growing demand the price on oil is kept high. The effects of a high oil price will not only affect the Volvo Group and their customers with a higher price on fuel and thereby a higher cost of transport. It will also affect them through multiple other factors, such as a possible increase in energy price, which might not be evident at first sight. These other, often indirect, effects will have an impact on the private individual, on companies as well as on the society as a whole. This indicates that there are many factors that can influence the sales of the Volvo Group's products. In order to be able to meet with the effects caused by a change in the oil price and the ever ongoing changes that follow, it is necessary that the company managers have a good insight in these effects both on the specific product as well as on the society as a whole.

1.3 Purpose

The purpose of this master thesis is to collect and interpret information on how a high oil price can affect the society in 2015. In order to exemplify a high oil price the fictive price of $300/barrel is used. The price is assumed to have a steady climb from today's price of about $60/barrel up to $300/barrel, see Figure 1.1, which is a 500% increase. This increase can be put in relation to the approximate 200% increase that occurred in 1973 and 1979[4].

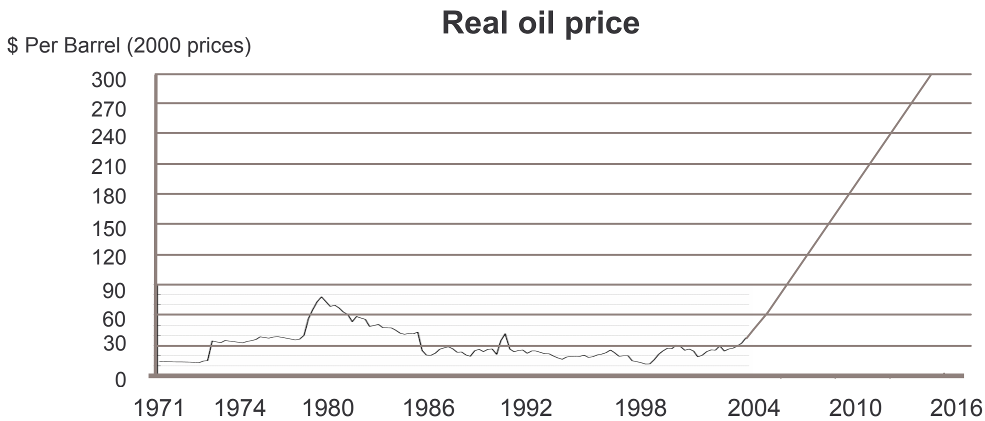

Figure 1.2: Fictive oil price development after 2006. [5, 6]

The objective of this master thesis is to develop a scenario based on collected information that can provide the decision-makers within the Volvo Group with knowledge and information that can help to build a base for future decisions.

[4] *OECD Economic Outlook No. 76 (2004)*
[5] Fictive price development has been extrapolated from current price to set future oil price.
[6] *OECD Economic Outlook No. 76 (2004)*

1.4 Problem Analysis

The question issued by Volvo Powertrain as a headline for this thesis was to investigate the consequences a high oil price will have on society. The consequences considered are those directly visible, such as a higher fuel price, and also indirect, such as a higher price on electricity and polymers. In order to create a credible scenario that can give one possible view on the future, areas both directly and indirectly affected by the oil price should be investigated. The sectors in which oil is used today are transport, non-energy use followed by the household and service sector and then the industry sector. After gathering information of which components are affected by the oil price and in which way they are affected, a picture of the future can be established through the development of a scenario.

The information needed as a base for building the scenario can be obtained through a number of questions which, if they can be discussed properly can give a possible and probable picture of the future. These questions outline the focus areas of this thesis and are therefore further developed. The questions consist of one main question, being the head title of this thesis, and four sub questions where the first one is of a more general nature and the final three focuses on specific sectors in society.

Main question:

What are the consequences of a high oil price?

Sub questions:

How does a high oil price affect a society's general economy?

How does a high oil price affect the transport market?

How does a high oil price affect industries with oil dependant products?

How does a high oil price affect the heat and electricity market?

1.5 Delimitations

When observing the oil price and the areas affected by the oil it can be noted that a lot of these areas interact with each other. This complexity and the macroeconomic consequences of a higher oil price make it difficult to conduct any in-depth experiments or surveys on the topic. The complexity of the subject and the difficulty to do an exact mapping of all the connections and implications explain why this master thesis focuses mainly on three sectors in society, why the level of the master thesis is sought to be kept on a more general level.

When issuing this thesis Volvo Powertrain asked for only one scenario why the focus of this master thesis has been to explore and create one instead of many scenarios. It was also stated that the price of $300/barrel should be used and this price has thereby not been further discussed or questioned. The timeframe of 2015 was also given.

When developing scenarios a timeframe of about ten years can in some aspects be very short and when it comes to short term strategies it is very long. The purpose of the scenario in this master thesis is not to alone serve as a base for strategies, but rather to be a mapping of possible future developments. It can be a base for future work within Volvo Group AB.

The scenario is requested to give a general picture of the world, although with focus on Europe and the US since these are the current main markets for Volvo Group. The separation of two so large continents from the global society can be complicated. Developments in other regions will affect the global development and thereby affect Europe and the US. In today's global society the economies and developments are linked and will therefore affect each other.

No models for inflation and GDP, gross domestic product, should be developed during the work of this master thesis due to the high complexity of this matter. Instead external models may be used and referenced to. To limit the complexity of the subject existing policies and means of control are to be considered fixed.

The consequences connected with a transition to alternatives due to a higher oil price, are explored in this master thesis. The alternatives covered are only alternative raw material, not alternative products (substitutes).

In the chapter concerning transports, only road transports will be considered. The alternative fuels covered in this chapter will not include hydrogen since the contribution from hydrogen to the total fuel consumption is considered limited 2015[7].

Within the sector of non-energy use the main focus is set on the plastic industry. This is done in order to give a more detailed example of an industry dependent on oil. In the section on oil-replacing resources, renewable energy sources such as wave and tidal are not discussed since their contribution to electricity generation 2015 is considered limited[8]. Instead more room is left for discussion of the other resources.

1.6 Thesis Structure

In order to make the reading easier the content of the different chapters are presented below. The interconnections and the layout of the chapters are further discussed in Chapter 2, Methodology, and Chapter 4, Model. If the reader does not have any particular interest in the theoretical background of this master thesis, such as methodology and scenario theory, chapters 2 – 4 do not have to be read thoroughly.

Chapter 1 - Introduction**:** In this chapter the foundation of this master thesis is given. This foundation starts with a short presentation of the Volvo Group and Volvo Powertrain initiator of this thesis question and where this master thesis was conducted. Background, purpose, problem analysis and delimitation for the master thesis are then presented and then the thesis structure is shown.

Chapter 2 – Methodology**:** In this chapter the methodology used in this master thesis will be presented and discussed. The chapter can be divided into two parts. The first part gives a more theoretical discussion concerning methodology while the second part concerns the methodology and work approach of this master thesis. The first part is started with discussing a selection of available research methods. Then an account of data collection proceedings is followed as well as criticism of method. The second part consists of a motivation for the method chosen and a presentation of the research approach used in this master thesis.

Chapter 3 – Theoretical Framework**:** In this chapter theory of scenario creation is presented. The chapter covers both general scenario outlines as well as a selection of scenario models and approaches. The theory presented represents the basis for the scenario model created in chapter 4.

Chapter 4 – Model**:** In this chapter a model for developing global scenarios is created. This model is based on theory from chapter 3 and represents the outline for a majority of the final part in the work approach of this master thesis, as presented in chapter 2. The chapter is

[7] WTW-report (2006)
[8] Boyle, G. (2004)

divided into two parts, the first is a presentation of the model and the second part includes a linkage between the model, the work approach of the master thesis and the different upcoming chapters.

Chapter 5 – Oil as a Resource: In this chapter oil as a resource is discussed. The development of oil consumption and the connection with economical development is visualized. Circumstances concerning supply and price of oil are briefly presented.

Chapter 6 – Macroeconomic Effects: In this chapter the macroeconomic effects of a higher oil price is discussed. The different factors that can affect the extent of the impact as well as the possible impacts on the economy are addressed. The difference in former price hikes in the 1970s compared to the recent ones is discussed.

Chapter 7 – Identify Key Areas: In this chapter the key areas are defined. These key areas are the base for the coming chapters. The key areas are chosen so that they cover the main areas of the thesis problem.

Chapter 8 – Transport: In this chapter the key area transport is presented. The effect an increased oil price has on the development of this sector is covered by looking at the society's dependency on transports, means of control for transports, increased efficiency and the most commonly considered alternative fuels. A few different industries dependence on transports and the developments in this field are referred to.

Chapter 9 – Non-energy Use: In this chapter the key area non-energy use will be explored. The main focus is set on the plastic industry within this sector. The plastic consumption, production and alternative feedstock to oil will be covered. In the final part of the chapter the view of two companies on oil price and alternatives is given.

Chapter 10 – Heat and Electricity**:** In this chapter the key area heat and electricity generation is presented. The use of oil in heat and electricity is investigated as well as the effect it has on those applications. Possibilities for a reduced use of oil within this sector and means of control affecting this use are discussed. Environmental aspects can influence which alternatives will be used instead of oil. This makes the technique of Carbon Capture and Storage, CCS, interesting why this also is covered.

Chapter 11 – Identifying Key Factors: In this chapter the key factors deriving from the key areas will be identified. The key factors are described both in area specific and in general terms. The general factors are broader in description whereas area specific factors more closely focus on the key areas.

Chapter 12 – Oil-replacing Resources: In this chapter some of the possible oil replacing energy sources will be discussed. Depending on which alternative resource used as the oil price gets high, the consequences of a high oil price will be different. The resources discussed are both renewable and non-renewable. Some examples are given to approximate the potential for the different resources.

Chapter 13 – Efficiency**:** In this chapter the potential for reducing consequences of an increased oil price through improved energy efficiency is discussed. Both investigated potential in the EU and the US is covered.

Chapter 14 – Analysis: In this chapter an analysis of the possible consequences of an increased oil price is made. The analysis is based on three possible developments, namely business as usual, use of alternatives and increased energy efficiency. These developments all poses challenges to the three sectors transport, non-energy use as well as heat and electricity causing consequences of the increase in oil price on society.

Chapter 15 – Scenario: In this chapter the scenario is presented which is the final product of this master thesis. The scenario is based on the three analysis chapters; "Identify key areas", "Identify and analyse key factors" and "Analysis". The scenario reflects on a possible future in 2015 with an oil price of $300 per barrel.

Chapter 16 – Master Thesis Evaluation: In this chapter an evaluation of the work progress and experiences made are discussed. This is in order to provide the reader with an understanding of how the authors have experienced the work process.

Appendix 1 – Questionnaire: In this appendix a general outline for the questions asked during the interviews is presented. The questions are in Swedish as the interviews were held in Swedish. This way the questions are kept as close to their original form as possible.

Appendix 2 – Well-to-Wheels report: In this appendix the conditions for the Well-to-Wheels report are given.

Appendix 3 – The Kyoto Protocol: In this appendix a further explanation of the Kyoto protocol is given.

Appendix 4 – Output by selected alternative fuels: In this appendix the calculations exemplified in Chapter 12 are presented.

2 Methodology

In this chapter the methodology used in this master thesis will be presented and discussed. The chapter can be divided into two parts. The first part gives a more theoretical discussion concerning methodology while the second part concerns the methodology and work approach of this master thesis. The first part is started with discussing a selection of available research methods. Then an account of data collection proceedings follows as well as criticism of method. The second part consists of a motivation for the method chosen and a presentation of the research approach used in this master thesis.

The methodology of a master thesis structures and gives direction to the work process. The methodology chapter is included to provide the reader with information about how this master thesis was developed. With this information the conclusions of this master thesis can be critically reviewed and the work re-created. The first part of the chapter is theory concerning methods of structuring a study and of collecting data as well as important criticism needed to be considered while writing a master thesis. The second part covers the method and work approach of this master thesis. The methodology chosen is motivated based on the nature of the problem researched. In the section of the research approach a figure and an explanation of the different steps concerning how the master thesis was conducted is presented. To be able to value the sources used in this master thesis an account for these are made. Criticism of the work approach is included in order to reflect over the choices made concerning method and data collection.

2.1 Thesis Methods

A study can have different approaches depending on what it sets out to accomplish. These approaches can be classified according to their focus. An *explorative approach* is used when there is limited knowledge in an area and the intent of the study is to give fundamental understanding on a topic. When the purpose is to map out facts and relations a *descriptive approach* can be used to answer more specified problems. This approach wishes to describe the situation, not to explain why it is the way it is. An *explanatory approach* extends further than to explain how things work. It sets out to explain the connections between elements and events. When using this approach, already identified and plausible explanatory factors, are of great interest. The last approach to be mentioned is the *predictive approach* which indicates an ambition to foresee the future.[9]

When using a predictive approach different techniques can be used. In *conventional forecasting* it is the existing "status quo" situation that is the main focus. When using this approach there is a risk that external factors are overlooked and that the forecast is merely an extrapolation of an existing situation. The approach is mainly to be used on limited and well-defined subjects and it can also be appropriate to back it up with other approaches such as one involving scenarios. Another approach to try to look into the future is to use *simulation models*. With simulation models it is possible to build numerous futures on the data put into the model. The data used in simulation models is often statistical or of other quantifiable nature. The main problem with simulation models is that they can produce an infinitive number of future situations and it can be difficult to digest the information given and to transform it into something useful. If the number of results is reduced, the information can be easier to handle and the simulations can contribute with important information.[10]

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[9] Lekvall, P. Wahlbin, C. (2001)
[10] Von Reibniz, U. (1988)

In addition to conventional forecasting and simulations there are other techniques available to use. The *Delfi-technique* uses an expert panel that through a repetitive process gets to answer different questions. The experts must be consulted at least twice on the same question. This is because it should be possible for the experts to reconsider their answers on the base of information that they get from the other experts. The experts are to be anonymous to each other or at least the answers are to be kept anonymous. The reason for keeping the responses anonymous is to prevent that the responses are weighted with terms of personality or status. There should also be controlled feedback during the process in order to eliminate irrelevant information. In the end the group response can usually be transformed into a statistical response where all the responses form part of the final answer. If a statistical output is wanted, the questions should be formulated so that the answers can be used quantitatively and statistically.[11] The Delphi-technique can be a method in itself to collect thoughts and ideas about the future or used as a tool in other methods[12]. Another technique that can be used is that of analogy. Most subjective prognoses are built on analogies and when using an *analogy technique* the current situation is compared to earlier and similar situations and through this a prediction can be made. The key to, and also the challenge with, this method is to be able to decide whether the developments of current and future situations are parallel and to compensate for expected deviations. This requires good knowledge about the possible deviations and their effect on the future. Finally *scenario-writing* can be a way to describe a possible future development. Scenario-writing is not a predictive technique per se since the intention is to describe a possible course of events, not to predict which path is the most likely. Scenario-writing is usually used for long-range planning. One advantage with this method is that the underlying assumptions should be made explicit and therefore it is possible to study the effects when one or more of these assumptions are altered. [13]

When an appropriate approach has been chosen, different methods are to be considered when outlining the work to come. A *case study* is a method that focuses on one main object through a detailed and often in-depth study. This method is often appropriate when having an explorative approach since it allows an opened mind and the possibility to go back and further explore interesting parts. When there are several objects in focus of a study and the purpose is to evaluate these in relation to each other a *cross-section analysis* is recommended since this method assumes a cross-section picture at a given moment. The cross-section approach can be divided into survey and experimental approach. In a survey approach the environment is kept as it is while in an experimental approach the environment is adjusted.[14]

The methods mentioned above can be used with a *qualitative* or *quantitative* method approach. A qualitative approach generates in-depth and specific information through mainly common and everyday talks, whereas a quantitative approach is characterized by distance and selection and generates more precise and quantifiable information. A qualitative study is characterized by flexibility while a quantitative study is characterized by structure.[15] The analysis of qualitative data is often seen as creative and requires intellectual discipline and hard work. The reason for choosing this approach can be both the attraction of a vivid and free approach towards the data but also the unwillingness to use numbers and figures.[16] When

[11] Landeta, J. (2006)
[12] Tanaka, Y. (1995)
[13] Edlund, PO, Högberg, O. Leonardz, B. (1999)
[14] Lekvall, P. Wahlbin, C. (2001)
[15] Holme, I. M. Solvang, B. K. (1997)
[16] Grenness, T (2004)

using a qualitative approach together with scenario-writing the intent is to clarify connections, identify key players, insecurities and potential questions though soft data.[17]

When working with data it also has to be decided how to use the data and extract conclusions from it. This can be done through an *inductive* or *deductive* approach. Induction means drawing general and theoretical conclusions on the basis of the material collected. The deductive method is quite the contrary where theoretical hypotheses are created and tested against the empiric to see if they can be verified.[18]

2.2 Data Collection

Collection of data can be done with several different techniques depending on the nature of the problem. *Measurements, tests* and *experiments* are techniques for collecting data which are used if the problem can be measured or experimented upon by the person conducting the study. These techniques are generally quantitative. *Observations* are used when problems can not be changed or tested but still be observed. *Questionnaires, interviews* and *conversations* are used when the data can not be directly measured. These kinds of data can despite this be turned into quantitative data such as statistics.[19]All the techniques mentioned above are usually preceded by literature studies in order to acquire an introduction and information about the subject. Sources of literature can for example be books, Internet, journals, reports and articles.

Collected data can be divided into primary and secondary data, where primary data is collected/ created by the author and secondary data is collected/ created by someone else than the author. All the techniques mentioned in the previous section are primary sources of data except for literature studies where the data is extracted out of secondary sources. This results in that almost every report has secondary data in them since literature studies often is conducted at some point.[20] In some cases interviews can be considered secondary data if the person interviewed presents facts about an historic event.

2.2.1 Interviews

During an interview there is direct contact between the respondent and the interviewer. This contact can be personal, a face to face meeting, via telephone or via mail.[21] A meeting face to face creates a better opportunity for interaction between the interviewer and the respondent. Personal contact implies in principle no boundaries on the questions asked. Figures and other illustrations can be used and there is possibility to explain and further develop a question. This kind of interview is in particular appropriate when in-depth and extensive research is made. One of the down sides with a personal interview is that it can be time-consuming and costly, especially if the interviewer has to travel to meet the respondents. This makes it suitable for research with few respondents situated close together and in a reasonable distance of the interviewer. Another problem with personal interviews is that it can be hard to reach and set up a meeting with the respondent due to lack of time.[22] When the group of respondents is large, difficult to access or far away telephone and mail can be used. An interview via telephone is cheaper, less time-consuming but still keeps some flexibility in the questions. An additional disadvantage is that a telephone interview should be kept shorter

[17] Lindgren, M. (1996)
[18] Wallén, G. (1993)
[19] Nilsson, B. (2004)
[20] Lekvall, P. Wahlbin, C. (2001)
[21] Holme, I. M. Solvang, B. K. (1997)
[22] Lekvall, P. Wahlbin, C. (2001)

than a personal interview since it is easier for the respondent to loose interest[23] and the possibility for personal interaction is lower. Interviews via mail have the advantage that the respondent can choose when to answer the questions and thereby not be limited by setting aside a specific time. This can also be a disadvantage because the appropriate time for answering may never come. Other factors like tone of voice and body-language are also lost in a written respond, but the risk of the interviewer to write down the wrong answer is limited. Illustrations and figures can also be included in this kind of interview but further explanations of the questions are not possible right away.[24]

During a qualitative interview a standardised form is not used. There should be possibility for the respondent to influence where the interview is going since it is the respondent's view that is in focus.[25] There can still be pre-formulated questions to make sure that all areas are covered, or the interview can be prepared by writing down the main areas where the focus of the discussion should be[26].

2.2.2 Data Visualisation

Different techniques can be used when visualisation of data and structuring of thoughts is needed. One of these methods is *mind-mapping*. Mind-mapping is a good way of organising thoughts and structuring new information. The basic idea of mind-mapping is to write down the main idea in the centre and then let the related ideas span out from the centre. Then other related ideas to the new ideas can be filled in and so on. This can visualise connections and branches to better understand the subject. Usually during construction of a mind-map no editing should be made, all the links and thoughts that come up should be written down and can then later be removed if it is clear that it is irrelevant. This way less obvious branches are possible to detect.[27]

Another method similar to mind-mapping is *brainstorming*. Brainstorming does not have to be structured in the way a mind-map is, it can be written down in many different ways (lists, randomly on a paper etc.). Brainstorming is used to get passed mental blockage by trying to bring out as much information as possible. This can be done either in a group or by just one person. There are two things that are important when having a brainstorm. Firstly, the time should be limited not last for longer than 10 to 15 minutes, and secondly, the goal should be quantity not quality. The decision about quality should be made later.[28]

2.3 Criticism of Method

After choosing an approach and method it is important to be critical towards this choice and to carefully consider what kind of problems or opportunities it implies. Often this criticism is done by looking into the *validity, credibility, transferability, reliability, relevance* and *objectivity* of the method.

Validity concerns whether the author observes, identifies or measures what he sets out to do.[29] A broader definition can be that the method used does not generate any systematic errors. This can be satisfied by being clear on definitions and relations.[30] Internal validity

[23] Lekvall, P. Wahlbin, C. (2001)
[24] Ibid
[25] Holme, I.M. Solvang, B. K. (1997)
[26] Lekvall, P. Wahlbin, C. (2001)
[27] *How to do a mind-map.* (2006-10-02)
[28] Lindgren, M. (1996)
[29] Bryman, A (2001)
[30] Wallén, G. (1996)

(*credibility*) has been argued to be strong in qualitative studies due to the fact of the closeness to the object which renders it possible to acquire a high level of consistency between concepts and observations. The internal validity can be strengthened through the use of respondent validation which gives the researcher a possibility to verify his interpretation of the information. When using case studies external validity (*transferability*), the extent to which the results can be generalized, tends to be weak due to the fact that this is a focused study and not a general outline.[31] In a cross-sectional analysis the risk for weak transferability is lower. By giving thought to the *transferability* the researcher can through a detailed and accurate description of the problem compare the findings to other research done and thereby confirm the accuracy. In other words the results of the study can be transferred to another context and shall there still be valid.[32]

Reliability on the other hand regards the accuracy of the method used. A general description can be that the method shall not generate any random errors.[33] When looking at how well a study can be replicated it is a question of external reliability. This can be a difficult criterion to fulfil when using a qualitative approach due to the fact that it is difficult to ensure the same social environment and conditions over again.[34]

A graphic presentation of the connection between validity and reliability is presented in Figure 2.1.

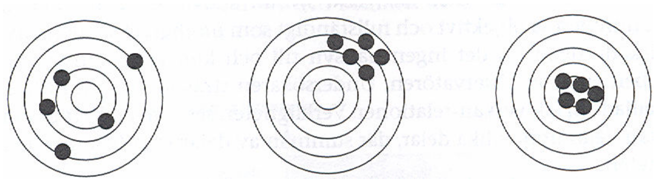

Figure 2.1: Illustration of validity and reliability. [35]

When conducting a study it is also important to evaluate the *relevance* of the subject, the approach and the sources used. The researcher shall strive to discover and clarify areas that add to the total knowledge of the reality. The approach used shall be one that in a relevant way entitles the researcher to do just this.[36] It is also important that relevant sources are used in the work done. The relevance of the sources can both make the results stand stronger or weaken them.

The *objectivity* of the research done can be influenced by both the methods used while doing the research as well as by the choice of sources and their objectivity in the subject. It can be argued that it is important to strive for a high level of objectivity so that it can not be argued that the findings of the work is just a reflection of someone's opinions.[37]

2.4 Chosen Thesis Method

In this master thesis a predictive approach was used. The predictive nature of the problem is the new scenario covering the consequences of a $300/barrel oil price in 2015. Even though

[31] Bryman, A. (2001)
[32] *Writing Guides - Generalizability & Transferability*, 2006-11-08
[33] Wallén, G. (1996)
[34] Bryman, A. (2001)
[35] Björklund, M. Paulsson, U. (2003)
[36] Lekvall, P. Wahlbin, C. (2001)
[37] Holme, I.M. Solvang, B. K. (1997)

there is extensive information in the area of oil price there is little information on how an oil price of $300/barrel affects society. At times both a descriptive and explanatory approach is used in some areas in the creating and finding of relevant aspects and facts. Within the predictive approach scenario-writing was chosen to be the most appropriate work method. This choice was based on the request of a scenario from the assignor, Volvo, and that a qualitative scenario technique generates descriptions on possible future developments and not predictions of the exact development[38].

The focus of this master thesis "Consequences of a high oil price" covers a wide area since it affects many different parts in the society. Because of this the method of cross-section analysis has been used to outline the work. This method generates a general knowledge in the subject and allows for several different factors to be investigated and thereby create a probable scenario. The need to identify connections and interactions between different elements called for a method that would allow an open mind and the flexibility to highlight specific areas.

Together with the method of cross-section analysis a qualitative approach was used. The reason for the use of this approach was that the magnitude of the area studied made more quantitative analysis difficult to conduct. The required information has been expressed in articles, books and interviews in a mostly non-numerical form. The reason for the approach has also been that most of the research done in the area has been qualitative and a lot of information is built on judgments and beliefs of professionals and experts. The qualitative approach also fitted well with the fact that qualitative scenario methods intends to clarify connections, identify key players, insecurities and potential questions which is the intent of this master thesis.

The final choice to be made was the choice between an inductive or deductive approach. In this master thesis an inductive approach has been used and this choice was made since there was a lot of information that could be obtained and because of the difficulty of conducting experiments and tests to verify a hypothesis.

The primary method used for collecting data was literature studies. These literature studies were complemented by interviews and seminars and as a result both primary and secondary sources were used in this master thesis.

2.4.1 Criticism of Thesis Method

The relevance of using a predictive approach is high when addressing what consequences something will have in the future. This makes the predictive approach appropriate for the question raised in this master thesis. A prognosis can always be questioned and is not an exact prediction. This implies that it is difficult to ensure a high reliability with this approach since many factors in the environment easily change.

There are several aspects of criticism that can be directed towards the qualitative approach used in this master thesis. This criticism is reflected in both validity and reliability. One aspect is the difficulty for a qualitative researcher to stay objective and not to be influenced during the study. This critic is based on the fact that a qualitative approach often calls for a relatively open view of the problem at the beginning of the study. Another aspect of criticism is the difficulty to replicate a study done with a qualitative approach. This is because the approach can be seen as somewhat unstructured and often dependent on the ingeniousness of the researcher himself. Since qualitative data can be unstructured the interpretation of the data

[38] Edlund, P.O. et al. (1999)

will be affected by the sympathy and subjective judgement of the researcher. There is also a problem with the possibility to generalize a qualitative study generating from the fact that a qualitative approach often includes a low number of in-depth, personal interviews. The interviews done can then not be seen as general for an entire population. Therefore, results from a qualitative study shall not be generalized on populations but instead preferably generalized into theory. One final source of criticism towards a qualitative approach can be the lack of transparency. A lack of transparency can be the consequence of lacking information regarding how the interview persons were selected and why.[39]

2.5 Our Research Approach

A general structure, see Figure 2.2, has been followed during the work of this master thesis. This general structure comprises the whole master thesis from problem drafting to evaluation of the work done.

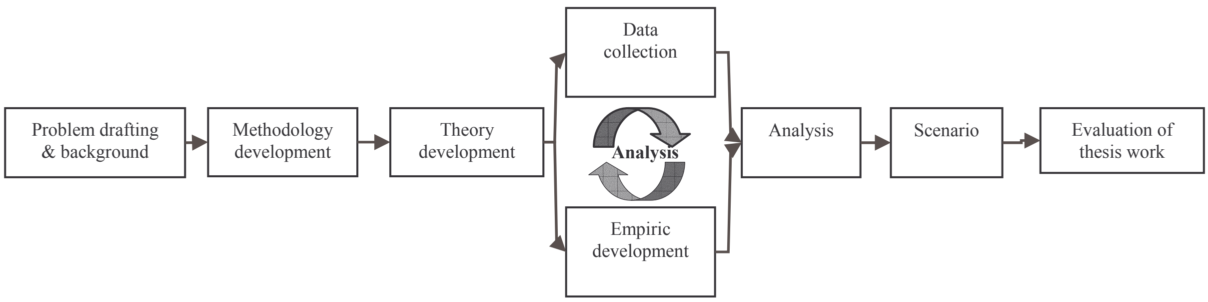

Figure 2.2: The work procedure of this master thesis has been an iterative process.

The first step to be handled in this mater thesis was to identify and verify the *problem* stated by the Volvo Group. Along with the problem formulation was the *background* and purpose of the master thesis established. This has then been a base for this master thesis. This base was developed during continuous discussions with supervisors both at LTH and Volvo and is presented in Chapter 1.

Once the base of the master thesis was set, the work to outline the *methodology*, to be used in the thesis, was performed. The methodology development was performed by studying the theory, and then choosing an appropriate approach, fitting the problem and purpose of this master thesis. A discussion concerning this was presented in section 2.4.

Since the objective of this master thesis was to present a scenario, *theory* concerning scenarios was researched and is presented in Chapter 3. No existing models for scenario creation were found appropriate for this master thesis which resulted in the creation of a new scenario model based on the theory in Chapter 3. The created scenario model is presented and described in Chapter 4. The creation of a scenario model resulted in that this thesis generated two products. One part is the construction of a scenario model suitable for the problem of the thesis and the other part is the construction of a scenario. The scenario model is kept at a theoretical and general level which means that it can be used in future similar scenario developments. This model represents the theoretical framework used to outline the following three steps of the work procedure.

The next step in the work procedure was an iterative process with *data collection*, *analysis* of data and *empiric development* writing combined. In this process both literature studies and interviews were done and two seminars were attended. The nature of the sources used is further discussed in section 2.5.1. Along with the data collection mind maps were created to

[39] Bryman, A. (2001)

visualize which aspects needed to be covered. The reason why not all analysis is collected at the end of this thesis is because some analysis had to be carried out earlier in order to outline the focus areas and then narrow down the scope of the empiric part.

The *analysis* step in the work approach was based on the empiric chapters as well as the former analysis chapters. Brainstorming was used to ensure that the analysis covered all the relevant aspects. The analysis contained a general analysis as well as analysis covering the focus areas. This was done in order to cover the possible consequences a higher oil price can have on the society and ensure that both the main question and the sub questions presented in Chapter 1 were treated. After the analysis was done the *scenario* was created.

In Section 4.1 the outline of the data collection, empiric development, analysis and scenario creation is presented in more detail. This is done in order to better correlate them with the created scenario model created in Chapter 4. A description of the chapter setups and the link between the thesis work procedure, Figure 2.2, and the scenario model is also presented at then end of Chapter 4. This implies that further discussion regarding the research approach of this master thesis can be found in Chapter 4.

The last step in the work approach, *evaluation of thesis work,* is also the last chapter in this thesis work. An evaluation of the work conducted during the thesis was done to reflect over how the work had evolved and what could have been done differently.

2.5.1 Sources

Since this master thesis primarily was a literature study many different types of literature were used. During the work process books, reports, articles and Internet sources were used to find information. This variety of sources were used to ensure that the material used was as diversified and comprehensive as possible. In addition to this, interviews were made to fill in where we could not find material, and to gather opinions from different sectors concerning the impact of a higher oil price. Two seminars were attended to get better knowledge of the area of this master thesis.

The *books* used in this report were literature from earlier courses at LTH, literature given to us by our mentor at LTH and literature found in the Volvo library. The books mainly covered areas such as methodology, scenario technique and energy systems. *Articles* were given to us by our mentors at LTH and Volvo, as well as found by using the databases accessible through the University library of Lund (ELIN and LOVISA). Also search engines on the Internet were used. The articles used are published in academic and scientific magazines which give them reliability. The reliability has also been ensured by trying to find more than one source giving the same or similar information, this concerns information from the Internet as well. Articles published by interest organisations have also been used but regard has been taken to the fact that they might not be objective.

When using material from the *Internet* an evaluation of the reliability of the source was done. Primarily Internet sites provided by public authorities, interest organisations (for example PlasticsEurope) and international agencies (for example IEA, International Energy Agency, and IMF, International Monetary Fund) were used. A lot of material was gathered from statistical databases such as Eurostat and the statistics provided by the IEA and the IMF.

The *interviews* were done in order to get a better understanding of the different areas as well as get a better opportunity to find out personal opinions. The primary mean for obtaining personal contact was via e-mail, although in some cases they were contacted directly via telephone. The interviews themselves were conducted face to face. The goal was to get at least one interview within each area of interest. The chosen respondents have been familiar with their areas. The methodology for the interviews was qualitative since the goal was to identify personal opinions and to enable the person interviewed to speak freely about the subject. This explains why there has been only one interview in each area, as these interviews are time-consuming. A general outline for the questions covered during the interview, see Appendix 1, was sent out beforehand to allow the respondent to reflect over them. The material later used from the interviews was sent out so the person interviewed could comment on the accuracy.

Two s*eminars* were attended, "EU Workshop on Hydrocarbon Prospects and Energy Futures" in Brussels and "Biobränsle – efter Oljekommissionen" in Stockholm. The workshop attended in Brussels covered the background of the problem concerning oil dependency, oil price and the effects of oil. This was used as a base for understanding the problem of the master thesis. The discussions held during this conference are referred too when used in this thesis. The other seminar covered the potential for biomass to grow and to be used in Sweden.

The aim at the start of this master thesis was to gather information from both Europe and the US, since these are the geographical areas covered. With the benefits of Internet the access to written material from both Europe and the US was extensive. Unfortunately the possibility for personal contact was less successful. This resulted in that all of the interviewed persons were Swedish which can question the transferability. This could possibly have been avoided by trying to contact people more over the phone. Also some of the data has only been covering Sweden. This one-side approach has been given thought to ensure not to make any unrealistic generalisations.

International sources like the IEA and the UN were used to gather information covering both Europe and the US. Since data was collected from many different sources the information given was not always uniform in the sense that it covered the same geographical distribution. This has for example resulted in reference to EU15, EU25 and the Euro-zone to cover Europe.

The information available to read covering the area and related topics has been extensive. This has made it impossible to read it all. Large parts have been included as sources, but far from all the material covered. Even though we have covered extensive amounts of information, it has not always been possible to find the information we have been looking for.

During the work process we have been influenced by the information we have assimilated, both the information referred to as well as the information not referred to. Due to this the objectivity of the master thesis can be questioned. We have tried to bear this in mind and reduce this risk by being as methodical as possible.

3 Theoretical Framework

In this chapter theory of scenario creation is presented. The chapter covers both general scenario outlines as well as a selection of scenario models and approaches. The theory presented represents the basis for the scenario model created in chapter 4.

In Chapter 1 it is defined that this master thesis should generate a scenario. A scenario model will be created for this master thesis and the theory behind this scenario model is covered in this chapter. To be able to create a scenario model it is important to be familiar with, and understand, the past and the fundamentals of scenario techniques. Definitions and functions are therefore included in this chapter as well as existing models and approaches used by others. Models and approaches used by others can be used as outlines in the creation of an approach fitted for a specific situation.

3.1 Scenario Characteristics

Scenario techniques, like many other writing and creation techniques, are not an exact science. They are rather an interpretation and therefore there are many views on the definition of scenarios, how they are constructed and how they should be presented. A reflection of this is covered in the following section.

3.1.1 Definition of Scenario

The descriptions vary from the early definition by Kahn and Weiner (1967) who states that a scenario is…:

"A hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points".[40]

…to the more recent descriptions done by Shell (2003):

"Building scenarios is like making a journey of exploration, it can change how we see and understand the world."[41]

The base for the modern scenario technique was developed by the US military in order to help combat groups handle unaccustomed environmental situations and events. After going through different scenarios, the soldiers and commanders were to be prepared when the real situation happened and thereby become victorious. This early method of scenarios was created by Herman Kahn on the order of the US Government.[42]

After the oil shocks in the 1970s many business managers felt a need for a tool that could help them efficiently deal with the uncertainties that surrounded the business organisations. The traditional forecasting methods did no longer feel reliable and adequate. There was a need for methods that did more that just extrapolating the past and saw the world as stable and constant.[43] When the use of scenarios was transferred from the military to the business environment in the early seventies two main methods could be distinguished. One of them was a quantitative method promoted by a group calling themselves the Club of Rome and the other method was a qualitative oriented one which was foremost promoted and used by the oil company Shell.[44]

[40] Kahn, H. Weiner, A. J. (1967)
[41] *Scenarios: An explorer's Guide.* (2003)
[42] Von Reibniz, U. (1988)
[43] Bood, R. Postma, T. (1997)
[44] Von Reibniz, U. (1988)

Scenarios can be a suitable way to give a possible future picture of the world. This is because the human brain works with scenario pictures of an imagined situation when it interprets what is happening around us and what therefore will happen next. By using this instinctive method on a wider scale, large business and global scenarios can be created.[45]

3.1.2 Scenario Functions

Today the scenario technique is still very useful. The traditional techniques for forecasting are usually based on the assumption that the future will stay similar to today. When building scenarios it is necessary to think in a wider perspective and more creatively about the future.[46] Scenarios can be used to fill a wide range of functions:[47]

- They can serve as a background for evaluation and selection of company strategies and since not one strategy is the best for all future environments, the scenarios can serve as a framework for discussion regarding the choice of strategy.
- Scenarios can serve as a future-oriented tool that helps to integrate various kinds of data into an idea possible to grasp and handle. Within scenarios both quantitative and qualitative data can be used to present the future. Through a presentation of the future, scenarios allow for exploration and identification of what might come further ahead, for example major shifts in the business environment.
- A good scenario can help the manager understand what aspects of the future are significant versus peripheral, and thereby function as an alarm clock for major changes and strategic problems that an organisation can be facing in the future. Scenarios can also work as a wake-up call for an organisation or a society to make them aware of what the consequences might be if the present development is allowed to continue[48].
- A scenario can be used in order to challenge and stretch managers' mental models. This can be done by entering assumptions that are thought to be "fixed" variables. To challenge a "fixed" assumption is to allow change to something in general taken for granted. By questioning and altering this general picture new ways of looking at a problem or solution can occur. Even though the assumption is still thought to be fixed just thinking about the opportunity of a change can widen the horizon. Since everyone creates mental models for themselves on the basis of previous experiences and knowledge, scenarios can also work to challenge these old perceptions and help to build a common reference base and consensus within a management team.
- Finally scenarios can be used in order to start off and accelerate processes of organisational learning. They can represent a "real world" in which different aspects can be tested and through this managers can be helped to learn faster than if they were to carry out the thoughts in the entire organisation.

Even though most scenarios developed have not succeeded in their predictions, it is still a technique widely used and adopted by many companies and organisations as a tool for communication. Even if creating scenarios cannot exactly predict the future, the process can teach the organisation a lot and this makes the effort worth while.[49]

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[45] Lindgren, M. (1996)
[46] Huss, W. R. Honton, E. J. (1987)
[47] Bood, R. Postma, T. (1997)
[48] Wahlström, B. (2004)
[49] Ibid

3.1.3 Scenario Model Characteristics

A lot of the material on scenario modelling is getting old but it can still be useful, because although the world is changing, the nature of the problems that are up for discussion is often the same. Not using the accumulated knowledge that exists is to deny oneself the progress made by others.[50]

Scenario writing is often based on a qualitative procedure but it may also include some results from quantitative models. The base of the qualitative approach is to rely more on gut then on computers. Qualitative approaches often try to identify trends and underlying problems and are therefore based on the assumptions that the future can not be foreseen through mathematical equations but are affected by many forces in the past, present and future. The quantitative models on the other hand are often based on mathematical equations and the belief that linkage can be described through statistics. When working more focused with a quantitative approach it is possible to create a scenario which should be the most likely one through the use of generated statistics. The critique towards the assumption that a most likely scenario could exist is massive. Schnaars (1987) strongly arguments that this assumption is direct misleading and points out that "scenarios are possibilities, not probabilities".[51] Even though the discussions between qualitative and quantitative approaches are vivid, many of the models that exist include a bit of both.

Scenarios can have different ways of distinguishing themselves. They can be *exploratory* and start with a known or assumed state and based on trying to explore what might be the effects of that state. The opposite is to start from an assumed or desired future state and try to distinguish the events leading up to that state. The scenario can be *descriptive* and present possible futures without considering whether they are desired or not. The opposite, *normative*, especially accounts for values and goal. Scenarios can also be distinguished by whether they consider surprising, trend-braking and improbable developments. If these aspects are included the scenario is regarded as a *peripheral* scenario, otherwise it is a *trend* scenario. All these different types of scenarios can be combined and have different elements of each other in them.[52]

The view on the time horizon and numbers of scenarios that should be produced differs between different authors on the topic. The time horizon spans from the opinion that scenarios should only address the near and reachable future, for example a horizon of five years, to the opinion used by Shell with a horizon of at least 15 years. Often the selection of horizon is connected to what the use of the scenario shall be. If it is to be used for strategic planning in a long perspective the scenario has to be based on a long view as well, but if the scenario will be used to describe events and developments more close in time a shorter horizon can be to prefer.[53] The opinion on what number of scenarios that should be developed differs as well. In general there is no limit to the number of scenarios possible to develop since there are so many events that can alter the course of the future, see Figure 3.1.[54] Some authors argue that three scenarios is the best number since that allows for the most optimistic, the most pessimistic and a general scenario to be produced. Others say that only the two extreme scenarios are required since they cover the middle one as well. The case with only two

[50] Godet, M. (2000)
[51] Schnaars, S. P. (1987)
[52] Warren, Kim. (1995)
[53] Schnaars, S. P. (1987)
[54] Von Reibniz, U. (1988)

scenarios has also been argued to be appropriate with regard to the fact that it is too easy to choose the middle scenario if there is one.[55]

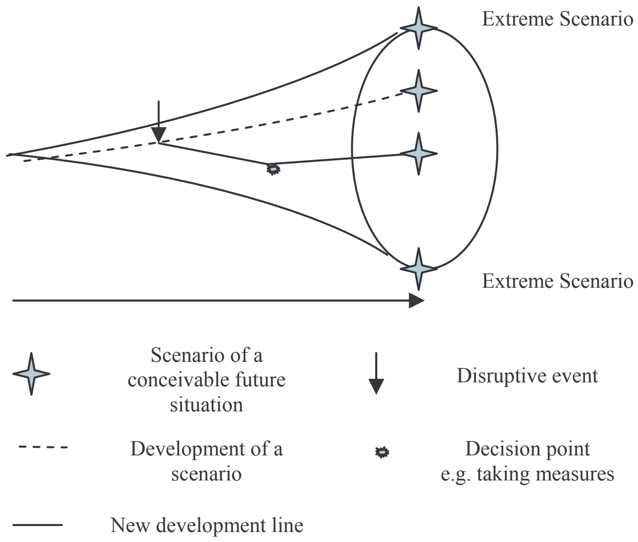


Figure 3.1: Conceptual model of scenarios. [56]

Tools and models are often used in bits and pieces when creating scenarios, often due to lack of time and resources. This however does not pose a problem as tools often can be selected and used individually or in combination.[57] Studies have shown that the most important aspects when working with scenarios is not to put all focus into methodological issues but to ensure the reliability of the underlying assumptions. One of the most important aspects of scenario analysis is simply to think about the problem, and to visualise the questions that exist.[58] A generated model is never to be regarded as the reality since it is only a mean of looking at it. The point of the methods is not mainly to provide results but to present a way of structuring thorough and intelligible communication on a given theme. The most important part when doing a study is not so much the result as the way of getting there. Godet and Roubelat state that what is too simple is stupid and wrong and what is too complex is useless. In order to work with scenarios there is a need for a tool that is straightforward and rational.[59]

3.1.4 Presentations of Scenarios

When it is time to present a scenario to others than those involved in the development, it is important connecting to the listeners. Godet and Roubelat states that the key to successful action comes through the wedding of passion and reason, of heart and mind.[60] If an idea is early anchored high up in the hierarchy it is easier to get it realized. In order for a scenario to be effective it has to be challenging or sometimes shocking in its design. This is because people often are very stubborn in there opinions and in holding on to their own thoughts. By having a challenging nature the scenario can trigger the imagination of the listener and thereby help them to judge their opinions. But there is also a danger when creating shocking scenarios because if it is too remote from the way people think or reason, the scenario can be

[55] Schnaars, S. P. (1987)
[56] Von Reibniz, U. (1988)
[57] Godet, M. (2000)
[58] Schnaars, S. P. (1987)
[59] Godet, M. Roubelat F. (1996)
[60] Ibid

perceived as unreliable and irrelevant. There has to be a balance between provocations and acceptance.[61]

3.2 Scenario Models and Approaches

The future can never be exactly predicted. It is not set and it can therefore not be written with absolute truth. Godet and Roubelat have stated that during the last two decades errors in forecasting have been caused by two main factors: overestimation of the pace of change and underestimation of the fundamental factors, such as structures and behaviours. This is why it is of outmost importance to be aware of sources used and estimates done.[62] Scenario should in every moment give an answer to questions regarding who the actors in the game are, what events are taking place, when in time the events occur, where the events are happening, how the events are carried out and with what and finally what are the motives behind the events. In short the scenario shall answer the question: who does what?, when?, where?, how? and why?[63] In order to satisfy the need for reliable data and procedure some data collection methods appropriate when gathering information for scenarios and methods of approach will be presented in the following section. This section can be seen as a further development of Chapter 2. Following the mentioned section is a presentation of models and approaches used by others in the scenario literature.

3.2.1 Data Collection

When working with scenarios the task is to generate a picture of the possible state of tomorrow. This can be done through the identification of trends and coming questions or for example the identification of what is happening today and what the reaction to this will be tomorrow.[64]

Many forecasting methods, as for example *macro-economic models*, are based on the development of complex and quantitative methods. In these methods a thought exists that a better prediction can be made as long as more effort is put into the model and that more equations and bucks can make it more accurate. This has proven not to be the case when complex methods have shown to be no more exact than simpler ones.[65] Although there has been critique directed towards the macro-economic models they are often used in scenario creation in order to provide the scenario with the necessary consistency and linkage of macro-factors.[66]

As mentioned in Section 2.2 *interviews* can be a good method of data collection. With regard to collecting data for scenarios, asking those who are initiated in the subject can be an excellent way of detecting interesting questions and to get a more detailed picture of specific questions. When working with scenarios it is common that interview data is collected through the Delphi-technique, opinion polls or for example panel debates with experts on the subject. The material collected can then be the base from which to detect the future trends, developments and “whispers”.[67]

The *media* can also be a useful tool in order to detect coming trends and developments. If one succeeds to identify what is said behind the big headlines and in more peripheral media such

[61] Bood, R. Postma, T. (1997)
[62] Godet, M. Roubelat, F. (1996)
[63] Lindgren, M. (1996)
[64] Ibid
[65] Schnaars, S. P. (1987)
[66] Chandler, J. Cockle, P. (1982)
[67] Lindgren, M. (1996)

as scientific magazines early trends can be possible to detect. It is important however to verify if this data can be used as facts or if it is of a more speculative nature, maybe used as a background for further information gathering. When working with the extensive amount of material that the media represents, it is important to work with a hypothesis in mind and then try to detect things that conclude or disagree with the hypothesis. It is also important to be open to the new indications of the future, the so called "whisper" of the future.[68]

3.2.2 Scenario Models

There are several different models that can be used when working with developing scenarios. Some are similar to, or a development of, others while some differentiates themselves substantially.[69] In this section a selection of methods are presented which are examples of general scenario models suited for broad questions.

General Electric model

A traditional model formerly used by *General Electric (GE)* is divided into six steps:[70]

1. Analyse the present and the background
   - Demography and lifestyle
   - All-embracing industry and economy
   - Laws and regulations
   - Research and technology
2. Pick out the critical key factors
   - Appoint a panel of experts to evaluate present and identify new key factors
   - Identify the key factors of the line of business and trends
3. Find out how the key factors have been acting earlier
   - Enter historical data for each key factor
   - Make a TIA – Trend Impact Analysis
   - Compare with the different background factors
   - Appoint a panel of experts
4. Identify possible future events
   - Ask the panel of experts
   - Evaluate earlier trends
   - Add possible influence of future trends
   - Add the probability for these future trends to be reality
   - Predict different future valuations
5. Make a prediction for every key factor
   - Make a CIA – Cross Impact Analysis
   - Make a TIA – Trend Impact Analysis
6. Write scenarios

The emphasis of this model is on how important it is to find the critical key factors. This model provides a way to develop scenarios and it also gives a systematic way of how an environmental scanning can be done.[71]

Cross Impact Analysis (CIA) is used when trying to analyse complex systems. By using CIA the connections between different factors and how they work together is brought out.[72] The

[68] Lindgren, M. (1996)
[69] Ibid
[70] Ibid
[71] Ibid
[72] Ibid

basic idea with cross impact analysis is that no development occurs in isolation. Instead of being an isolated event the development is influenced by other developments. One way to bring structure to the connections between developments is to arrange them in a spread-sheet and then evaluate how strongly they are influenced or influences others, see Table 3.1. The different factors are arranged by how they affect others; positive, negative or not at all on a scale from (-2) – (2). The sum of the impact can then give an indication on how strong the factor is. Cross impact can be a useful tool when working with a qualitative approach.[73]

Table 3.1: Example of Cross impact spread-sheet.[74]

Variable	1	2	3	4	5	6	SUM
1		-2	-1	2	0	1	0
2	2		0	0	0	0	2
3	-1	0		0	2	0	1
4	-2	2	1		2	1	4
5	2	0	2	0		-1	3
6	0	2	-2	2	-1		1
SUM	1	2	0	4	3	1	

Trend Impact Analysis (TIA) aims at looking at the effects different trends can have over time. TIA not only looks at predictable trends but also at what might make the trend change its course. The trends that can be looked at are for example market trends and population development.[75] TIA can be seen as a different version of CIA and operates in the same manner but with trends instead of variables.[76]

Shell Model

The *Shell Company* were pioneers when they started to work with scenarios some forty years ago. They study the future by using scenarios as a tool and then develop strategies that are adapted to cope with changes in the surrounding business environment. Shell develops several scenarios that represent different possible futures. Their scenarios cover not only one aspect at a time but connect elements of economics, politics and social behaviour. This is because they have realised that it is difficult to only look at one aspect without considering other elements. When working with the development of their scenarios they use modelling, brainstorming, reflection and interviewing.[77] Below follows the model used in the global scenario created in 2003.

[73] Lindgren, M. (1996)
[74] Ibid
[75] Wahlström, B. (2004)
[76] Lindgren, M. (1996)
[77] Kassler, Peter. (1995)

The Shell model includes five steps: [78]

1. Preparation – Be clear about the goals and resources of the project
   - Plan the project
   - Allocate responsibilities
   - Secure timing
   - Set research priorities
   - Conduct interviews
2. Pioneering – Broaden your perspectives and challenge your assumptions
   - Cross frontiers
   - Identify themes
   - Plan a route
   - Outline scenarios
   - Scenario building
3. Map-making – Create coherent and vivid stories about the future
   - Tell stories
   - Clarify dynamics
   - Illustrate information
   - Gain endorsement
4. Navigation – Successfully find your way as events unfold
   - Systematic use
   - Get traction
   - Scenario presentation
   - Focused scenarios
5. Reconnaissance – More effectively scan the environment for important developments
   - Understand implication
   - Interpret signals
   - Share perspectives
   - Recognise differences

The steps presented above can be connected in a circle so that the end is always the beginning of the next round. The aim with this model is not to give exact guidance on how to build scenarios but rather to provide guidance and ideas in the creation of scenarios. Shell argues that scenarios provide you with different perspectives of what might to come so that you can navigate more successfully into the future.[79]

SRI International Model[80]

SRI International early developed a model for business planning scenarios. The model is based on that businesses are affected by many different factors such as economical, political and technological. These factors are later considered when making decisions in the company. Even though they are external factors they should be considered when considering new product development, capacity expansion etc. Some factors are predictable or quantitative but some are qualitative and vague which makes scenario analysis a good tool to map out a business' environment. The eight steps of the *SRI International model* are:

1. Analysing the decisions and strategic concerns
2. Identifying the key decision factors
3. Identifying the key environmental forces
4. Analysing the environmental forces

[78] *Scenarios: An explorer's Guide.* (2003)
[79] Ibid
[80] Huss, W. R. Honton, E. J. (1987)

5. Defining scenario logics
6. Elaborating the scenario
7. Analysing implications for key decision factors
8. Analysing implications for decisions and strategies

The first step is to identify the key company decisions. These can be decisions regarding, for example, market strategies. When the key company decisions have been identified the scope of these decisions are defined. If it is a narrow scope the scenario will be less complicated to build up. In step two, the key decisions factors are identified. A key decision factor is something that will affect the result of the decision. This can be environmental factors, price trends, energy or human resources.

The environmental forces in the third step are forces such as political, social, economic and technological. The key decision factors are formed by these environmental forces. They can be identified with help from for example outside consultants, different models, scanning systems and analysts. In the fourth step the environmental forces are to be analysed. This includes looking into areas like the history, uncertainties and trends for the forces and also the relationships between them. The discussions about the forces should be kept short but it must be made sure that all the relevant information is included and nothing critical missed. The environmental forces that contribute to considerable change can be recognized in this discussion.

The centre part of the SRI International method is step five, defining scenario logics. An effective way of bringing out the scenario logics is by having workshops. The scenario logics should make sure that each scenario foundation is consistent and plausible by organising principles, themes and assumptions. It should be made sure that all the different conditions and uncertainties, brought forward while analysing the environmental forces, are included but the scenario logics do not need to go into all the different possibilities. Scenario logics can bring out scenarios such as buyers or sellers market instead of solely optimistic or pessimistic scenarios. In the sixth step environmental analyses and scenario logics are combined. Focused information concerning the key factors for decisions should be in the scenarios.

The implications each key decision factor has on the scenario are analysed in step seven. In this step it is important that the information brought forward to the decision makers is understandable and informative. In the final, eighth step, questions concerning what special cases and critical issues brought forward in the scenarios, should be further looked into. It should also be identified what strategies that are appropriate in the light of the scenarios created.

The SRI International approach is built on an intuitive logic approach and this makes it possible to create internally consistent and flexible scenarios based on logical and intuitive perspectives. It is a qualitative approach which makes it easier to adapt to different situations and requests and not very suitable for situations where more quantitative aspects are needed.

3.2.3 Tools

In this section two models are presented that can be used as tools during the creation of scenarios in order to generate ideas and to structure the creative process.

Corporate Radar Model[81]

Another model used within scenario planning is a model presented in "*Corporate Radar*" (2000) written by Carl Albrecht which is based on the PEST-model. PEST stands for political, economical, social and technological environment. The model presented by Carl Albrecht adds a few areas to fully complete the picture of the environment. This results in totally eight areas which include some factors to consider within each area:

1. The environment of the company's or organisation's customer. The customer's:
    - Identity
    - Needs
    - Habits
    - Life situation
2. The environment of the competitor. The competitor's:
    - Identity
    - Motives
    - Strengths
    - Weaknesses
    - Present and possible behaviour
3. Economical environment. Factors that can affect the customer's behaviour, the competitor's strategies and the company's possibilities such as:
    - Market development
    - Capital needs
    - Critical resources
    - Costs
    - Currencies
    - National economical development
    - International trade
    - Prices
4. Technical environment. All the technical possibilities and solutions that already exist or are on their way that can contribute to the company.
5. Social environment. Aspects that contribute to different peoples' preferences such as:
    - Values
    - Faith
    - Styles
    - Heroes
6. Political environment. How the industry is affected by national, regional and local authorities as well as activities done by lobbyists.
7. The legal environment. How the company is affected by things such as:
    - Laws
    - Regulations
    - Preparatory work for legislation
    - Patents
    - Copyright
    - Brands
8. The geophysical environment. The company's surroundings such as:
    - Ecosystem
    - Natural resources
    - Access to raw material
    - Transportation possibilities
    - Other infrastructure
    - Access to intellectual capital
    - Access to well educated staff

This model might be somewhat limited for those who work with building scenarios but it is a good model to use when the process of thinking and creativity is set to start.

[81] Wahlström, B. (2004)

SWOT Analysis

When working with models and approaches, as those mentioned in this chapter, it can be helpful to use a tool in order to systemize and organize thoughts. This can be a tool such as a SWOT Analysis. In a SWOT analysis the key points of a company or a situation are summarised and listed as; strength, weaknesses, opportunities or threats. Strength and weaknesses point toward the strategic position of a company and aims to form a view of the internal influences and constrains on the strategic choices for the future. Opportunities and threats identify the possibility of a strategic gap in the competitive environment that can occur when a situation is not fully exploited by a company or its competitors. By using the SWOT tool in analysis a holistic view of the present situation can be created and it can also help focus discussion on future choices and strategic opportunities.[82]

As mentioned in Section 3.1 tools and models are often used in bits and pieces when creating scenarios, often due to the lack of time and resources[83] or the fact that the model need to be adjusted in order to fit the current task. This is why, in this chapter, a number of different models have been presented.

[82] Johnson, G. et al. (2005)
[83] Godet, M. (2000)

4 Model

In this chapter a model for developing global scenarios is created. This model is based on theory from Chapter 3 and represents the outline for a majority of the final part in the work approach of this master thesis, as presented in Chapter 2. The chapter is divided into two parts, the first is a presentation of the model and the second part includes linkage between the model, the work approach of the master thesis and the different upcoming chapters.

The model presented in this chapter is created as a part of this master thesis in order to generate a structure and approach fitted for the specific scope of the thesis, since no appropriate model was found among the existing ones. In the first section of this chapter the model that has been created is presented and the different steps are explained. The second section explains the linkage between the model, the work approach for this master thesis and the upcoming chapters. This linkage is done in order to get a better understanding for the structure of the master thesis.

4.1 Model Presentation

The model that has been created for this thesis is based on the three most suitable models presented in Chapter 3. It is a nine step model graphically presented in Figure 4.1. The nine steps are:

1. Define problem & set up goals
2. Analyse background and present situation
3. Identify key areas
4. Study key areas in six aspects
5. Identify and analyse key factors
6. Identify possible future developments and consequences
7. Define scenario logics & mapmaking
8. Prediction for each key area
9. Write scenario(s)

In the first step of the model, *Define problem & set up goals,* the problem and focus of the scenario is defined. The goals that are to be reached are presented in order to clarify what the scenario(s) is to accomplish. These goals can include aspects such as time horizon and future field of use. During this initial step a plan is set up in order to give structure and present a framework for the work that need to be done. This step is similar to the first step of the Shell model and should address questions such as planning, allocating of responsibilities, securing of timing and setting of research priorities.

In the second step, *Analyse background and present situation,* the background and present situation of the problem is analysed and mapped out. Areas such as historic developments, past trends and data are of interest. This work is done in order to provide a platform out of which the main areas of interest can be defined. Although this step is the foundation for the rest of the work it is important not to be too detailed or to get stuck in petty questions. If this happens there might be a risk that the project looses focus and becomes too time consuming. This step is similar to the initial step in the GE model and helps to map out what has happened in the past and in current settings.

The third step*, Identify key areas,* is based on the material collected in the second step. Out of the collected material the main areas of interest are defined. These main areas are named *key areas* as they represent the basis for the continuing work. The key areas should be defined so that they can help to divide the problem into smaller parts that can be further focused on. Each key area should have a uniform development pattern and be distinctly differentiated from the other key areas. By focusing on these key areas it should be possible to identify important players and characteristics that can help to map out significant factors and developments.

In the forth step, *Study key areas in six aspects*, the key areas are analysed using six aspects: geophysical, legal, technical, economical, social and political. These aspects do not have to be covered in detail but should be kept in mind in order to help focusing the information gathering. The areas should be analysed individually so that trends and aspects detected in each area can be compared later on in order to identify more general trends and aspects concerning the main problem. In this step it is important to keep an open mind, otherwise there is a risk that new and unforeseen aspects are disregarded. The data collection done in this step is closely connected to the work done in the Corporate Radar model.

In the fifth step, *Identify and analyse key factors,* the key factors are derived by analysing each key area using the six aspects; economical, technical, political, legal, social and geophysical. The key factors are used to clarify important factors affecting the future development of each key area. As these factors indicate important aspects they are called key factors. The key factors are factors within the different key areas that will have an impact on the main problem. When the key factors for each key area have been identified they are put in more general terms in order visualize trends and important future developments for the main problem in focus.

In the sixth step, *Identify possible future developments and consequences*, the general future developments and factors identified in step five are further explored. This is done in order to find second hand effects that might not be evident when investigating each key area. This step is similar to the fourth step of the GE-model and provides a further base for the final analysis of the problem.

In the seventh step, *Define scenario logics & mapmaking,* the scenario logics are clarified and mapmaking of the future events done. This step is inspired by the fifth step of the SRI-model and the third step of the Shell-model. During this work the possible future developments are narrowed down and it is made sure that their results are consistent and coherent. In this step TIA and CIA can be used as tools to distinguish how the different key factors affect each other. The use of these methods must however be fitted to the identified key factors. If the key factors are of a nature that they can not be compared to each other, TIA and CIA can be difficult to use and can therefore be disregarded. With the mapmaking, work dynamics between key areas and key factors can be clarified, and the results and connections can be illustrated as mentioned in the Shell model.

In the eighth step*, Prediction for each key area*, an analysis for each key area with the perspective of the further developed key factors and future directions is done. This analysis is done in order to generate a base for creation of a scenario. In this step it is possible to compare different developments and future trends to each other to generate discussion regarding the different aspects.

The ninth and final step, *Write scenario(s),* is to write the scenario(s). This step is the same as the sixth step of the GE-model. In this step it is important to assure that the problem in the first step is properly addressed and that the goals that were set up are achieved. If by any chance these two aspects are not covered properly it needs to be reflected over why this situation has occurred. There is always a risk of getting sidetracked along the way, especially if the project runs over a long time and involves a lot of people. The scenario(s) should first be sketched out using brainstorming with the analysis in the eighth step as a foundation. When the initial brainstorming is done, the logic of the scenario should be assured and it should be narrowed down into a suitable length in order to make it attractive and easy to grasp.

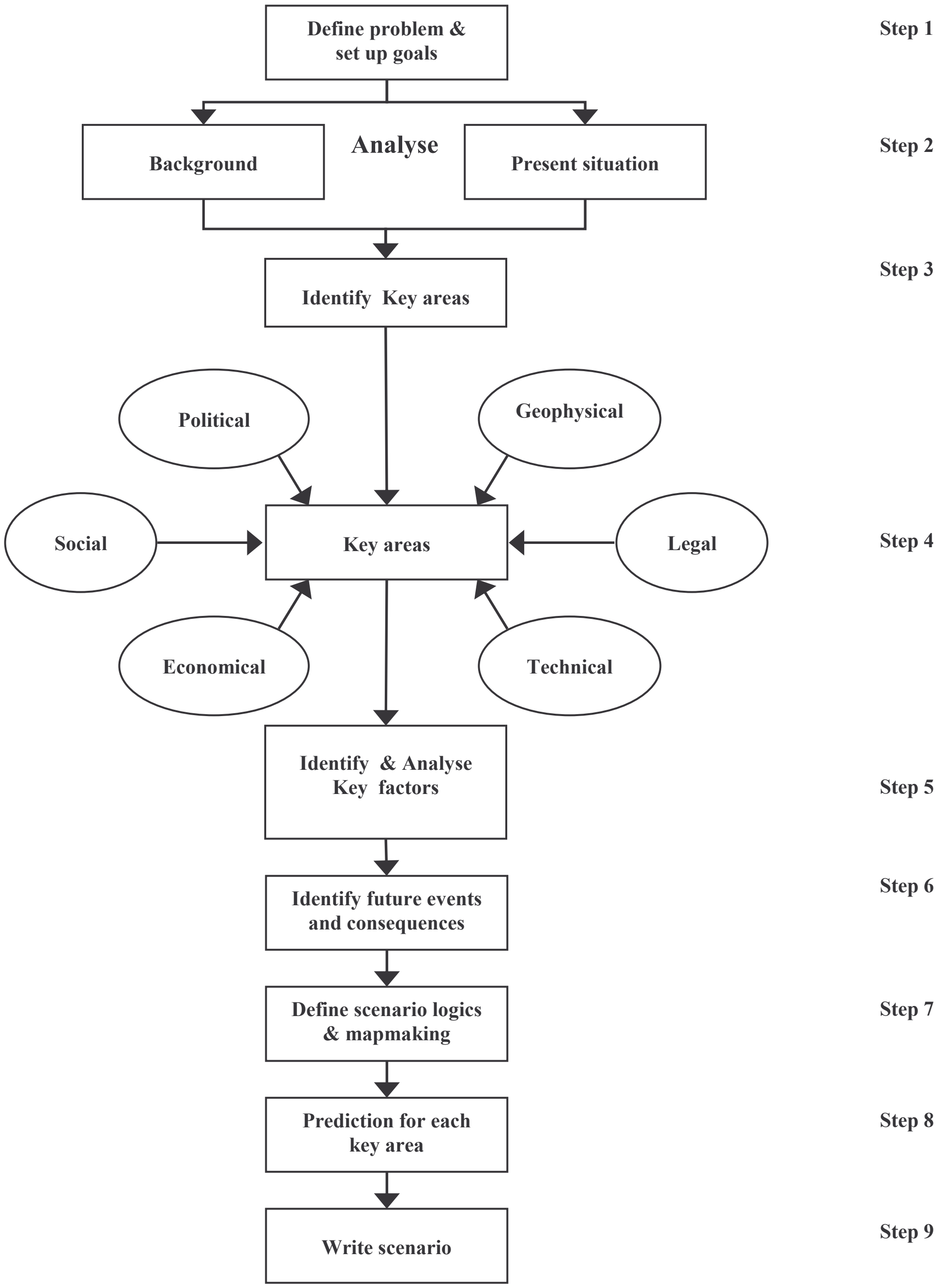


Figure 4.1: Scenario creation model used in this master thesis.

Comments

In this model no restrains are set with regard to time horizon or numbers of scenarios that should be developed. This discussion is instead directed back to the theory. In this thesis the time horizon and number of scenarios have been restricted by outside factors, see Chapter 1.

The six aspects considered in step 4 include the geophysical aspect. This aspect intends to cover not only ecosystem and natural resources, but also factors such as migration patterns, infrastructure and access to intellectual capital. This implies that it can be applied in a wide range of scenarios and not only those relating to resources.

This model is a base and structure that can be further developed in each scenario process it is applied. The model is of a general nature and can therefore be used in other areas and under other circumstances than in this master thesis. The created model will be a base for the following work in this thesis in order to define connections for oil dependency and a as a method to create a scenario.

The creation of scenarios is often an ever ongoing process. The situation and environment change constantly and it is therefore of outmost importance to keep the creation of scenarios alive and in progress. The model presented in Figure 4.1 can be seen as a circle with regard to this fact. The end is never the end, only the beginning of the next round as mentioned in the Shell model.

4.2 Model and Chapter Linkage

The steps in the scenario model, introduced in figure 4.1, can be linked to the layout of this thesis. The linkage is presented in Figure 4.2. This linkage is shown in order to facilitate the reading and interpretation of this thesis.

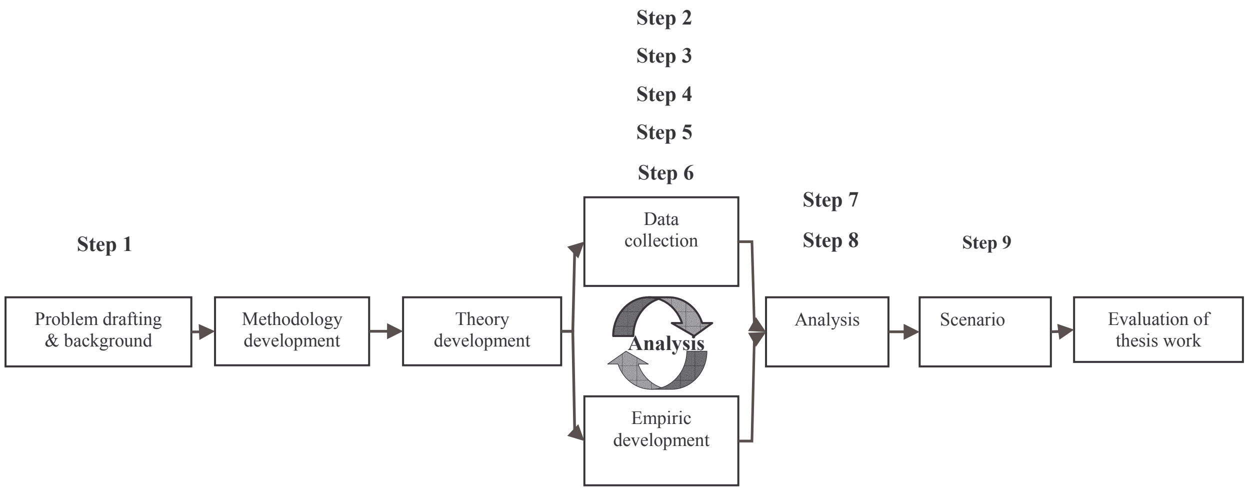


Figure 4.2: Work approach and scenario model linkage.

Step 1, *Define problem & set up goals,* from the scenario model and *Problem drafting & background* from the work approach are identical in their nature and are developed and presented in Chapter 1, *Introduction*.

Step 2, *Analyse background and present situation,* is performed in Chapter 5, *Oil as a resource*, and Chapter 6, *Macroeconomic effects*. In these chapters the background, nature and impact of oil and its price is presented. These chapters strive to generate a general understanding of oil, its history and the effects it has had on society. A basic understanding of macroeconomic aspects and connections are important in order to get a holistic view of the impact an increase in oil price can have on the society. Both Chapter 5 and 6 contain *Data collection* and *Empiric development*.

Step 3, *Identify key areas,* is performed in Chapter 7, *Identify Key Areas*. This chapter contains all parts of *Data collection, Empiric development* and *Analysis* as it tries to map out and present the areas where oil is consumed. Instead of observing the effects of the oil price on an aggregated level as in Chapter 6, Macroeconomic effects, this chapter tries to identify the different sectors in the society where the oil price is likely to have an impact. These areas are then titled Key Areas and are the areas covered in the following three chapters.

Step 4, *Key areas,* is performed in Chapter 8 – 10. In these chapters information concerning the different Key Areas is presented. These chapters give a general picture of how oil is used within the different sectors. They also go into how the different sectors are affected as well as their possibilities to respond towards the increase in oil price. First hand as well as second hand effects are taken into account. The data is collected while keeping the six aspects presented in Step 4 in mind. These three chapters are of *Data collection* and of *Empiric development* nature.

Step 5, *Identify and analyse key factors,* is performed in Chapter 11, *Identify and Analyse Key Factors*. In this chapter the key factors in each key area is defined by analysing the data presented in the key areas. The information is analysed using the six aspects presented in Step 4. In this chapter the different ways in which the sectors can come to tackle the increase in oil price are identified. The key factors are generalized and two main directions identified. This chapter only contains *Analysis*.

Step 6, *Identify possible future developments and consequences,* is performed in Chapter 12, *Oil replacing energy sources*, and Chapter 13, *Efficiency*. In these chapters the two main directions are further investigated in order to provide more insight in these areas. These chapters contain *Data collection, Empiric development* and also some data visualization as a few calculations are presented. These calculations are very general in the nature and only used to visualize relationships. They should only be interpreted as theoretical examples presented to generate discussions and increase the understanding of critical issues.

Step 7, *Define scenario logics & mapmaking,* and **Step 8,** *Prediction for each key area*, are performed in Chapter 14, *Analysis*. In this chapter only *Analysis* is carried out as key areas and key factors are combined and discussed. This chapter operates as a summation of all the work done and tries to find answers to the questions stated in Chapter 1. In this step neither the TIA nor CIA method is used as the nature of the key factors do not allow for these tools to be used. Instead brainstorming was used as a creative tool.

Step 9, *Write scenario(s),* is performed in the creation of Chapter 15, *Scenario*. The scenario is based on the analysis performed in Chapter 14. This scenario only pictures one of an infinite amount of possible futures and shall therefore not be regarded as an absolute truth but rather a discussion. The aspects and possible events mentioned in the scenario works toward presenting some major movements and effects and do not intend to cover every aspect mentioned in previous chapters.

4.3 Model and Chapter Visualization

In order to visualize the connection between the model and the chapters, a graphic presentation of the scenario model will be used, see Figure 4.3. The grey area will indicate to which part in the model the chapter is connected. A shaded area represents a part that will be discussed in the chapters following the current chapter. The figure will be shown in chapter 7, key areas, 11, key factors, and 14, analysis as they are the connection of the different parts in the thesis. Figure 4.3 exemplifies this graphic presentation regarding Chapter 5 and 6 as they cover Step 2 and are the next following two chapters.

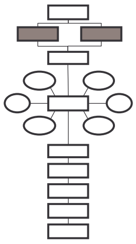


Figure 4.3: Model visualization.

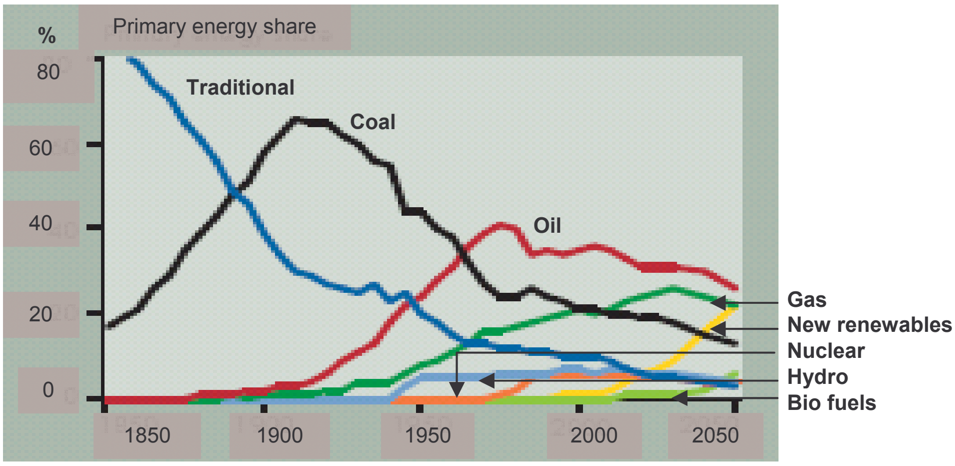
5 Oil as a Resource

In this chapter oil as a resource is discussed. The development of oil consumption and the connection with economical development is visualized. Circumstances concerning supply and price on oil are briefly presented.

To be able to understand the function oil serves in society this chapter goes into the development of oil-usage and how this can affect society. With the wide use of oil in many different applications an increased oil price can affect the global economy. Earlier price hikes have had substantial impact on the economy and have therefore somewhat influenced the continued use which is briefly touched upon in this chapter. There are several factors affecting the price on oil which have contributed to the sometimes turbulent history, this is covered in the last section of this chapter.

5.1 Development of Oil Usage

Before industrialisation the main energy sources were renewable, such as wood, see Graph 5.1. Along with industrialisation coal took a greater part as energy source. Following in the tracks of the coal utilisation came the discovery of oil, the black gold.



Graph 5.1: Energy transition,% of primary energy share.[84]

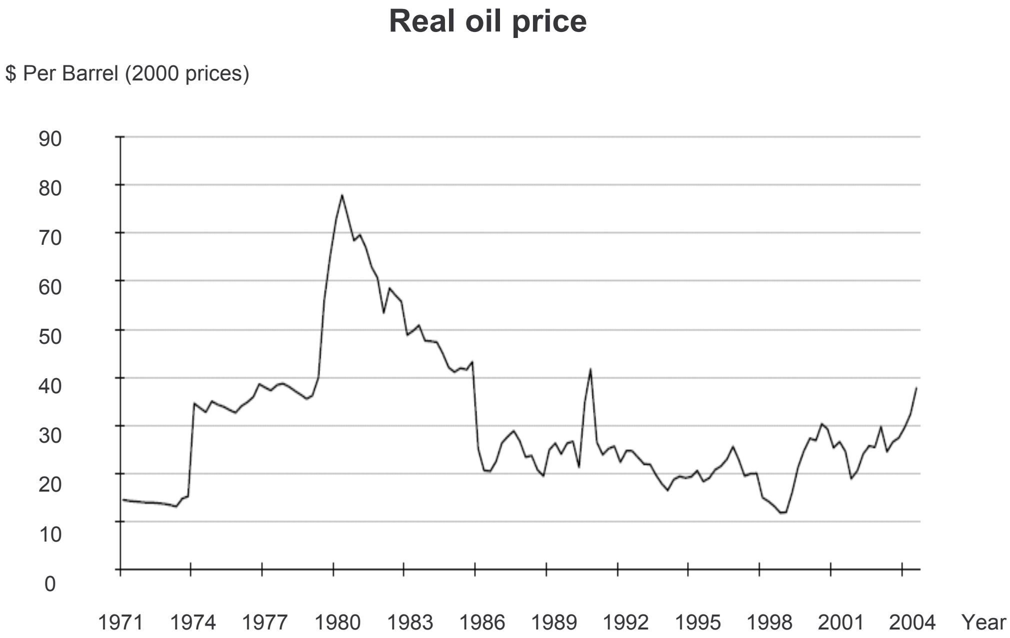
Along with the discovery of oil there was no need to dig mines since the oil practically just flowed from the ground. The cheap energy led to a rapid growth of industry, transport and trade in the aftermath of the Second World War. With the new found benefits of oil agriculture became more efficient. From now on farming was mechanised and the petroleum based pesticides and synthetic nutrients was used, resulting in more efficient farming and larger crops. This newfound energy led to a rapid expansion of financial capital. Confident in "tomorrow's expansion" the banks lent more money than they had in deposit. The beliefs in the oil based energy helped the empires to grow based on money and trade.[85]

5.2 Correlation of Oil and Economic Development

In 1973 and 1979 the world experienced two major oil crises, see Graph 5.2. The crisis in 1973 was a result of the OPEC oil embargo and in 1979 it was the Iranian oil cut-off due to

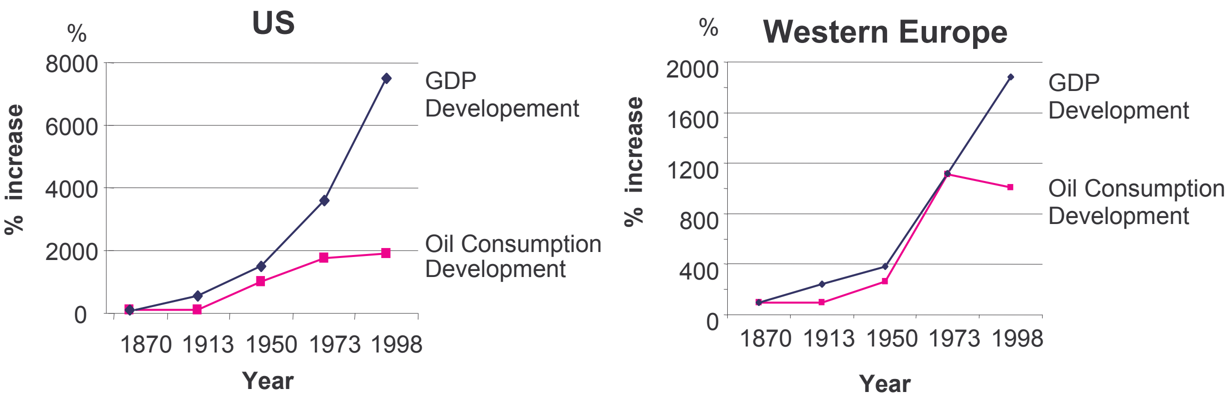
[84] *Energy Needs, Choices and Possibilities Scenarios to 2050.* (2001)
[85] Cambell, C. Brussel conference. (2006)

the Iranian revolution. The characteristics of these oil crises and the associated high oil price differs from the situation experienced today.[86]



Graph 5.2: Quarterly Brent crude oil prices deflated by US consumer price index.[87]

In the 70's the increase in price was abrupt and thought to last only for a limited time until returning to a more normal state. The effects of past high prices on oil have been economical difficulties and recession. As can be seen in Graph 5.3 the oil consumption followed the increasing GDP of Western Europe and USA from the 1950s until the 1970s. Along with the crises in the 70s came an increased awareness that the modern economy had become closely linked to oil usage.[88] With this in mind most countries tried to work towards a reduction in oil dependency. At this time nuclear power was introduced as a source of energy and along with increase in efficiency and other methods of oil reduction, the GDP and oil consumption became somewhat less connected, see Graph 5.3[89].

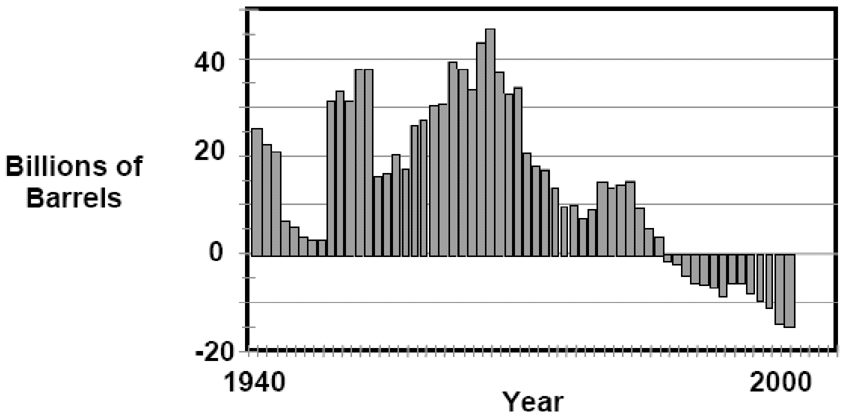


Graph 5.3: GDP and oil consumption in Western Europe and USA 1700-1998.[90,91]

[86] Hirsch, R. et al (2005)
[87] *OECD Economic Outlook No. 76. (2004)*
[88] Hirsch, R. et al. (2005)
[89] Hagström, P. (2006)
[90] *Total Petroleum Consumption*. 2006-11-02
[91] *Level and Rate of Growth of GDP: World and Major region.* 2006-11-02

5.3 Factors Affecting Price and Supply

The situation the world is facing today is different from the previously mentioned oil crises. Earlier the increase in oil price led to findings of more oil in the ground as money was invested in exploration. This time the increased price has not lead to a large increase in discoveries. This is due to the fact that oil is a limited resource and that the sources of oil most easy to retrieve, are not left last to be found. This has for the first time caused a negative net balance between addition to the world oil reserves and the annual consumption, see Graph 5.4. This is by many seen as an indicator that a peak in oil production is close.[92]



Graph 5.4: Net Difference between world oil reserves additions and consumption[93].

In the US and Europe the demand for energy and oil has been relatively steady during the last decades. However, due to the increasing economic activity and living standard in developing countries combined with the increase in world population from current 6 billion up to forecasted 9 billion in 2020[94] the demand for energy is predicted to increase, see Graph 5.5

The matter of increasing energy demand connected with a possible peak in oil production would imply an increasing gap between available oil and oil demand, resulting in shortage of oil. Even if an oil peak would not be close to happening the current limitation in production capacity still makes it difficult to keep up a surplus of oil. With limited access to production capacity and eventually even the oil itself, the current increase in oil price is likely to continue and not as before return to a "normal" state with cheap oil.[95]

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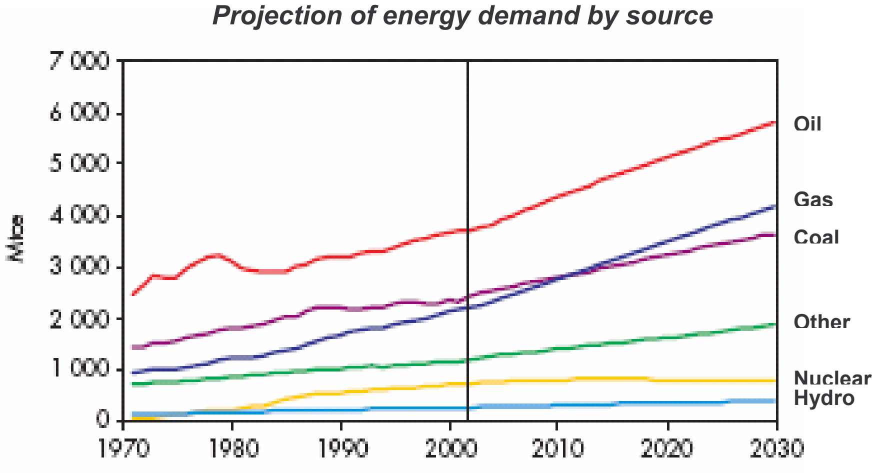
[92] Hirsch, R. et al. (2005)
[93] Ibid
[94] *World Energy Outlook 2006.* (2006)
[95] Hirsch, R. et al. (2005)



Graph 5.5: Projection of world energy demand by source.[96]

Even though the energy used per unit of goods have decreased in the Western world since the 1970s, energy and oil is still essential in many processes. The continued dependency on oil is not problem-free. Although the relative contribution of oil to economical growth has declined, securing access to cheap oil is still an important part of national economic and foreign policies. But the security of supply and price is not guaranteed which is causing worries in the world.[97] A selection of factors affecting the supply and price on oil are:

- the sources of oil are largely located in regions that are not controlled by the western world[98]
- the lack of transparency in oil producing companies and countries generates speculations on level of supply[99]
- oil is used as a means of control between countries and governments[100]
- there is a growing demand for energy in emerging economies[101]
- oil is a limited resource close to a peak[102]
- production capacity is limited and can not meet the growing demand[103]
- growing environmental concern adds worries towards the use of oil[104].

All these factors of concern add to the problem of oil dependency. Speculation on how much oil is actually left in the ground and available for production, how the countries with the resources manage their affairs and how the use of oil affects the environment work along with price development and the willingness to invest in production capacity and alternative solutions all affect the attitude towards oil.

[96] *World Energy Outlook* 2006. (2006)
[97] Van der Linde, C. et al. (2005)
[98] Ibid
[99] Van Geuns, L. Brussel conference. (2006)
[100] Ibid
[101] Capros, P. Brussel conference (2006)
[102] Cambell, C. Brussel conference (2006)
[103] *High oil prices- new opportunities for energy and environmental technologies*. 2006-09-25
[104] Loughhead, J. Brussel conference (2006)

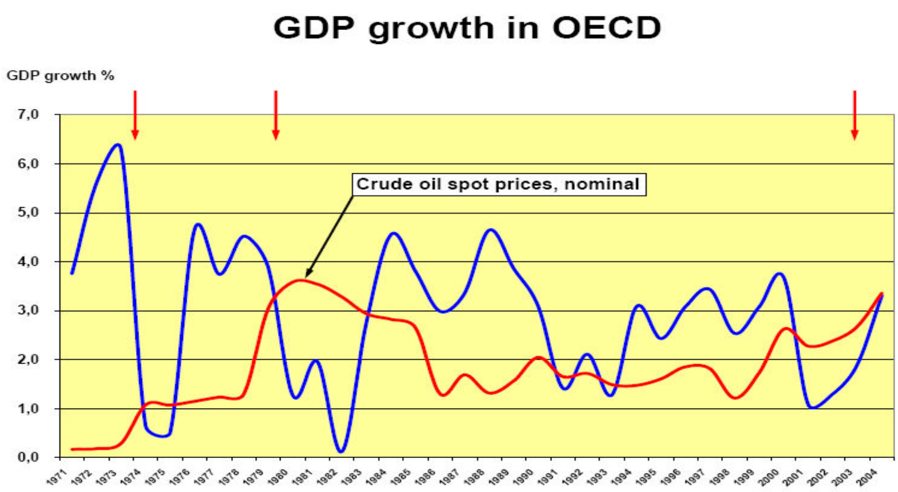
6 Macroeconomic Effects

In this chapter the macroeconomic effects of a higher oil price are discussed. The different factors that can affect the extent of the impact, as well as the possible impacts on the economy, are addressed. The difference in former price hikes in the 1970s compared to the recent ones is discussed.

A higher oil price affects many different areas within a society. It might result in a change of nation's GDP and/or inflation. According to the IEA a higher oil price contributed to the global economic downturn in 2000 – 2001 and was dampening the economic upturn coming afterwards. A high oil price can contribute to high levels of unemployment and budget-deficit problems.[105] Even though the OECD countries have decreased their oil consumption and reduced their oil intensity, they still are vulnerable to oil price increases[106]. These factors as well as impact of a higher price on oil on the society today are covered in this chapter.

6.1 Theoretical Relationship between Price on Oil and GDP

Research over the years has been trying to identify the relationship between oil price and economic activity. The historical development of GDP and the oil price is shown in Graph 6.1. The interest for this started after the major oil shocks in the 1970s. Some research has shown that the economic activity is linearly linked to the oil price, and some show that it is only linked when the price goes up but not down. Some economists claim that the reason for a higher oil price to have a general negative effect on the economy is due to monetary policies and might therefore be avoided if no new monetary policies are issued because of an increase in oil price.[107]



Graph 6.1: GDP growth in OECD compared to the oil price.[108]

Different macroeconomic models can be used to try to assess the influence a higher oil price has on the economy. The models are based on different ratios for different areas. These models do not go into any depth in any specific areas since it is easier to make predictions on an aggregated level. On an aggregate level the trade can appear homogenous even if there are

[105] *Analysis of the Impact of High Oil Prices on the Global Economy* (2004)
[106] Ibid
[107] Hunt, B. Et al. (2001)
[108] Willkrans, R. (2006)

big changes within the trade.[109] Factors considered in different macroeconomic models are for example core inflation, currency relationship, wages, unemployment and reliance on oil[110]. In general it is well understood how a higher oil price affects the economy, but the magnitude of it is more uncertain[111]. This results in that the simulations that are made with these models can be more illustrative about the scale of effects instead of a precise prediction since the accuracy for example can differ depending on how much the oil price increases.[112]

6.2 Impact due to Higher Oil Price

There can be several impacts on a country's or region's economy due to a higher oil price. The higher the increase and the more sudden it is, the more substantial are the consequences[113]. Five major consequences that have been noted during previous oil shocks seem particularly significant during the first years after an oil shock. These consequences may influence GDP and inflation and are[114]:

- *Transfer of income*: An increased oil price leads to a transfer of income from oil-importing countries to oil-exporting countries. This is since oil-importing countries increase their spending on oil more than the oil-exporting countries increase their demand on other imported goods.
- *Reduction of non-oil output*: Higher prices on raw material can in the short run reduce the output of non-oil goods since the flexibility in for example wages might be small and thereby the profitability is low.
- *Higher prices on finished goods and services:* The unwillingness for workers and producers to lower their wages and profits might call for higher prices on finished goods and services.
- *Tighten monetary policies:* Monetary policies might be tightened if core inflation is affected by higher headline price indexes (for example consumer price index, CPI). Higher energy prices are one factor affecting headline price indexes.
- *Influence on inflation:* Due to misguided monetary policies from monetary authorities their credibility might be worsened and inflation might be affected.

Global demand for goods and services will most likely be reduced after an oil price increase and thereby decrease global GDP. Depending on how the oil-exporting countries spend their money, the effect of a higher oil price can change. If the money is spent on imported goods and services the reduction in global GDP will be less. If it on the other hand is used for building up reserves and reducing debts, the impact on the global economy is bigger.[115]

In general workers' nominal wages can easily be shifted upwards but are very hard to shift downwards. This can somewhat explain why changes in economic activity are larger for an oil price increase than for an oil price decrease. Monetary policies might also have played a role in this.[116] Jeff Rubin (2005) claims in the article "Not just a spike" that due to the low-wage economies this one-way-wage development might not be certain anymore. He states

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[109] Hjalmarsson, L. 2006-10-18
[110] Hunt, B. et al. (2001)
[111] *Analysis of the Impact of High Oil Prices on the Global Economy* (2004)
[112] Hunt, B. et al. (2001)
[113] *Analysis of the Impact of High Oil Prices on the Global Economy* (2004)
[114] Hunt, B. et al. (2001)
[115] *Analysis of the Impact of High Oil Prices on the Global Economy* (2004)
[116] Hunt, B. et al. (2001)

that with an increased oil price the North American wages have to be lowered to meet the competition from other countries since it is easier to shift over businesses to other countries today. This lowering of wages however results in a decrease in purchasing power for the workers.[117]

The value of the dollar against different currencies can further increase or decrease the effects a higher nominal oil price can have on the economy. The consequences from the increase in price experienced between 2002 and 2004 were partly dampened in the OECD countries due to the decreased value of the dollar.[118]

There are also impacts on the microeconomic level when the price on oil increases. An increased incentive is created to reduce consumption and use other alternatives. This can have positive economical effects on countries with alternative resources such as coal.[119]

6.2.1 Factors Affecting the Extent of Impact

Oil price shocks can have considerably different affects depending on the country. Oil-importing countries are more vulnerable than oil-exporting countries. To which extent a country is a net importer and their level of oil intensity affect the degree of the consequences. End-users ability to switch away from oil also affects the level of the consequences.[120]

In macroeconomic models the import and export elasticity are the most difficult factors to estimate. The elasticity estimations are one of the main factors that determine how much something will influence an economy. If an economy is flexible it can handle shocks better than if it is inflexible. This will imply higher or lower costs. An inflexible economy will experience higher costs, and flexible economy lower costs. The US handles shocks more easily since they are more flexible, especially when it comes to the labour market. The European countries are more inflexible and can not handle shocks as well. But Europe is better prepared today compared to the 1970s.[121] This flexibility, resulting in the variation in impact on different countries, is often due to the difference in the wage/price connection. The Euro area has in the IMF model a considerably greater responsiveness of expected inflation to oil price changes than for example the US. The US has instead a weak responsiveness of expected inflation but a higher degree of resistance to real income declines.[122]

Oil-importing developing countries are generally more affected by an increased oil price than developed countries. This is partly because they are dependant on imported oil to a larger extent, the energy is used less efficiently and it is harder for them to handle the financial disorder. For one unit of economic output developing countries use on average more than twice the amount of oil used in OECD countries.[123]

The relationship between the price on oil and other energy sources used for the same applications, also affects the consequences of a higher oil price. The natural gas price is often correlated with the oil price which makes it relevant if a country is very gas intensive. The models used for assessing the impact of a higher oil price do not in general take a direct

[117] Rubin, J. (2005)
[118] *Analysis of the Impact of High Oil Prices on the Global* Economy (2004)
[119] McKibbin, W. Stoeckel, A. (2004)
[120] *Analysis of the Impact of High Oil Prices on the Global Economy* (2004)
[121] Hjalmarsson, L. 2006-10-18
[122] Hunt, B. Et al. (2001)
[123] *Analysis of the Impact of High Oil Prices on the Global Economy* (2004)

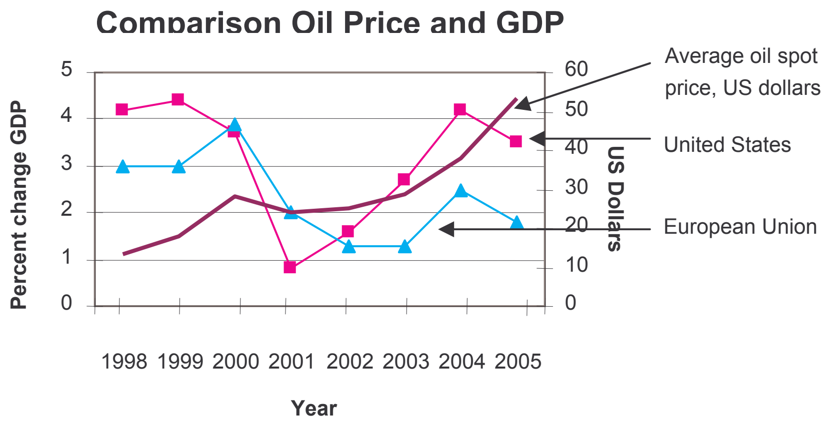
increased price on these resources into account. If it was accounted for the impact would be larger.[124]

6.2.2 Influence on GDP and Inflation

With an increased oil price domestic consumption and investments declines and the average rate of unemployment goes up. Unless the real wages are adjusted downwards this unemployment will sustain and might raise even more. These factors will in turn affect the country's GDP and inflation. The net effect on the global economy is negative after an increase in oil price.[125]

In 2004 IEA analysed how the world economy would be affected by a sustained increased oil price from $25 to $35/barrel. The result from this analysis showed that since the Euro countries are greatly dependant on oil imports, they would experience a larger short term impact than the US. GDP was expected to drop by 0,5% and inflation to rise 0,5%. The US would only experience a 0,3% drop in GDP since they have a larger share of domestic oil production. In general, an increase in unemployment will be the result from a higher oil price, especially in short term. As global trade in non-oil goods and services recover in the following three years the losses in economical activity start to diminish. This means that this kind of increase in oil price has more of a short term impact than long term.[126]

Graph 6.2 shows the actual development of the oil price compared to GDP in US and the EU between 1998 and 2005. The continued rise in oil price after 2003 was followed by a declined GDP in both the US and within the EU between 2004 and 2005 as the IEA report indicated. The decline in GDP was however larger than predicted but so was also the rise in oil price.



Graph 6.2: Oil price compared to GDP, constant prices, annual percent change.[127]

An increase in oil price can affect the CPI. When a 50% increase in oil price was modelled to examine the impact on CPI it was shown that CPI inflation in the U.S. and the Euro area rose by 1,3 percentage points and the U.K. by 0,6 percentage points. The average global effect was 0,9 percentage points.[128] Due to the increased competition in especially wholesale and retail markets, the latest increase in oil price has resulted in decreased CPI. This indicates eroded profits in the industry. CPI fell in 2003 in many countries, for example in the US from 2,4% to 1,9% and in the Euro zone from 2,3% to 2,0%.[129]

[124] *Analysis of the Impact of High Oil Prices on the Global Economy.* (2004)
[125] Ibid
[126] Ibid
[127] *World Economic Outlook Database*. 2006-11-26
[128] Hunt, B. Et al. (2001)
[129] *Analysis of the Impact of High Oil Prices on the Global Economy.* (2004)

Oil-exporting countries experience a growth in GDP the year after an increased oil price. Later, as there is a declined export on non-oil related goods to oil-importing countries, the growth in GDP is dampened. Although, an increased oil price has in general always had a negative net effect on the world economy. This is because the increase in economic growth in the oil-exporting countries has never been larger than the decrease in economic growth in the oil-importing countries.[130]

6.3 Oil Price Hike Comparison[131]

The oil price increase between 2003 and 2005 has affected the global economy but not as much as can be expected. GDP and CPI have in many countries been negatively impacted but then recovered again. This difference in impact compared to earlier oil price shocks is probably a result of many different factors.

One factor is the different nature of the shock. The increase has taken longer time compared to the other price shocks. The oil price hikes in 1973-74, 79-80 and in 1990 were associated with armed conflicts in the Middle East while the rises in 1999-2000 and 2004-2005 were primarily based on higher demand for oil. The European and the US economy's are less dependant on oil today compared to the 1970s which also contributes to the reduction in impact.

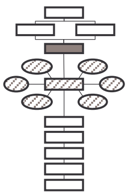
Another factor can be that the economies are better able to handle an oil price increase. In the 1970s the demand for higher wages due to the higher price affected the overall economy. Today the labour market is more flexible resulting in a smaller impact. The ability to issue functioning monetary policies by governments is also an impact reducing factor. These two factors indicate that the western economies are better prepared today than they were during the earlier oil price hikes.

[130] *Analysis of the Impact of High Oil Prices on the Global* Economy (2004)
[131] Walton, D. (2006)

7 Identify Key Areas

In this chapter the key areas are defined. These key areas are the base for the coming chapters. The key areas are chosen so that they cover the main areas of the thesis's problem.

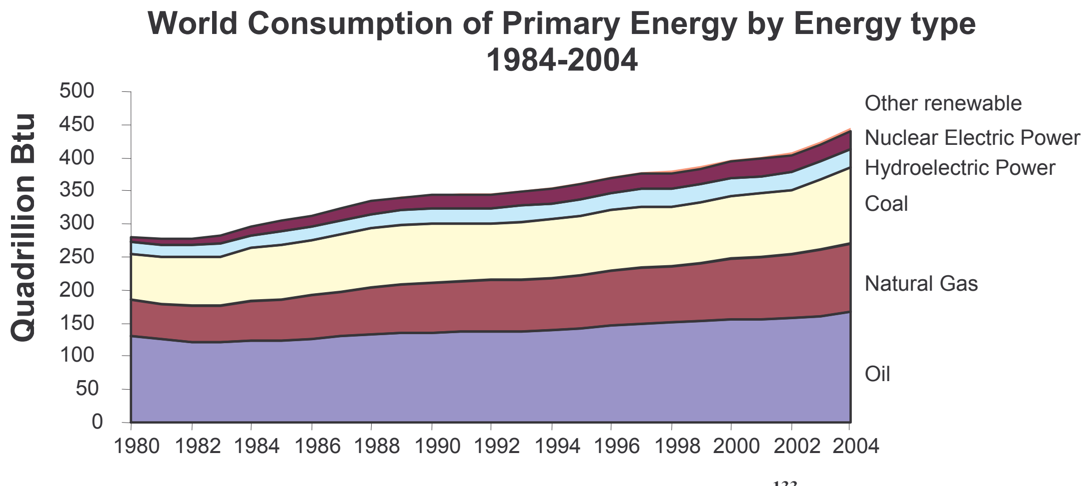
The identification of key areas represents the third step in the scenario creation model as can be seen in the figure on the right hand side. This step is followed by the further exploration of each key area which will be presented in Chapter 8-10. In this exploration six main aspects are considered, as mentioned in Chapter 4.



In Chapter 6, Macroeconomic effects, the effects of a high oil price on an aggregated level are described. These effects are caused by the impact a high oil price has on different areas in society. The areas initially affected are those where oil is directly consumed as a base product. These areas are separated by their individual way of consuming oil. Due to the difference between the areas, each area will be affected in its own way. In this chapter these areas, key areas, will be identified. In the next following three chapters these key areas will be further investigated. Those chapters will be aimed at identifying how the different areas are affected by the increase in oil price as well as their possibilities to respond towards this increase. These different ways of responding will eventually result in second hand effects also being consequences of an increase in oil price.

7.1 Oil Consumption

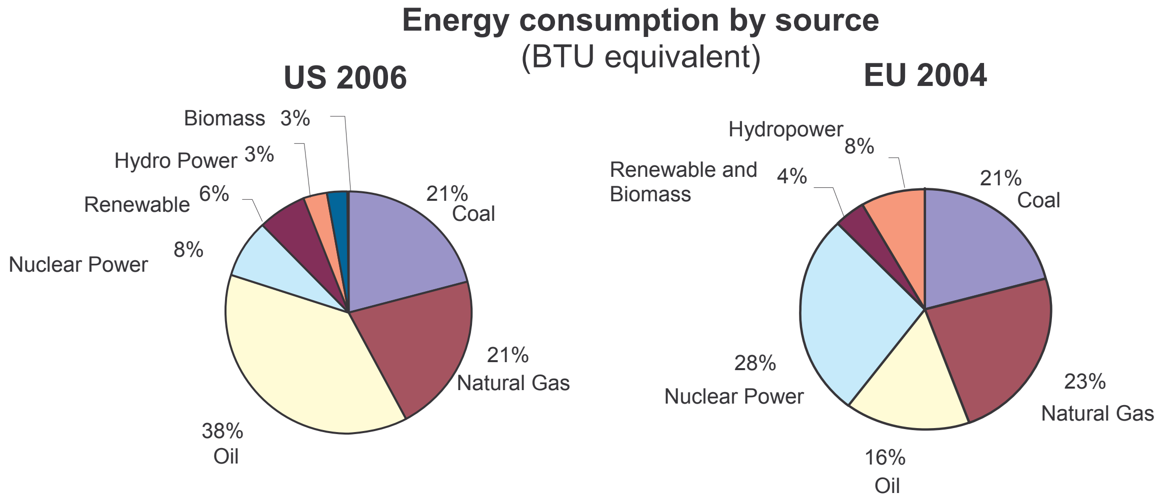
The total world consumption of energy has been in a steady increase since before 1980, see Graph 7.1. In 2004 the global oil consumption equalled 167,5 quadrillion Btu/year, the equivalent of 28,5 billion barrels/year or 4503 billion litres/year.[132]



Graph 7.1: World consumption of Primary Energy by Quadrillion BTU[133].

In the US and the EU coal, natural gas and oil are the most commonly used energy sources just as in the world in general. These fossil fuels represents about 80% of the energy consumed in the US and 60% of the energy consumed in the EU, see Graph 7.2. The US is more dependent on oil than the EU which instead uses a larger percentage of nuclear power. Both regions have about 12% of hydropower and other renewable sources of energy.

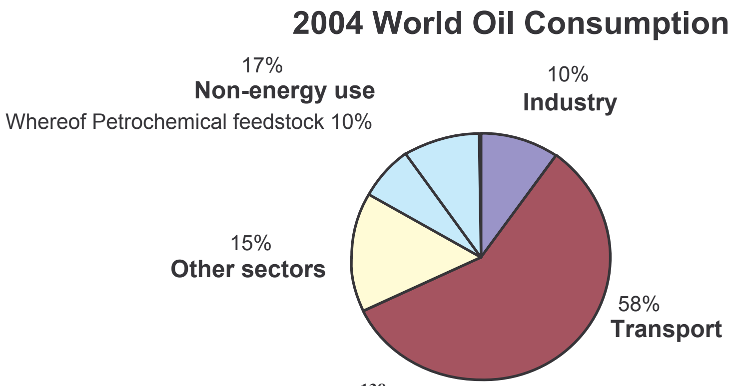
[132] *Energy consumption by source* 2006-11-22
[133] Ibid



Graph 7.2: Energy consumption by source in the USA[134] and EU[135].

7.2 Key Areas in Oil Utilization[136]

The consumed energy which derives from oil can be divided between different sectors in the society. The distribution of oil between the different sectors is shown in Graph 7.3. This distribution has been calculated from figures used by IEA in their Key World Energy Statistics 2003-2004.[137] The oil consuming sectors identified in Graph 7.3 are Transport, Non-energy use, Industry and Other sectors. The Transport sector includes all fuels for transport except international marine bunkers. It includes transport in the industry sector and covers road, railway, aviation, domestic aviation, fuels used for transport of materials by pipeline and non-specified transport. Non-energy use covers use of other petroleum products such as white spirit, paraffin waxes, lubricants, bitumen and other products as well as oil used as petrochemical feedstock. In the Industry sector oil is used to generate heat and electricity. Examples of industries included are Iron and steel industry, Paper, pulp and print industries as well as Textile and leather industries. Other sectors cover agriculture and forestry, fishing, residential, commercial and public services and non-specified consumption.



Graph 7.3: World Oil Consumption 2004[138]

[134] *USA energy consumption by source*. 2006-11-27
[135] *Selected country groups*. 2006-11-27
[136] *Key World Energy Statistics.* (2005)
[137] Between the statistics from 2003 and 2004 IEA changed their way of reporting from stating petrochemical feedstock as a part of Industry to instead reporting it as a part of Non-energy use. By using this transformation the approximate use of oil as petrochemical feedstock could be calculated. Petrochemical feedstock is used principally for the manufacture of chemicals, synthetic rubber and a variety of plastics.
[138] *Key World Energy Statistics.* (2005)

In the identified sectors the oil is used in mainly two different manners; as feedstock or as energy source. Oil is used as feedstock in the sector for non-energy use. When the oil is used as an energy source it can be even further divided into transport fuel as well as heat and electricity generation. Transport fuel is used in the Transport sector and heat and electricity generation is the use in the Industry sector as well as in Other sectors. This leads to the possible definition of three areas of oil consumption. These areas are *Transport*, *Non-energy use* as well as *Heat and Electricity generation,* which includes all oil consuming sectors in society. In the following part of this master thesis these three areas will be used as key areas since each of them represent a unique way of using oil and as a consequence these areas will be affected in different ways by an increase in oil price.

8 Transport

In this chapter the key area Transport is presented. The effect an increased oil price has on the development of this sector is covered by looking at the society's dependency on transports, means of control for transports, increased efficiency and the most commonly considered alternative fuels. A few different industries' dependence on transports and the developments in this field are referred to.

The transport industry is currently the largest consumer of oil products, around 97% of the energy used in transports is based on crude oil[139], which makes it vulnerable to increases in the oil price. Along with globalisation the transportation of products all across the world has increased and the global society is dependant on cheap transports. With higher oil price the interest for improved efficiency and alternative fuels have increased and research is done on these areas. There are alternatives to oil based fuels on the market today, but many factors have to be considered before a major shift can be realised. Depending on which road for alternative fuel is chosen there might need to be major changes in the infrastructure.

8.1 Transportation Modes

The two main refined petroleum products used as transport fuel in Europe and the US are gasoline and diesel[140]. The consumption of gasoline and diesel in United States, Europe and total consumption in the world 2003 is showed in Table 8.1. There is a clear difference in what type of fuel is used in Europe and in the US. Gasoline is used to a much larger extent than diesel in the US and vice versa for Europe.

Table 8.1: Consumption of refined petroleum products 2003.[141, 142]

Fuel consumption

(million litre/year)	Motor Gasoline	Distillate Fuel Oil
United States	518 471	227 878
Europe	172 619	354 273
World Total	1 184 393	1 252 415

The difference in consumption of gasoline and diesel between Europe and the US can to some extent be explained by the different distribution of modes of transport used, see Table 8.2. For passenger transport, car and airplane were the most common modes in the US, while bus/coach and rail were as common in EU 25 as air. The amount of person kilometres, pkm, by car is almost double in the US compared to EU 25.[143]

139 *Volvo Future Fuels and Strategy Proposal.* (2004)
140 *Petroleum Consumption by Type of Refined Petroleum Product*. 2006-11-14
141 Ibid
142 In this example motor gasoline equals gasoline and distillate fuel oil includes diesel.
143 *Petroleum Consumption by Type of Refined Petroleum Product*. 2006-11-14

Table 8.2: Passenger and freight transport, figures from 2003 and 2004.[144]

Transport mode utilisation

	EU 25	USA
	Passenger transport (billion pkm)	
Passenger car	4444	7008
Bus/ coach	483	226
Railway	345	22
Tram + metro	72	18
Waterborne	35	1
Air (domestic / intra-EU 25)	449	813
	Freight transport (billion tkm)	
Road	1684	1845
Rail	379	2341
Inland waterways	130	476
Oil pipeline	124	861
Sea (domestic / intra-EU 25)	1484	424

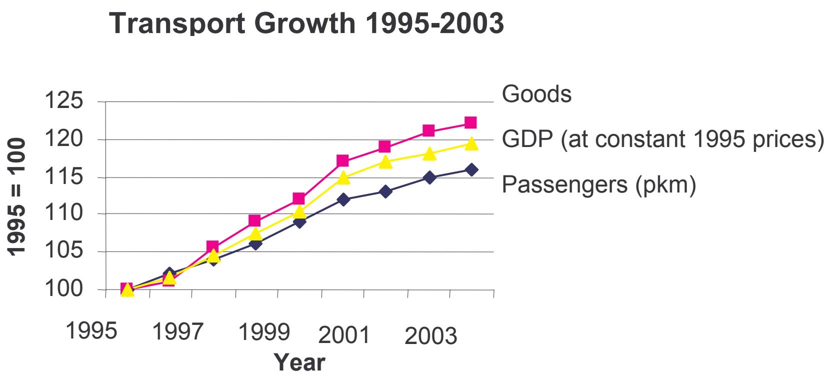
For freight transport the distribution of common transport modes is quite different. For freight transport the main modes used in the US was via rail and road, in the EU 25 the main modes were road and via sea. In the US transport via rail is mainly low value goods[145]. If only the total mass of the goods transported is considered road transports are used to a much higher extent than rail in the US[146].

In EU 25 year 2004 private households spent around 13,3% of their total expenditure on transport which was mainly private transport[147]. In the US the same figure was 11,4% year 2001[148].

8.2 Transport Dependency

Along with globalization comes an increased need for transports. This worldwide and commercial trade has increased since ideological, political and customs boundaries have changed and there have been advances in information and communication technology.[149] A correlation between GDP development and increase in transport in Europe, covering both goods transport and passenger transport, can be seen in Graph 8.1.

144 *Energy & Transport in Figures 2005*. (2005)
145 *Table 2-2. Total Freight Shipments: 2002.* 2006-11-24
146 Ibid
147 *Energy & Transport in Figures 2005*. (2005)
148 *Table 3-12: Personal Expenditures by Category.* 2006-11-24
149 *The first trend: Globalization of production and commercial trade.* 2006-11-08



Graph 8.1: Transport growth EU 25. [150]

The increased globalization has resulted in that companies have easier access to the expertise, workers and materials they need as well as the customers and the suppliers, but they are also experiencing competition from all over the globe. As a consequence of the increased possibility for transport there is, and have been, a trend of increased outsourcing and offshoring. An example of this increased use of transports taking place all over the world is illustrated in Figure 8.1.[151]

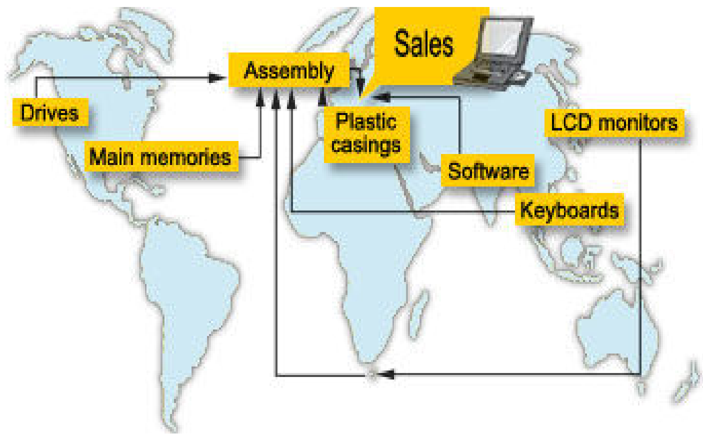


Figure 8.1: An example of a laptop production.[152]

As the purchaser has access to products from all over the world and the competition between companies increases, other key values than just low costs have to be added in order to become market leader. The competition changes from being cost- and price-based to becoming time-based instead. Companies, who are able to introduce new technology or products on the market first and react quickly to customers' needs, can enjoy big advantages over the competitors.[153] This puts higher demands on transports. With the increased use of transports there is also an increased awareness of the environment and how transports affect it. Optimization of distribution and combined transports among other measurements are developed for more sustainable management.[154]

[150] *Energy & Transport in Figures 2005.* (2005)
[151] *The first trend: Globalization of production and commercial trade.* 2006-11-08
[152] Ibid
[153] *The third trend: An "on-demand" world and the accelerated pace of the "time-is-money" society*. 2006-11-14
[154] *The forth trend: Growing environmental sensitivity*. 2006-11-14

The increase in oil price has affected the costs for transports. Many transport companies have added a fuel surcharge on every transport to make up for their increased costs. This extra charge follows the price development for fuel.[155, 156]

8.3 Reducing Fuel Consumption through Efficiency

If the price on oil increases substantially the consequences of this can be reduced by increasing the efficiency in the use of transport fuel. There are many different ways of reducing the fuel consumption in transports. Technical ways can include improved engine efficiency, a reduction of idling, hybrid technology and improved transmission efficiency[157]. There are also other ways of reducing the fuel consumption, as a more efficient transport system and an improved driving technique[158].

Currently the average fuel consumption for new cars in Europe is around 6,5 l/ 100 km while it ends up around 12,5 l/ 100 km in the US[159]. Two US studies indicate that within 10 – 15 years it is possible for the US to reduce the average fuel consumption for cars and light trucks, to between 6 – 7 l/ 100 km with conventional technologies (no hybrids), in a cost-efficient manner[160]. This is a reduction of about 45%. In the EU the potential for improved efficiency in transports is considered to be 26% by 2020[161].

Improved efficiency through technical solutions can make a big difference in for example long-haul trucks. Studies in the US has shown that for example by improving aerodynamics, engines, transmissions and auxiliary systems a 39% reduction in fuel consumption can be obtained. By using new technology for reducing idling an 80% reduction in fuel use during idling can be reached.[162] For short-haul trucks hybrid technology is considered a promising way of reducing fuel consumption. A reduction up to 35% is possible for traffic in populated areas. Plug-in hybrids can even further reduce the need for oil based transport fuel.[163]

Other ways of reducing the overall consumption of transport fuel can be change in behaviour and preferences, for example a transition to cars that are more fuel efficient. A transition to an increased use of public transport would also reduce the use of transport fuel[164], but this would mean a need for changed transportation pattern. Ecologic driving would not reduce the amount of transports but it does change the way of driving. The Finish Post Office educated their drivers in ecologic driving which resulted in reduced fuel consumption by 15%[165].

8.4 Means of Control for Transports

There are several different means of control concerning the transport industry such as taxes and directives concerning alternative fuels. The different means of control can for example be used to influence the overall consumption of fuels as well as the development of alternative fuels. Some means of control will be further addressed in the following section.

155 *Bränsle- och valutatillägg*. 2006-11-14
156 *Fuel Surcharge*. 2006-11-14
157 Elliott, R. et al. (2006)
158 *På väg mot ett oljefritt Sverige*. (2006)
159 Millikin, M. 2006-11-24
160 Elliott, R. et al. (2006)
161 *Saving 20% by 2020.* 2006-11-10
162 Elliott, R. et al. (2006)
163 *På väg mot ett oljefritt Sverige.* (2006)
164 Ibid
165 Eriksson, O. (2006)

8.4.1 Taxes

One of the main means of control that affect the buyer of transport fuel is taxes. Depending on where the gasoline is bought different taxes are added to the cost for the consumer. The distribution of cost for gasoline in the US is showed in Figure 8.2.

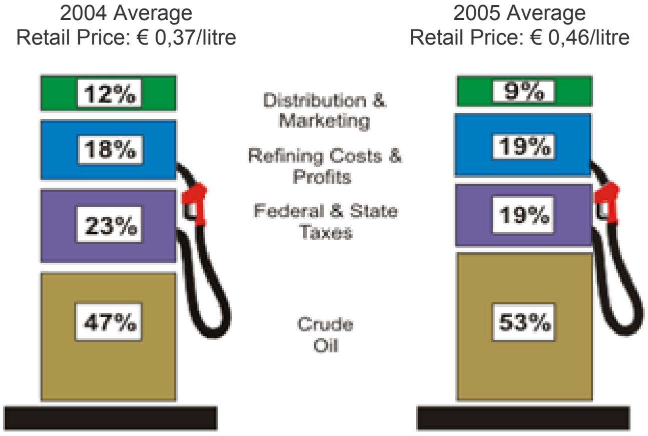


Figure 8.2: The distribution of cost for one gallon of gasoline in the US 2004 and 2005.[166], [167]

This figure shows that in general the cost for the product, crude oil plus refining cost and profit, accounts for approximately 70% of the total cost in the US.

In the EU most countries have similar methods when pricing gasoline and diesel. This means that a general conclusion can be made for basically all the EU countries if you know how the gas price is constructed in one country.[168] According to the Swedish Petroleum Institute, SPI, the distribution of cost for one litre of gasoline in Sweden is as shown in Figure 8.3.

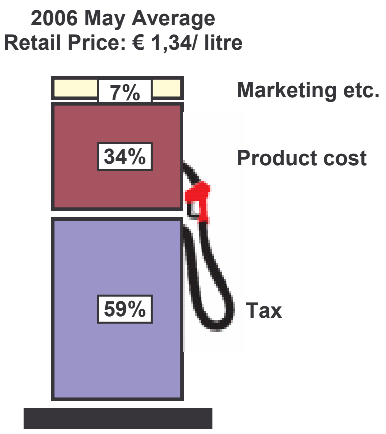
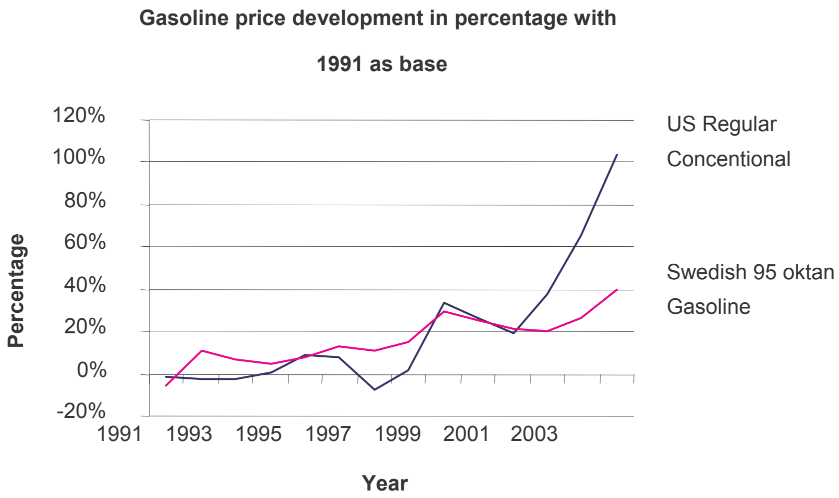


Figure 8.3: The distribution of cost for one litre of gasoline in Sweden may 2006.[169], [170]

The taxes in Sweden are divided into energy tax, CO_2 tax and VAT. VAT is the only variable tax (25% in Sweden) and otherwise the taxes are a fixed sum per litre gasoline or diesel. The figure shows that approximately 35% of the gasoline price is the cost for the product and

[166] *A primer on gasoline prices* (2006)
[167] \$ 1 = € 0,76, 2006-12-01
[168] Hjalmarsson, L. 2006-10-18
[169] *Bensinpriser, månadsvärden.* (2006-10-25)
[170] 1 SEK = € 0,11, 2006-12-01

about 60% is tax. The fixed tax ends up around € 0,55/ litre[171].[172] This means that if the US and the EU is compared, the EU has a bigger "tax cushion", which means that an increase in oil price calculated as a percentage of the total, is higher in the US than in the EU. This makes the consumers of gasoline and diesel in EU less sensitive to an increase in product cost since they are already accustomed to a high price.[173] A comparison of the development in percentage can be seen in Graph 8.2. The increase in price in percentage from 1991 to 2005 in the US is approximately 105% and in Sweden it is 40%[174].



Graph 8.2: Gasoline price development in percentage, base year 1991.[175, 176]

According to a Eurobarometer study on attitudes towards energy carried out in Europe 2006, 22% of the citizens would use their car a lot less and 31% a little less if the price on gasoline reached €2/litre. 26% on the other hand responded that they would continue to use their car just as often while the rest responded that the question was not applicable or did not know how they would react. When asked what sort of transport they would use instead a majority of them, 37%, responded that they would increase their use of public transport.[177] If the crude oil price reaches $300/barrel it would result in a gasoline price of approximately 24 SEK/litre (equivalent to € 2,64/litre[178]) in Sweden[179]. This equals an increase of approximately 215% compared to 1991 and a 118% increase compared to 2006.

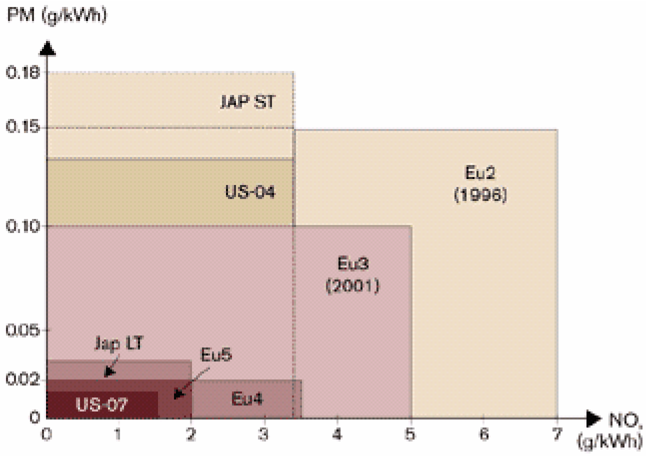
The comparison of the distribution of cost for diesel is similar to the distribution for gasoline. The energy tax for diesel in Sweden is much lower than the one for gasoline which is the main reason for the diesel price to be lower than the price on gasoline[180].

8.4.2 Emissions

Emissions from transports are regulated in most parts of the world. Emissions from fuels such as particulates, NO_x, HC and CO are regulated for diesel engines and CO, NMHC, CH_4, NO_x and particulates for gasoline engines. In Europe, the US and Japan there are already set targets

[171] 1 SEK = € 0,11, 2006-12-01
[172] *Så här byggs bensinpriset* upp. (2006-10-26)
[173] Hjalmarsson, L. 2006-10-18
[174] For real gasoline price development see Appendix 5.
[175] *Weekly Retail Gasoline and Diesel Prices.* (2006-10-27)
[176] *Bensinpriser 1981-2005 95 oktan.* (2006-10-27)
[177] *Attitudes towards Energy.* (2006)
[178] 1 SEK = € 0,11, 2006-12-01
[179] Björklund, M. 2006-12-07, see Appendix 5 for conditions
[180] Pile, C. (2006-10-26)

for future regulations as can be seen in Graph 8.3. The figure shows the current and the future regulations concerning particulates and NO_x. EU4 was set to be applied October 1st 2006 and EU5 is set for October 1st 2009.[181]



Graph 8.3: Emission legislation for heavy trucks concerning particulates and NO_x.[182]

There are also voluntary commitments when it comes to emissions from fuels. Association des Constructeurs Euopéens d'Automobiles, ACEA, made a voluntary commitment in 1998 to reduce the new car fleet average CO_2 emissions with 25% by 2008 compared to 1995 which is 140 g/km[183]. ACEA consist of 13 major European car, truck and bus manufacturers[184].

8.4.3 Targets for Alternative Fuels

The EU has been addressing the area for alternative fuels which has, among other things, resulted in a directive called "Directive 2003/30/EC" by the European Parliament and the Council on the promotion of the use of bio fuels or other renewable fuels for transport. This directive is one way of reducing the Communities' dependence on imported energy and thereby increasing the security of supply. The other aims for the Directive are to promote the use of bio fuels and other renewable fuels to meet climate change commitments and in general to promote renewable energy sources. Even though a directive is given to increase the amount of bio fuels used, other alternatives such as compressed natural gas should not be discarded and regulations concerning fuel quality, air quality and air emissions have to be followed. Targets for the amount of bio fuels or other renewable fuels placed on the market in the EU are set to 2% for December 31st 2005 and 5,75% for December 31st 2010. Starting 2006 an evaluation report shall be made each year to follow this development. The Commission Green Paper has a goal to have 20% alternative fuels in the transport sector by 2020. This is not only limited to bio fuels.[185]

The goals concerning renewable fuels for the US are set in the Energy Policy Act 2005. The goals are to have about 15 billion litres of renewable fuels in 2006 and 28,4 billion litres in 2012. In the years after 2012 the amount of renewable fuel should at least amount to the percentage that 28,4 billion litres represented in 2012.[186] 28,4 billion litres is approximately 4% of the current fuel consumption.

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[181] *Call for submission of evidence*. 2006-11-14
[182] *Cutting down exhaust ingredients*. 2006-11-14
[183] *Volvo Future Fuels and Strategy* Proposal (2004)
[184] *ACEA*. 2006-10-24
[185] *Directive 2003/30/EC.* 2006-10-26
[186] *Annual Energy Outlook 2006.* (2006)

8.5 Alternative Fuels

With a higher oil price there is a growing interest in alternative fuels for transports. Depending on which alternative is chosen the consequences will be different. Not only the price but also the increased understanding of the greenhouse effect due to greenhouse gas emissions, GHG, contributes to the interest in alternative fuels. So it is not only the economic side that has to be taken into consideration, when comparing alternatives, it is also the environmental side. The overall energy efficiency of the fuel is also important to consider in order to make sure that the fuel solution does not consume more energy during for example production than it transfers into the vehicle.

Several factors affect whether an alternative fuel is feasible or not within the timeframe of 2015. Examples of these factors are; access to and the amount of raw material, where it is located, if it can be transported to a reasonable cost to the production facilities, distribution of the fuel, if the engines have to be modified and if this is reasonable within ten years.

An aspect which also has to be taken into consideration when making predictions about the future is the constant development of engine efficiency and vehicle technology. These aspects will contribute to reduced fuel consumptions and reduced GHG emissions. There are also developments of filters for particle reductions.

A large part of the following sections in this chapter is based on the "Well-to-Wheels analysis of future automotive fuels and powertrains in the European context" later referred to as the WTW-report. The objectives and the base for that report are further explained in Appendix 2. A major part of the possible alternatives developed before 2015 is discussed below.

8.5.1 Gaseous Fuels[187]

The main problems a gas fuel faces are that the major part of the vehicle fleet is not adjusted for gas and the infrastructure for distribution and especially refuelling is not developed. The two main possible gas fuels that can be used, and which are already used to some extent, are natural gas and biogas.

Natural Gas

One option for alternative fuel is natural gas. Compressed natural gas, CNG, can be used by itself in a vehicle or in a bi-fuel vehicle combined with gasoline.

When reflecting on fuels based on natural gas the access to natural gas sources has to be taken into consideration, since they are only situated in some parts of the world and it is a non-renewable resource. The accesses to sources affect the overall cost for natural gas. If there would be a shift in source for transport fuel to natural gas, additional pipeline expansion and shipping will have to be taken into consideration when calculating the effects. The main issues and cost, however, concern the refuelling stations and not the distribution network. Some areas might have liquefied natural gas, LNG, delivered instead if they are not served by the grid. In general GHG-emissions for CNG end up in between gasoline and diesel, where gasoline emits more than diesel.

Biogas

Biogas is similar to natural gas but it is based on biological material. This means that it can be used in basically the same way as natural gas when considered as transportation fuel. Due to

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[187] *WTW-report* (2006)

this similarity with CNG and the possibility to be mixed in the same pipelines and thereby sharing the infrastructure, it has basically the same cost for infrastructure.

Biogas is the gas that comes from anaerobic fermentation of organic matter. The main components of this gas are methane and CO_2. Carbohydrates, proteins and fatty acids are a good base for biogas. Biogas is commonly produced automatically from gatherings of for example crop residues, manure and municipal waste. Biogas can fuel its own production, and since it is quite an energy intensive process this is an advantage because it is based on waste that would not be used for anything else. This in combination with that the feedstock for biogas is fossil free results in a low use of fossil energy and GHG emissions.

The cost for biogas depends, besides from the infrastructure similar to natural gas, on the shape of the feedstock and transport costs. The organic waste is usually free of charge but depending on the shape it needs different ways of processing.

8.5.2 Liquid Fuels[188]

There are several different possible ways to produce alternative liquid fuels. They can in some cases be blended in with gasoline or diesel or be used neat in the infrastructure and vehicles we have today.

In general, liquid fuels have a few advantages over gaseous fuels. When it comes to infrastructure, such as distribution and refuelling stations, it basically already exists. If the alternative is not blended but used by itself there is an increased need for infrastructure, but not as much as gaseous fuels need. The required changes to conventional fuel vehicles are less extensive than for gaseous fuels even if the alternative fuels are used neat. If alternative fuels blended with conventional fuels are used in a small percentage, no or just minor modifications are needed to the existing vehicles.

The costs in general considered for the liquid alternatives in the WTW-report are the cost of feedstock, operating cost and investment for the production plant and the credits associated with the by-products. Credits mean that if the by-product can be used in for example production of heat and electricity this energy produced should be taken away from the total energy consumption of the fuel.

Ethanol

Ethanol is presently used in several parts of the world blended in with conventional gasoline but also neat in some places. If there is more than 5% ethanol blended in with conventional gasoline some adjustment of the engine might be needed, but otherwise no effects are expected. Basically any kind of carbohydrate can be used to produce ethanol. Sugar beet, wheat, sugar cane and corn (maize) are presently the main crops used for industrial production. In Europe wheat would be the main crop for large scale production of ethanol. There is an interest in widening the sources used for producing ethanol by making it possible to use cellulose as a source and therefore a lot of research is done on the subject.

It is energy intensive to purify ethanol by distillation which affects its overall energy consumption. Depending on how this energy is produced the amount of GHG released will differ.

[188] *WTW-report.* (2006)

Bio Diesel

Bio diesel can be blended in to a level of 5% with conventional diesel fuel without affecting a standard diesel engine negatively. The main crops for producing bio-diesel in Europe are rape and sunflower. In Europe most farming areas are more favourable to rape.

The relation between diesel and bio-diesel is similar to the relation between gasoline and ethanol when it comes to possibilities for blend-ins. When it comes to energy-intensity in the manufacturing process bio-diesel is less demanding than ethanol. This is because the process is relatively simple. The GHG emissions on the other hand are higher.

Bio-diesel made of rape is called RME*,* Rapeseed Methyl Ester. When producing RME, savings up to 64% of fossil energy and 53% of the GHG emissions can be done in comparison with conventional diesel. Sunflower Methyl Ester, SME*,* needs less fertilisers and this, among other things, gives even better results.

Even though there is fossil energy savings to be made the solutions are not necessarily energy-efficient. The use of fossil energy can in most cases be greatly reduced but the needs for other energy types are greatly increased. The WTW-report therefore claims that these solutions are inefficient in the use of biomass, there can be other ways to better use it.

Synthetic Diesel (Fischer-Tropsch diesel, FTD)

Synthetic diesel can for example be made from coal, natural gas or biomass. Synthetic diesel is a product from the Fischer-Tropsch synthesis based on partial oxidation of hydrocarbons or wood. When the product is natural gas the process involves steam reforming. Impurities such as sulphur are very low when using this process.

Natural gas is mainly transported in pipelines but locations far from users of natural gas have, or are starting to convert the gas into liquid. This conversion is called gas-to-liquid, GTL*,* and is a synthetic diesel. The process has not been common in large scale for very long since the economics has not been favourable.

Synthetic diesel can also be made out of coal and the development of CCS makes the process of coal-to-liquid, CTL*,* more interesting. Not many plants for this process are used today but if CCS, further discussed in Chapter 10, is put into practice at a larger scale than today might be developed. The process of coal gasification is well known and it delivers a similar product to GTL.

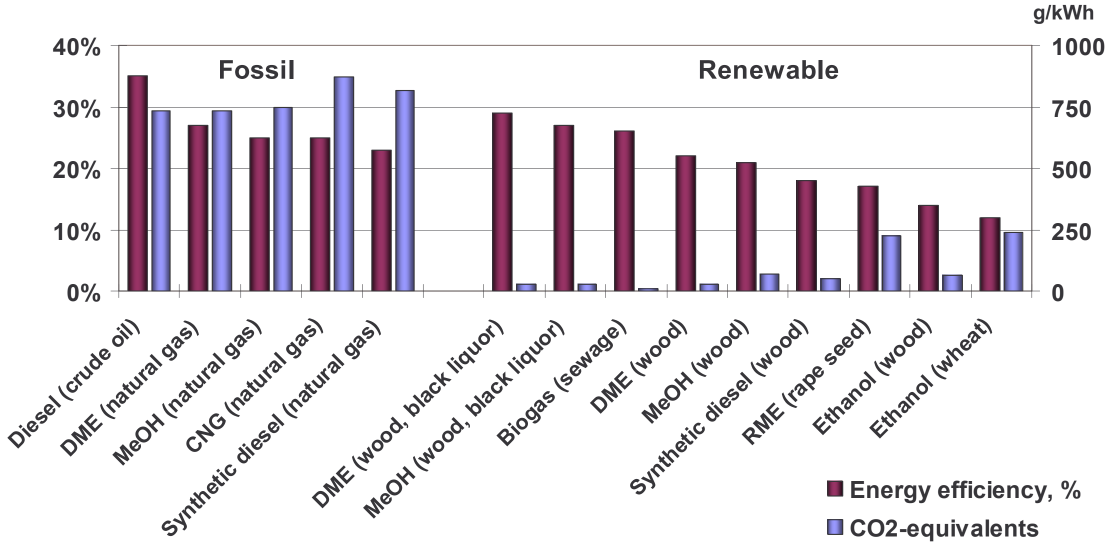
Wood gasification, biomass-to-liquid (BTL), is similar to CTL but it is very dependant on what kind of biomass is used since different problems arise for different feeds. Since Fischer-Tropsch plants are expensive and complex it is important to ensure economy of scale. Since biomass usually is a spread-out feedstock and has low energy content it can be difficult to make it financially sustainable. One of the most promising ways is using black liquor. This is a by-product from the pulp and paper industry.

DME

Di-Methyl-Ether, DME, is produced in a similar way to synthetic diesel fuel and is a direct substitute for diesel fuel. It is gaseous, but can be liquefied under moderate pressure. But since it is gaseous it does not have the general advantages like the liquid fuels. It needs adapted vehicles and a change in infrastructure to be distributed. DME burns very cleanly and emits almost no particles, which makes it attractive as a fuel for compression ignition engines. DME can be produced from different feed stocks. It is produced in a similar process to methanol and has a similar efficiency, which is a bit higher than the synthetic hydrocarbon process. Black liquor, which was mentioned with BTL, is a suitable feedstock for DME. This is very likely in Scandinavia. Otherwise natural gas is the most likely feedstock but wood or coal can also be possible to use.

8.5.3 Comparisons between Alternative Fuels

The different possible alternative fuels can be compared with each other and with diesel when it comes to energy efficiency and overall emissions of GHG as seen in Graph 8.4.

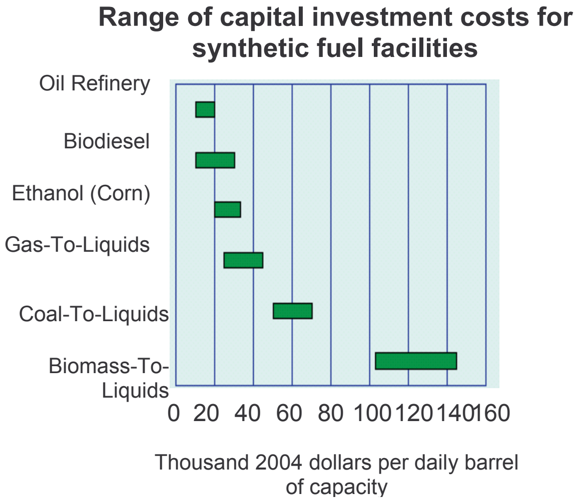


Graph 8.4: Well to wheel analysis. [189]

The graph shows that none of the alternative fuels are as energy efficient as diesel made from crude oil, DME made from black liquor is the alternative that comes closest. Ethanol made from wheat is the alternative fuel with the lowest well-to-wheel energy efficiency. When it comes to GHG emissions CNG is the alternative with largest emissions and biogas from sewage has the lowest contribution. The renewable alternatives do not in general give a net contribution of GHG. If the raw material is farmed there are NO_x emissions, but the amount is uncertain[190].

The cost for production facilities also varies greatly between which solutions for alternative fuels that is chosen. In Figure 8.4 the costs of alternative fuels are presented. Here it can be seen that biomass-to-liquids represents the largest capital investment needed and that both bio-diesel and ethanol require less capital investment then both gas- and coal-to-liquids.[191]

[189] Willkrans, R. (2006)
[190] *WTW-report.* (2006)
[191] *Annual Energy Outlook 2006.* (2006)



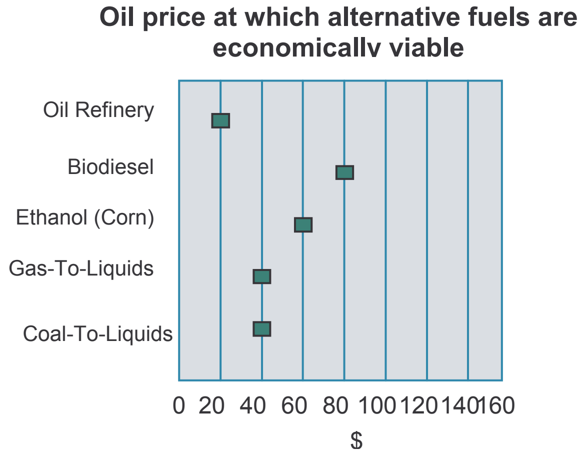


Figure 8.4: Price comparisons of alternative fuels.[192, 193]

8.6 Transport Fuel Dependant Industries

The industry directly affected by a higher oil price is the transport industry. Companies like DHL and UPS are greatly dependant on the price on fuel.

According to DHL the cost for fuel constitutes approximately 12 – 15% of the total cost, but this varies depending on transport solution. A continuous work is done within the company to reduce the impact the cost on fuel has on the company and the company impact on the environment. This is done by:

- reducing the total amount of transports done by for example improving the efficiency in the transport network
- using the alternative fuels and techniques available on the market
- develop green transport services for the customers that reduce the dependency on fossil fuels, not only DHLs transports but also the customers' transports
- communication and education with/of customers considering efficiency with concern to the environment
- measuring the environmental impact
- combining rail and trucks
- continuous evaluation of the road carriers employed by DHL. The aim of the evaluation is continuous improvement of the system to obtain a better output. Measures like fuel reducing driving techniques, usage of alternative fuels and ensured right tire pressure are implemented.

Ulf Hammarberg, Head of Corporate Citizenship at DHL Express AB, thinks that with a fivefold increased cost for fuel there will be changes in the transport industry. These changes will probably be that some types of transports will stop and other will change in structure.

[192] Ibid
[193] *Special Report: Steady as she goes - The oil industry.* (2006)

This kind of increase in cost will also change the behaviour of the overall industry which will mean that the transport industry systems will have to adapt.[194]

Not only transport companies like DHL and UPS are affected by the development of the transport industry. Car and truck manufacturers like Volvo, GM and Ford are also greatly affected. The price on fuel can change the demand from customers and a crossover to vehicles adapted for alternative fuels can be crucial to be able to gain market shares.

Volvo AB considers oil based diesel to be the dominant fuel for the next twenty years in commercial vehicles. But they have acknowledged the fact that a change in the energy supply will happen and that this change will take a long time. Factors like low GHG emissions, energy efficiency, security of supply and long term availability are considered important when deciding on alternative fuels. Volvo AB predicts natural gas to increase in use when oil is declining. Volvo AB standpoint on alternative fuels based on agriculture products is not to support it. They mean that it is energy inefficient and the yield per area of land is comparatively low. If there are alternative fuels based on agricultural products a low blend in should be preferred. Alternative fuels derived from synthesis gasification are pointed out to be a key technology for production of fuels. It can be derived from many different sources which makes the supply more secure. They mean that sometimes the security of supply might be even more important than energy efficiency. The alternative fuels presently preferred by Volvo are methane and DME, but alternatives are evaluated continuously. Methane from biogas or natural gas is expected to increase and biogas has the advantage of being close to CO_2 neutral. DME is considered a good alternative in the future since it for example has good energy efficiency, low emissions, almost CO_2 neutral if based on biomass and it can be produced from many different sources.[195]

Volvo AB is also working the reduction of fuel consumption in heavy vehicles. A hybrid solution is being developed that with the help of an electric motor might be able to reduce the fuel consumption up to 35%. Along with the reduction in fuel consumption comes lower emissions and lower noise levels.[196]

8.7 Summary

The transportation patterns in Europe and the US differs somewhat which contributes to difference in use of primarily type of refined product. This indicates that an increase in oil price will affect these areas differently.

Globalization and increased GDP has contributed to the increase in transports and many products are today shipped all around the world to be manufactured, assembled and sold wherever it is most profitable. As society has become dependant on transports the increase in oil price will come to challenge these structures and business environments. Between 10 – 20% of the total cost for transport is related to the cost for fuel. Many transport companies have added a variable surcharge on the transport cost due to the recent increase in fuel cost. The transport companies work constantly to reduce their consumption of fuel by for example optimising their distribution network. They also work on reducing their impact on the environment. One of the ways to do that is to use alternative fuels.

There are many different alternative fuels on the market and under development. All the different alternatives have both advantages and disadvantages. The energy efficiency, release of GHG, need for new distribution infrastructure and change in vehicle can differ between

[194] Hammarberg, U. (2006-11-17)
[195] *Volvo Future Fuels and Strategy Proposal.* (2004)
[196] *The Volvo FM Hybrid Concept.* 2006-11-26

them. The differences in the fuel solutions indicate that their breaking point, when they become economically viable, compared to oil based fuels, will differ. One way to reduce both the need for oil based fuel and the impact on the environment is to improve the efficiency in the vehicles. This can be done by improving the engine, use hybrids and changing the way of driving. With an increasing oil price these efforts also becomes economically viable.

Different means of control can be used in order to influence which type of fuel is profitable. It can also be used in order to dampen the total use of transport fuel if prices are heavily increased. Taxes and legislation concerning allowed emissions are common means of control currently applied to the transport sector.

9 Non-energy Use

In this chapter the key area non-energy use will be explored. The main focus is set on the plastic industry within this sector. The plastic consumption, production and alternative feedstock to oil will be covered. In the final part of the chapter the view of two companies on oil price and alternatives is given.

The chemical content in everyday materials used in many households is high. In an analysis carried out by Moore Economics, referred to by ACC, the chemistry share of a bottle of shampoo is 100%, a carpet 68%, tires 62% and semiconductors 30% to state some examples. This indicates that an increase in the cost of raw material used by the Chemistry industry will hit hard on the consumer.[197] The most common feedstock for plastic today is oil and natural gas which means that the plastic industry is very dependant on the price of these two resources. There are alternatives that can replace oil and gas, but they are not used to a large extent. These areas will be covered in this chapter to give an insight in what the consequences of a high oil price will be for an industry with oil as a feedstock.

9.1 Plastic Consumption

The main raw materials in the Chemistry industry are crude oil and natural gas. Out of the raw material different chemical chains can be derived, such as for example[198]:

- *Ethylene*: produced from either crude oil or natural gas and can for example be used to produce food packaging, bottles, PVC, lenses and detergents.
- *Propylene:* produced from crude oil and can be used in the production of fibers, coatings, carpets, telephones and detergents.
- *Benzene:* produced from crude oil and can be used in the production of tires, carpets footballs, nylon fibers and pesticides.
- *Ammonia:* produced from natural gas and can be used in the production of fertilizer, explosives, carpets and home furnishings.

Out of some of these chains, as for example ethylene and propylene, polymers can be produced. These polymers are the base for the production of plastics. Plastics consist of one or many polymers combined with an additive.[199]

The per capita consumption of virgin plastics[200] in Western Europe was 100kg in 2004 rising from 98kg in 2003 and 96kg in 2002. Even though the price on plastics has gone up, the consumption and its increase have remained relatively robust. The growth in the consumption of plastics indicates a growing recognition of plastic's strength and flexibility and it remains an attractive alternative even if price increases.[201]

The total world consumption of plastics is today about 90 million ton and the plastic industry consumes about 4% of the total world oil consumption. For Europe, the US and Japan about 4% of their individual oil consumption goes to the plastic industry.[202]

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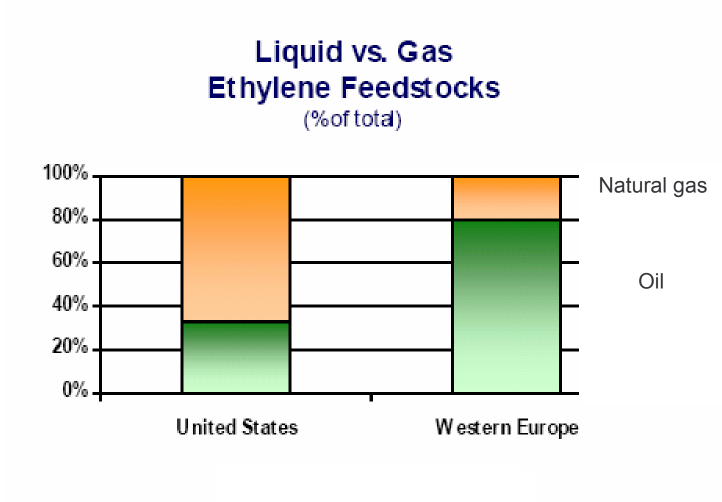
[197] *White Paper: Higher Natural Gas Prices Impact Manufacturing*. 2006-09-15
[198] *Chains*. 2006-10-09
[199] *Plast tillverkning*, 2006-10-08
[200] Virgin plastics are produced from virgin materials such as oil and do not include any recycled materials.
[201] Nnamdi Anyadike. 2006-09-14
[202] Hjertberg , T. (2006-09-29)

9.2 Plastic Production

The US Chemistry industry relies more heavily on natural gas than the western European industry which uses more oil, as shown in Graph 9.1. The Chemistry industry is the single largest user of natural gas in the US and consumes one-eight of the country's demand. [203]



Graph 9.1: Oil vs. Gas feedstock.[204]

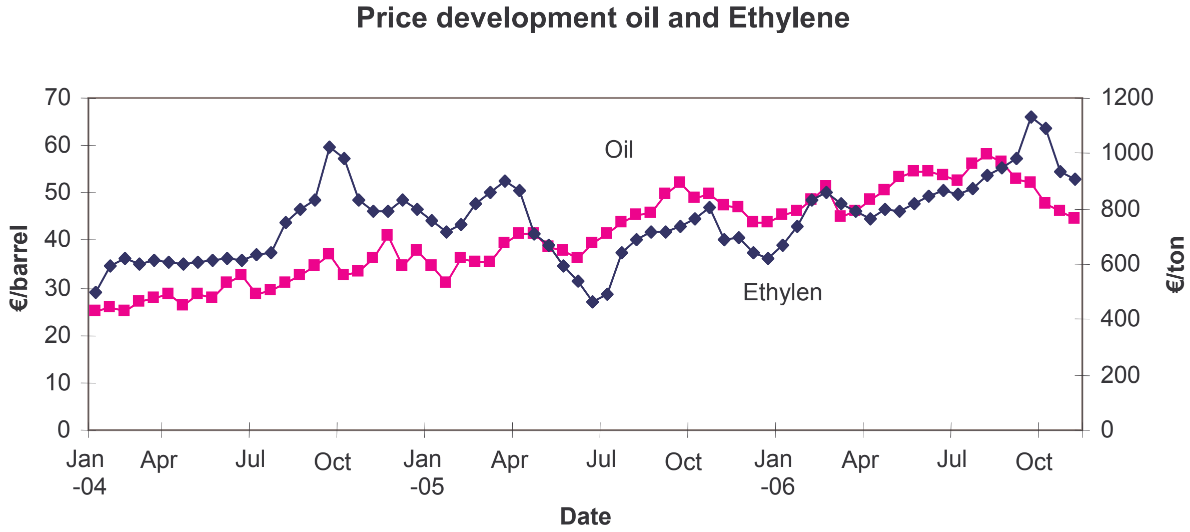
In recent years the price of natural gas has increased heavily on the US market resulting in effects on both companies and customers. The increase in price is linked through the entire value chain eventually causing an increase in the retail price of plastic products.[205]

The oil and gas prices have shown to have a high correlation of about 90% and there is no sign of decoupling. This indicates that a gas price will follow an increase in oil price and vice versa. The reason for the close linkage in price between oil and gas prices is among other aspects that they can be used in similar processes.[206] The close linkage can indicate that a high oil price can have the same effect on societies elsewhere in the world, as the local and recent high price on natural gas in the US has had with regards to the Chemistry industry. The Chemistry industry is often the supplier of raw material to other industries and can therefore work as an indicator of the next evolution on those industries. Unfortunately, the American Chemistry Council, ACC, says, it is only a matter of time before the effects of the high price on natural gas causes effects such as plant closings, job losses, vanishing trade surplus and capital investment flight experienced in chemicals spreading to all of its downstream customers.[207]

The fact that merely 4% of the oil in Western Europe, the US and Japan is used for plastic production can by some people be seen as an argument that plastic is not an area that should be focused on with regard to replacing the oil with alternatives. This however is an argument that professor Hjertberg does not see as valid. He believes that oil should be replaced wherever possible. Today the pressure to replace oil in plastics comes from two directions. One is the environmental concern from governments and the public starting to request products that does not contribute to the greenhouse effect or growing problem with garbage. The other aspect is the pressure from the increasing price on oil that shows no sign of

[203] *Testimony on the Impact of High Energy Costs on Consumers and Public*. 2006-09-18
[204] *White Paper: Higher Natural Gas Prices Impact Manufacturing*. 2006-09-15
[205] Ibid
[206] Capros, P. (2006)
[207] *Testimony on the Impact of High Energy Costs on Consumers and Public*. 2006-09-18

decreasing. The price on plastics has had a similar trend in price development as oil, as can be seen in Graph 9.2. An estimate made by professor Hjertberg is that the end-consumer can tolerate a price increase from the current price of € 0,9-1/kg plastics to about € 1,32-1,43/kg[208] before switching over to alternative products. When using the goodwill connected to more environmental solutions, such as bio-plastic professor Hjertberg believes the producer might be able to increase the price 10-15% more, up-to maybe € 1,54-1,65/kg[209] and still not loose in sale volumes.[210]



Graph 9.2: Trend in Ethylene price compared to the oil price.[211]

Today the European plastics industry is undergoing an adoption to the new situation with high oil price, the increased competition from Asia and the Middle East as well as the fact that the plastic market in many aspects now is mature. A report based on interviews with 20 executives from plastic producers indicates that the companies can adapt to new ways of working through greater efficiency, improved technical innovations and product branding, new price-management techniques and increasing integrations across their supply chain.[212]

9.3 *Alternative Feedstock*

The possibilities to produce chemical feedstock directly from plants or through different chemical processes present a great opportunity to replace a lot of the oil-based products that are currently used in Chemistry and plastic industry.

9.3.1 Bio-Plastics

One of the materials that can be based on biomass is bio-plastics. Bio-plastic is a relatively new material closely related to the regular plastic.[213] One of the first public events where bio-plastics were used was during the Olympic Games in Lillehammer 1994. During the games some of the cutlery and plates used in food corners were made out of starch based plastic mixed up with softening agent. The plastic was both bio-generated and biodegradable. The problem that arose was that you had to eat fast otherwise your plate would start to degrade and get soft, especially if the food contained a large amount of liquid as for example in sauce.

[208] 1 SEK = € 0,11, 2006-12-01
[209] 1 SEK = € 0,11, 2006-12-01
[210] Hjertberg, T. (2006-09-29)
[211] *Feedstock Trends*. 2006-12-12
[212] *Keeping competitive in commodity plastics.* (2006)
[213] *Bio-plastics at a glance*. 2006-09-20

In other words the durability was a problem. A lot of the research that has been done in the area of bio-plastics has been directed towards a plastic that is both bio-generated and biodegradable. Since there is a problem to control the breakdown process, the bio-plastic has mostly been used in products with short life time expectancy. These products make out about 30-40% of the plastics used. Another 20% of the plastic products have a demand for much longer durability, as in the building sector, where the demand is 50 years for some products such as water pipes and cables. The remaining parts of the plastics are used in applications that do not have the same durability restrictions or short period of use.[214]

There is a discussion regarding sustainable plastics and what is to be regarded as a sustainable solution. Some argue that bio-plastics are the only truly sustainable choice. Bio-plastic is a collective name for all biological decomposable plastics where the decomposition is done by bacteria, fungus or alga.[215] Others, such as professor Hjertberg, hold a wider view and say that sustainable plastics should be plastics that originate from renewable raw material.[216] The idea behind the request that sustainable and bio-plastics should be decomposable is the wish to imitate the closed loop of nature with regard to circulation.[217] Professor Hjertberg looks at the circulation in a larger perspective and says that it can concern the circulation of carbon which goes from plant to plastic to air again through burning.[218]

One of the attractive aspects of bio-based plastics is that the biological origin can easily be certified and controlled through the C-14 method and therefore the goodwill for the companies can be assured.[219] Examples of bio-plastics that are decomposable are starch based polymers, polylactic acid (PLA) based, polyhydroxykonater (PHA), cellulose polymers, protein based and starch filled polymers:[220]

- *Starch based polymers* can be produced out of corn and have good resistance against oxygen but bad resistance against wet and damp. Starch based polymers are the most common biopolymers today and are quite common in packaging and wrapping. An example is the Mater-Bi product produced by the Italian company Novamont.
- *Polylactic acid* (PLA) is produced out of sugar beets, potatoes, corn or wheat. According to some experts PLA has the greatest potential as a polymer since it can be produced in large scale to a relative low price and the product can be fully decomposed. PLA can resist water but are less resistant towards heat. Today polylactic acid based plastics are the only bio-plastics that are produced in large scale.
- *Polyhydroxyalkanoate* (PHA) is produced through fermentation. The material can for example be used in paper cups due to its good heat resistance of 120 centigrade.
- *Cellulose polymers* are produced out of wood pulp and can be turned into for example cellophane. Cellulose polymers can also be used as extra filling in pharmaceutical pills and as thickening agent.
- *Protein based polymers* can be produced out of gluten, soy or gelatine. These polymers can for example be used in the production of pharmaceuticals with special restrictions as for example regarding allergies.

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[214] Hjertberg, T. (2006-09-29)
[215] Karlöf, S. Svedjetun, F. (2003)
[216] Hjertberg, T. (2006-09-29)
[217] *Bio-plastics at a glance*, 2006-09-20
[218] Hjertberg, T. (2006-09-29)
[219] Ibid
[220] Karlöf, S. Svedjetun, F. (2003)

- *Starch filled polymers* are regular synthetically plastics that have been mixed with 5 – 10 percent starch based plastics in order to make it decomposable. These mixed products have succeeded in combining the best characteristics from syntactical plastics with the degradability of bio-plastics.

Non-decomposable sustainable plastics can be based on ethane produced out of ethanol instead of naphtha which originates from crude oil. Ethane is the most commonly used base for plastics. The ethanol based ethane can be used in the existing production plants without any large adjustments. Professor Hjertberg argues strongly that more focus should be put on plastics that are produced from renewable raw material but which is not biodegradable. According to him life-cycle analysis has shown that it is better for the environment to burn the bio-plastics for heat instead of letting it degrade into a small pile of dirt. By doing this the bio-generated plastic can help replace some of the oil used for heating. The technique to produce bio-plastic out of ethanol already exist but the key is to have access to cheap raw material and also to produce the bio-plastic with thought given to the whole value-chain so that all steps in the production can be taken advantage of. Ethanol-based plastic is not only favourable compared to oil based plastic with concern to the raw material. It is also favourable with regard to energy consumption. Conventional oil-based plastic is produced out of naphtha, which is heated to 800 centigrade. At this temperature ethane can be extracted and plastics produced. The high temperature required leads to high heating costs and also an increased environmental pressure. When producing ethane out of ethanol the temperature can be lowered to 350 centigrade, resulting in lower heating needs.[221]

9.3.2 Bio-plastics Production

As previously mentioned ethane is one of the base components in conventional plastics. In Stenungsund, Sweden, 850 thousand tons of ethane is consumed in one year. Out of this 600 thousand tons are produced locally and 250 thousand tons are imported. The PLUS-project at Chalmers, initialized by professor Hjertberg, intends to replace the imported part by ethanol-based ethane, to be produced locally. 240 thousand tons of ethane would require 400 thousand tons of ethanol. To make the production of ethanol energy effective the ethanol has to be produced close to the raw material in about 3-4 plants located close to water in order to ensure easy and effective transport. In the short run the required ethanol could be produced using 1,2 million tons of wheat which is about equal to the surplus of wheat produced in Sweden today. [222]

The European bio-plastic organization states that today one hectare farmland can produce about two tons of bio-plastics. This can be set in perspective with that about 50 million hectares in Europe (EU 25) are currently not needed for food production anymore. As a consequence of this the plastic consumption of Europe could in theory be covered by local biomass production.[223] The bio-plastics and biodegradable polymers industry association, IBAW, agrees to some extent and states that bio-plastics have potential to replace some of the oil based plastics of today. They estimate that about 10 per cent of the present consumption in Europe on 40 million tons can be replaced but in order to succeed there will be a need for heavy investments. This effort might however be a chance to avoid farming set-aside programmes in Europe and instead use the land to produce "millions of tons of plastics".[224]

[221] Hjertberg, T. (2006-09-29)
[222] Ibid
[223] *Bioplastic and agriculture*. 2006-09-20
[224] *High oil prices spur growing interest in bioplastics,* 2006-09-21

Problems related to bio-plastic have been the high production cost, the question of durability and mental barriers. Mental barriers exist since the systems surrounding the petrochemical and plastic industry is tuned in on using oil as raw material and this results in that some people regards replacements as too expensive and as requiring too much effort. With regard to production cost Professor Hjertberg believes that a stable oil price at about 60-80 $/barrel makes it profitable to replace oil with bio-based raw material. This however requires that the price on the bio-based raw material keep its relatively low cost. Professor Hjertberg also believes that an oil price of 300$/barrel would generate a price of € 3,3/kg[225] for polythene which would substantially lower the plastic consumption with about 15-20%.[226]

9.4 Recycling

It is not only the finding of a new raw material that is crucial for the plastic industry. The thought of recycling is also of the outmost importance. Plastic can be recycled in three different manners, each offering a different way to reuse the material stored in the plastic. Thermal recycling means that the energy is recovered by burning the waste and then to re-use the generated heat. In chemical recycling fuel or other materials of chemical articles are made by the gasification or liquefying of waste plastics. Finally plastics can also be recycled as raw material for new products.[227] In Western Europe 47% of all plastic is recycled whereof 7% is mechanically recycled.[228] The variation in recycling patterns differs greatly between different regions and countries. In the USA only 5% of the consumed plastic is recycled. If more plastics were recycled less oil and gas would be required in the production of plastics. If the recycling in the USA was increased to the same level as in Germany, who recycles 57%, their request for virgin plastics could be reduced by 12%.[229]

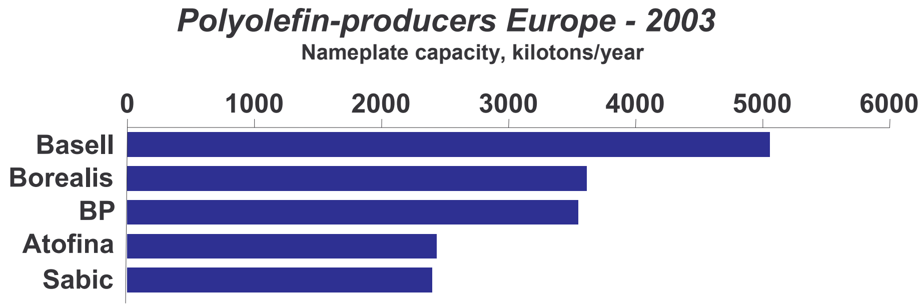
9.5 Oil Dependant Industries

Borealis is a leading company in providing plastics solutions based on polyethylene and polypropylene. According to Bernt-Åke Sultan, the plastic industry is characterized by fierce competition. During the years of 2000 -2003 the price on plastics was so low that the plastic producing companies sold their products almost without any profit. These were very hard times for many plastic producing companies. As the price on oil started to increase so did the price on plastics. Bernt-Åke Sultan believes that the plastic companies were helped by the increase in oil price since that helped to push up the price on plastics as well. A lot of the customers seem to have continued to build up storage in case of an even higher oil price.[230]

In the case of Borealis, one of its main owners is the sultan of Abu Dhabi. There might be a trend, believes Bernt-Åke Sultan, that companies and investors in the Middle East are focusing their attention on global chemical companies. Borealis are currently investing heavily in the area of Abu Dhabi. This is because there they can take advantage of, and use, the surplus of natural gas that exists in the area. The increasing production in the Middle East is mainly meant to cover the Asian market where the demand for plastic products is growing enormously with the expanding economy. The trend that many petrochemical industries also have one foot in the oil business might reflect what kind of investments that are prioritized. An investment that intends to reduce or break the oil dependency within the petrochemical industry might not be well looked on. Bernt-Åke Sultan says that this can be one reason why

[225] 1 SEK = € 0,11, 2006-12-01
[226] Hjertberg, T. (2006-09-29)
[227] Kawaguchi, Y. et al. (2005)
[228] *An analysis of plastics production, demand and recovery in Europe.* (2006)
[229] *Recycling Plastics*. 2006-11-02
[230] Sultan, B-Å. (2006-10-09)

the plastic industry is so quiet about alternative solutions to oil.[231] This thought can be further argued by studying the owner structure of the five largest plastic producers in Europe, see Graph 9.3. Number one, Basell, was previously owned by BASF and Royal Dutch/Shell then to be sold in 2005 to two American companies, Access Industries and Chatterjee's TDC both with interests in oil and gas[232]. Borealis, the number two producer, has as mentioned before close connection to Abu Dhabi. Number three, BP, obviously has close connection to the oil and gas industry as well as number four, Atofina[233], which is owned by the French oil company Total. Number five, Sabic[234], is owned to 70% of the government of Saudi Arabia and 30% by private investors in the Middle East.



Graph 9.3: Major polyofine-producers in Europe, 2003. [235]

Bernt-Åke Sultan mentions that there is an interest among consumers to buy bio-generated plastics. In order to make the bio-plastic even more interesting he would like to see some action on EU level to develop standards and guidelines regarding packing materials. Today the green dot fee acts as a tax on companies that use packaging materials in their products. If there was a way to get rid of this tax by using bio-generated products Bernt-Åke Sultan believes the interest would grow even stronger. Sometimes the industry needs to be pushed forward by political initiatives especially if the industry has interests elsewhere, he says.[236]

Although companies such as Borealis can substitute 100 percent of their oil based feedstock[237] if they wish, this is not the case for all companies. One example of a production where it is difficult to substitute oil is in the production of bitumen dependent products. Bitumen is obtained by fractional distillation of crude oil. By being the heaviest and the fraction with the highest boiling point, bitumen appears as the bottom fraction. Bitumen can almost be regarded as a waste product in crude oil distillation.[238]

One example of a company that uses bitumen as feedstock is the Icopal Group. The Icopal Group is the world's leading producer of bituminous roofing and waterproofing membranes and the market leader in the Nordic countries in the area of roofing contracting activities. In the production bitumen is mixed with oil based polymers at a temperature of 200 centigrade. The raw material represents about 80% of the product cost and is divided in 25% bitumen, 25% polymers, 25% reinforcement and 25% others.[239] The high percentage of oil based raw material makes the company sensitive to fluctuations in the oil price. The company has been

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[231] Sultan, B-Å. (2006-10-09)
[232] *New Shareholders "With a Strong Belief" in the Future of Basell.* 2006-11-02
[233] *Group organisation*. 2006-11-02
[234] Ibid
[235] Sultan, B-Å. (2004)
[236] Sultan, B-Å. (2006-10-09)
[237] Ibid
[238] *Bitumen.* 2006-10-04
[239] Dedenroth, N. (2006-09-26)

able to meet the recent years increase in oil price by producing more and by lowering profit margin. Fortunately there has been an increase in sales as the building industry is more active due to economical rise in the society. Unfortunately for many small companies the building merchants are often very strong customers since they buy large quantities. This makes it very difficult to pass on the increased price. The increase of activity in Asia and India has helped to keep the sales up on the entire market. If sales were to drop the Icopal Group would be much more hard hit by the effects of the increasing oil price. This is because the products the Icopal Group produces are partly commodity products that are characterized by high price pressure. Niclas Dedenroth, Production Director at Icopal Group Sweden believes that they could increase the price of their product with a maximum of 10-15%, under the condition that the increase in oil price hit all industries alike, before the customer would give up the product. The rest of the increase in cost will have to be absorbed within the company itself. An alternative to the bitumen based products are PVC based products. Niclas Dedenroth believes that the use of thinner PVC products would increase, and even though price increase would affect the entire industry, bitumen based products would probably be exchanged for other alternatives.[240]

Today the Icopal Group tries to reduce the effect of a volatile oil price, and thereby bitumen, by setting up longer contracts with raw material suppliers. Previously bitumen was bought with regard to a price constructed by formula but today there is a need to secure the price for a longer time period and therefore the price shall be negotiated for three months at a time. The Icopal Group also carries out research on how to reuse waste bitumen in the production. Currently the waste can be used for heating but they are working on a way to add it into new products. By introducing fixed delivery dates to their customers, the Icopal Group have also been able to reduce the cost for transport.[241]

The Icopal Group is affected by the oil price in terms of transport cost, raw material cost, packaging cost and heating cost. Niclas Dedenroth believes that it is the same for many other industries and that a high increase in oil price will have large effects on both society and industry.[242]

9.6 Summary

Oil based plastic products are present in most of our everyday life since plastics is such a diversified and cheap material. This had led to a constant increase in utilisation in Western Europe and the US. Currently oil and natural gas are used as main feedstock in plastic production, the US depending more on natural gas than Europe. The close correlation in price however, indicates that the effect due to a higher oil price upon this sector will be similar in the two geographical areas.

There are alternative sources of raw material that can be used in the production of plastic materials. Both plastics which are bio-degradable and not bio-degradable can be produced out of biomass instead of oil and gas. However, in order to break free from the dependency on oil and gas the willingness and interest to invest in technical development and production facilities has to be present. In the US there is potential to lower the need for virgin plastics through increased recycling. As the price on oil increases these kinds of initiatives can become economically viable. In many companies the increase in the raw material price has not been fully transferred to the consumer but instead been met with lowered margins and increased sales.

[240] Ibid
[241] Ibid
[242] Ibid

10 Heat and Electricity Generation

In this chapter the key area heat and electricity generation is presented. The use of oil in heat and electricity is investigated as well as the effect it has on those applications. Possibilities for a reduced use of oil within this sector and means of control affecting this use are discussed. Environmental aspects can influence which alternatives will be used instead of oil. This makes the technique of Carbon Capture and Storage, CCS, interesting why this also is covered.

The use of oil in power generation in the OECD countries has decreased substantially since the seventies. From constituting almost 25% of the power generation before the seventies it was down below 10% in the nineties.[243] Today it is even lower, in the U.S. power industry the oil use is down to around 3%[244] and in EU 25 around 5%[245]. Further efficiency improvements to reduce the oil consumption in this sector are investigated covering both the EU and the US. The consequences of an increased oil price will be different depending on which energy resource that will replace the oil. Different means of control and the possible development of CCS will affect this choice of replacement source.

10.1 Trend of Oil Usage

In most OECD-countries the main uses for oil in electricity supply systems are for[246]:

- flexibility when electricity from other fuels is disrupted
- intermediate and peaking load
- power in isolated areas
- planning flexibility

In many countries it has been a deliberate strategy to reduce oil within heat and electricity generation. In some cases this can be difficult as the access to alternatives such as natural gas and hydroelectricity is limited or connected with a high cost. The possibility to use nuclear power and coal plants to help the reduction of oil dependency can be limited due to the public opinion regarding these solutions. Countries that have limited access to alternative solutions to oil are often using more than average oil in power generation. However, there has been a general reduction of oil in this sector. Some of the reasons for the low utilisation of oil in power generation are that it is more expensive compared to other fuels and the efficiency in oil-fired boilers is similar or lower than other solutions with other fuels.[247]

The product used in oil power generation is residual fuel oil. This is a by-product when light oil products are produced and there are not many other fields of applications for this product. Since light oil products are produced at a steady rate, so is residual fuel. This means that residual fuel can be considered a secure source of energy compared to most other sources that have a risk of being interrupted in their supply. Still it is often promoted by governments to switch away from oil in favour of other alternatives.[248]

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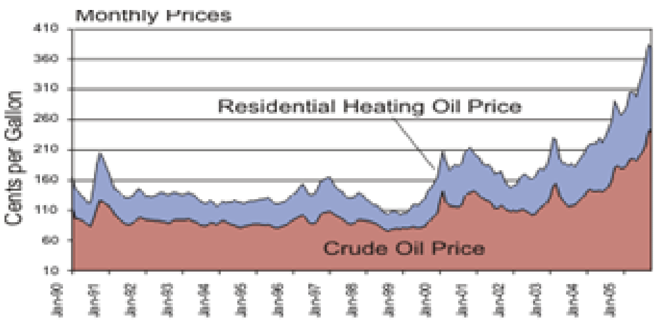
[243] Oil in power generation (1997)
[244] *Electricity in North America 2003.* 2006-10-11
[245] Energy yearly statistics 2004. (2006)
[246] Oil in power generation. (1997)
[247] Ibid
[248] Ibid

10.2 Heat Generation

In many households it is common to produce one's own heat. Common fuels for household use are gas and heating oil. In Sweden even pellets are commonly used. In the U.S. about 8% of all the households use heating oil as the primary source for heat[249]. Partly due to the fact that many households produce their own heat, it is not common with a joint heat market. In Europe it is mainly in Sweden, Finland and in the northern part of Germany where there is an actual heat market. Otherwise heating is often individually produced. In Sweden, Norway and a few other countries even electricity is used to generate heat. The costs for the individual heating systems differ greatly and even if an average value can be found it is misleading since they are so altering and different. The need for heating also varies a lot. In the southern part of Europe and in the U.S. air-conditioning is a bigger consumer of energy and it most often uses electricity. In the U.S. heating is mainly based on natural gas and due to the nature of natural gas the prices are relatively local.[250]

Other sources than oil and natural gas can be used for heating. Common sources are biomass, waste, peat, coal, solar and geothermal. Waste heat is common to take care of where district heating is used. This waste heat can for example come from industries that use water to cool down processes.

The price on heating oil follows closely the price on crude oil, see Graph 10.1.



Graph 10.1: Comparison of prices of crude oil and residential heating oil in the US.[251]

The price components in heating oil are crude oil, refining, marketing and distribution. In the US 2004 crude oil took up 57%, refining 14% and marketing and distribution 29% of the total cost.[252]

In Sweden an alternative to heating oil is available, due to the high taxes on heating oil. This alternative is refined rape oil. It can be used basically directly in the boiler and only the burner has to be changed. Because of this a renewable alternative can be easily implemented without big costs. However this solution is still not common and the production volumes are very low. The current cost for this rape oil is lower than the cost for heating oil and it has advantageous emissions.[253]

10.3 Electricity Generation

Just as the general energy consumption in the world increases so does the consumption of electricity. In Graph 10.2 it is shown that the consumption of electricity in Europe and the US

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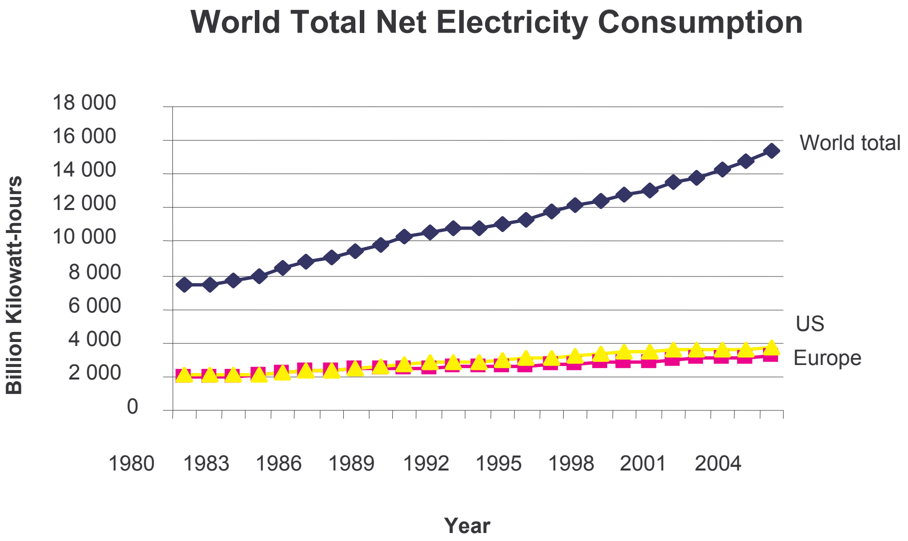
[249] *Residential heating oil prices.* (2005)
[250] Hjalmarsson, L. (2006-10-18)
[251] *Residential heating oil prices.* (2005)
[252] Ibid
[253] Haaker, A. (2005)

increase every year, but not to the same extent as the World total. The reason for the World total to increase is the fast increasing need for energy in the developing countries, foremost China and India. The electricity consumption can also be expressed in consumption per capita for comparison. The US had in 2004 a consumption of approximately 12680 kWh/person, Europe had 5500 kWh/person and an estimate for the average consumption in the World total is 2420 kWh/person.[254]



Graph 10.2: World Total Electricity Consumption.[255]

Electricity can be produced from many different sources and the distribution of sources used can vary greatly from country to country. This difference is due to the different conditions and access to different resources depending on the country. Also public opinion can affect where the electricity comes from, for example nuclear power can be neglected due to public opinion as discussed further in Chapter 12. As can be seen in Figure 10.1, coal, nuclear and gas are the major sources for electricity in EU 25 and in the US. Hydropower also plays a big role in electricity production in these two regions then followed by oil. As mentioned in the introduction, oil is mainly used as top load or as a flexible fuel when there is a sudden interruption in the supply of other sources. The last source playing a noticeable role in these regions in electricity production is biomass. Sources that fall under "Other sources" are for example solar (photovoltaic), geothermal, wind and the burning of waste materials. Also garbage is burnt in order to generate electricity and heat. Garbage is currently often seen as a source of cost but as the need for all types of material increases in combined power and heat plants the cost of garbage can be turned into an income[256].

As previously mentioned natural gas is used in electricity generation. Natural gas is a feedstock that E-ON regards as very attractive in the future according to Håkan Feuk at E-ON. Presently E-ON is using a lot of natural as in their facilities in Europe, mainly in the UK. According to Håkan Feuk the interest in natural gas also exists in other countries such as the US and Japan and many production facilities for foremost LNG is being constructed.[257]

[254] *International Energy Annual 2004* (2006)
[255] Ibid
[256] *Avfall blir energi*. 2006-11-26
[257] Feuk, H. (2006-09-26)

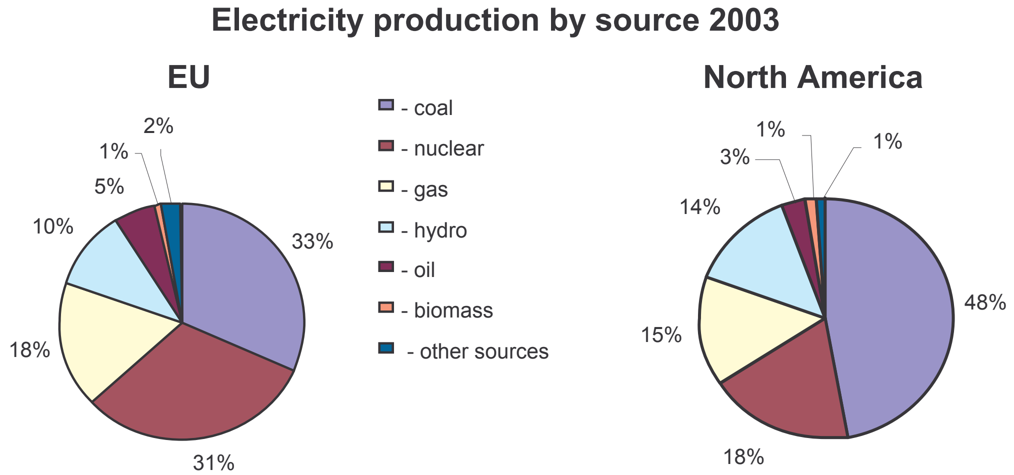


Figure 10.1: Electricity production by source in EU25[258] and North America[259] 2003.

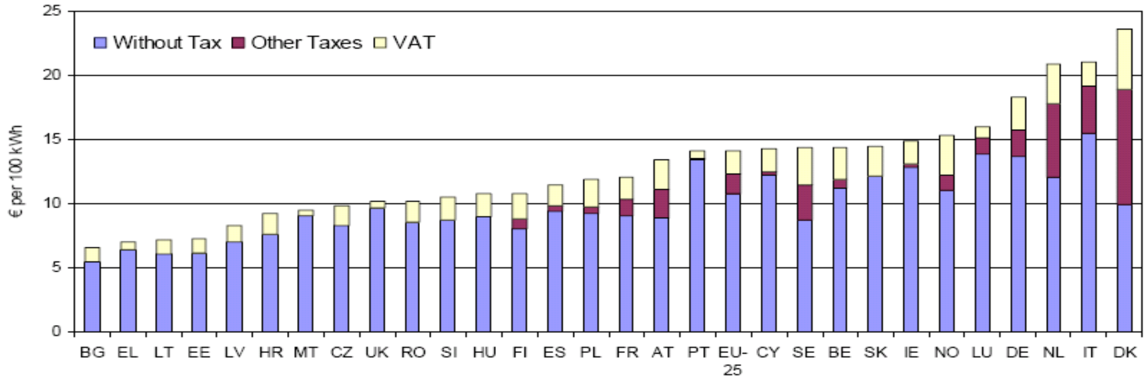
In the US coal is the predominately source for electricity production. It is predicted by the US Department of Energy that it will remain the major source for electricity for the foreseeable future. Some of the reasons for the large use of coal in the US are the low cost for the coal and the large quantity of it. Since coal has these advantages work is done to minimize the environmental effects and increase the efficiency of it. The biggest challenge is to lower the environmental effects. This can be done through new technology in the process to reduce sulphur, nitrogen and mercury emissions.[260] Many countries have recognised the effect these emissions can have on the environment and therefore chosen to work in an active approach towards the reduction of emissions. The nations included in the Kyoto Protocol have signed an agreement forcing them to reduce these emissions, see section 10.5. Unfortunately the US has still not ratified this Protocol. They however still work to reduce their emissions. The release of CO_2 can be reduced with better efficiency and might be further lowered with the introduction of carbon capture and storage, see section 10.6. The fastest growing fuel in the US is natural gas, probably more than 90% of the new power plants within 20 years will be fuelled with natural gas. [261]

10.3.1 Cost Development

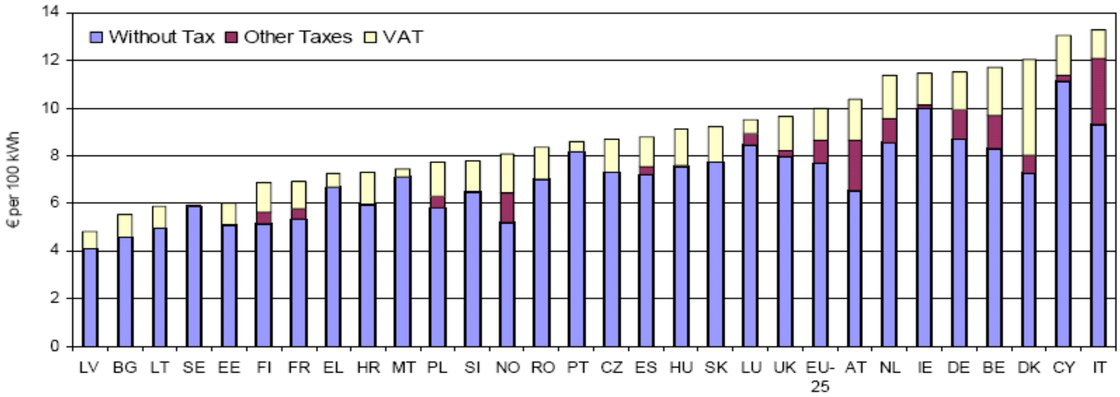
Electricity is in general priced by the marginal cost. This means that the price on all electricity is decided by the cost on the last produced kWh.[262]

The electricity price in Europe can not be generalised in the same way as the gasoline and diesel price can. The taxes as well as the base cost for electricity varies greatly depending on which country is considered. This is illustrated in Graph 10.3 and Graph 10.4, where one considers domestic consumers and the other industry consumers.

[258] *Electricity in European Union – 25 2003.* 2006-10-11
[259] *Electricity in North America 2003.* 2006-10-11
[260] *Electric Power.* 2006-11-08
[261] Ibid
[262] Magnell, L. (2005)



Graph 10.3: Electricity price distribution for domestic consumers in Europe January 2006.[263]



Graph 10.4: Electricity price distribution for industrial consumers in Europe January 2006.[264]

The price to the final private consumer today consists of cost of electricity, cost of using the distribution network and taxes. For example, taxes in Sweden make up about 50% of the price today. VAT is calculated as a percentage on top of the price while the other taxes are a fixed cost per kWh.[265]

With Graph 10.3 and Graph 10.4 it is clear that there is no joint market for electricity in Europe. There is one for the Nordic countries, Sweden, Norway, Finland and Denmark, called Nordpool. Discussions within the EU have been made about a joint market for the EU, but this will not happen in many years. A common electricity market without bottlenecks means that all customers will pay the electricity price based on the cost of the marginal production unit in the total market.[266]

The price on electricity has had an increasing trend for the last couple of years both in the US[267] and in EU 15[268]. Reasons for this increase have, for example, been increased price on fossil fuels[269] such as natural gas which is linked to the price on oil, and in Europe emission rights[270]. Power plants in the EU are included in the system of emission rights which means that if they can not keep or reduce their emissions of GHG they have to buy rights from

[263] Goerten, J. Clement, A. (2006)
[264] Ibid
[265] Feuk, H. (2006-09-26)
[266] Ibid
[267] *Electric sales, Revenue, and Average Price 2004.* 2006-11-07
[268] Goerten, J. Clement, A. (2006)
[269] *Electric sales, Revenue, and Average Price 2004*. 2006-11-07
[270] Källstrand, B. (2005)

someone who has, this will increase the price on electricity[271]. Countries with a large portion of hydropower is also very dependant on the annual precipitation, and this will affect the price on electricity[272]. The most common fuels setting the prices in Europe are coal and natural gas[273].

Many industries have high energy-intensity manufacturing which means that they need a lot of energy to produce their products. Iron and steel, cement, chemicals and paper manufacturing are high in energy-intensity[274]. Some companies' electricity cost accounts for 10 to 40% of the processing value[275]. This makes them very vulnerable to increases in the electricity price. Many of the energy intensive companies use financial tools in order to reduce the effect and risk with volatile energy prices. If an increase in price causes them to close down the energy companies are affected negatively too since they loose a big customer.[276]

10.4 Efficiency

Within the heat and electricity sector there is a large energy saving potential. A report from American Council for an Energy-Efficient Economy shows that the US industry has a saving potential in their heat and electricity of between 8-16 thousand barrels oil per day in 2015. The same estimate for households and commercial buildings is 20-130 thousand barrels per day, or approximately a reduction of between 1,5 – 10% of oil consumption.[277]

In Europe there is also an optimistic view towards the possibility of energy savings potential. The Oil-commission in Sweden (2006) pointed out that the Swedish non-energy intensive industry had a potential of saving 40% of their electricity consumption, and households and commercial buildings 20% of their electricity consumption.[278] This electricity reduction is not as in the American case directly related to oil but it shows a great potential for energy saving. Another publication pointing towards the great potential of energy savings in buildings, also this publication from Sweden, mentions that an energy reduction of 25% should be possible in buildings. This potential includes increased regulations concerning building new buildings with regard to energy efficiency as well as mandatory call for energy improvements in all old buildings.[279] On EU level the energy saving potential is estimated to 27% in households by 2020 and 30% in commercial buildings by the same time. They also estimate an energy saving potential in the manufacturing industry to 25%.[280]

10.5 Means of Control

As can be seen in Graph 10.3 & Graph 10.4 countries vary on how they tax electricity. Different taxes are strong means of control that can be used by governments in order to promote or hold back different energy solutions. These taxes are often added to the electricity and heat costs in the purpose of either controlling emissions or to control the amount of energy used. Taxes do not represent the only means of control that can be used by governments. Subsidies and fees are often also used in order to promote different energy

[271] *The Kyoto Protocol* 2006-11-10
[272] Magnell, L. (2005)
[273] Feuk, H. (2006-09-26)
[274] *Annual Energy Outlook 2006.* (2006)
[275] *Om energin.* 2006-11-08
[276] Feuk, H. (2006-09-26)
[277] Elliott, R. et al (2006)
[278] *Kommissionen mot oljeberoende.* (2006)
[279] Eriksson, O. (2006)
[280] *Saving 20% by 2020*. 2006-11-10

solutions. The trading with emission rights under the Kyoto Protocol is one example where environmental concern helps to guide toward a mean of control that is directed towards the source of energy used in heat and electricity generation[281].

10.5.1 Kyoto Protocol[282]

Under the Kyoto Protocol (further explained in Appendix 3), the agreeing industrialised countries are required to reduce their emissions of six greenhouse gases (CO_2, being the most important one) by around 5% below the 1990 level during the first commitment period of the Kyoto Protocol which covers 2008 to 2012.

The Kyoto Protocol implies three market-based mechanisms, known as the Kyoto flexible mechanisms: emissions trading between governments with Kyoto targets, the Clean Development Mechanism and Joint Implementation. These mechanisms will allow industrialised countries to meet their emission targets cost-effectively by trading emission allowances between themselves and also opens up the possibility to gaining credits for emission-curbing projects abroad.

Emissions Trading

Under the Kyoto protocol countries are assigned a fixed maximum of emission that they may emit in the period 2008-2012. Countries that emit less then their allowance can sell their unused quota to others that emit more. Inspired by this system, the EU has developed and implemented its own emissions trading scheme. This scheme operates at company level and became effective on January 1st 2005. The scheme covers all 25 EU Member States and is the first multi-national emissions trading scheme in the world.

In this scheme almost 11,500 European energy intensive factories (steel factories, power plants, oil refineries, paper mills, and glass and cement installations) have received allowances. These factories together account for almost half of the EU's CO_2 emissions. Companies that emit less than the number of allowances they receive can sell the surplus to companies that have problems staying within their allocations, or for which emissions reduction measures are more expensive than buying allowances on the market. Any company can buy emission rights if they need to increase their emissions above their allocation.

By implementing emission rights the companies are forced to fully integrate the costs of CO_2 emissions in their decision making. This tempts them to make emission cuts where they are cheapest and thereby making sure that reductions are made at the lowest possible cost to the economy. In a wider perspective this will foster innovation as it gives companies an incentive to improve their energy efficiency and invest in climate-friendly technologies.

Clean Development Mechanism and Joint Implementation

A country does not have emission rights as the only mean to control how much emission they can have. The Clean Development Mechanism, CDM, and Joint Implementation, JI, will allow industrialised countries to achieve part of their emission reduction commitments by investing in emission-reducing projects abroad. These initiatives and reductions can then be counted as reductions achieved toward their own commitments. JI will allow for projects in other industrialised countries with Kyoto targets, while CDM projects are carried out in countries without targets, i.e. developing countries.

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[281] *The Kyoto Protocol.* 2006-11-10
[282] Ibid

Both the trading with emission rights as well as CDM project and JI have forced European companies to take an economic responsibility for their production processes and products. These initiatives operate as a means of control pushing companies in the direction the commission wishes.

10.6 CO_2 Capture and Storage[283]

With the increased understanding of the effects of GHG, the wish to reduce them is high priority. One option for reducing these emissions is carbon capture and storage, CCS. Carbon dioxide, CO_2, is one of the most common GHG. If CCS is successful no emission rights need to be used up on the captured CO_2 amount. The estimated cost for CCS can vary greatly. Most estimations ended up around 0,0076 – 0,038 € per kilowatt hour. If CO_2 is priced around € 19-23 /tCO_2 CCS is estimated to be an interesting solution.[284]

A surplus of CO_2 is produced when burning fossil fuel. The main stationary user of fossil fuels is the power industry. CCS means that CO_2 would be separated from the emissions generated and then transported to a storage area where it will be placed and kept from mixing into the atmosphere. As much as 85 – 95% of the CO_2 can be captured in a capture plant. If CCS was used for biomass fuelled processes the total amount of global CO_2 would be reduced and possible economical gains could be made depending on the value on the market for CO_2 emissions reductions. When using CCS the CO_2 has to be transported and stored and even though different solutions exist there is no experience in fully connecting them yet.

10.6.1 Transportation

The main ways of transporting CO_2 are by pipeline or by ships. Depending on how far and how much CO_2 being transported one or the other is more suitable. In general pipelines is the preferred mean of transportation when it is large amounts going smaller distances. This technique is already used today in for example the U.S. With smaller amounts and over larger distances ships might be more economically interesting.

10.6.2 Storage

CCS would be suitable for large sources where the CO_2 could be compressed and transported to the storage areas. These storage areas can be for example the ocean, in mineral carbonates and geological formations. Research shows that many large industry areas are close to possible storage areas for CO_2. CO_2 can also be used in some industrial processes but this would probably not result in a net reduction of emissions. The estimation for possible storage capacity is largely uncertain but at least 2000 GtCO_2 is the technical storage capacity in geological formations.

10.6.3 Problems Concerning the Use of CCS

Even if there would be an economical possibility to use CCS there are other factors that will present problems. These factors are for example risk of leakage, environmental impact and limited public acceptance.

There are leakage risks involved with transportation of CO_2 in pipelines. If there would be a leak of CO_2 in a large concentration it would cause an instant danger to human life and health if the concentration would be greater than 7 -10% by volume in air. This requires that the planning of the pipelines takes this into consideration with concern of leak detection and

[283] Metz, B. et al. (2005)
[284] $ 1 = € 0,76, 2006-12-01

population etc. There are also problems connected with the site of the storage. These problems are gradual and abrupt leakage. There are no known observations of abrupt leakage from the ocean to the atmosphere but increased concentration of CO_2 at the surface can contaminate the water and have lethal effects on plants and animals. Small seismic events can also be triggered by the build up pressure from the CO_2.

10.7 Summary

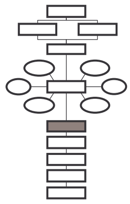
During the past decades oil has come to take a smaller part in heat and electricity generation. Oil however, still holds a unique position as it is suited for top-load generation. The flexibility and high energy value of oil also still makes it a product used in households and industries that generates their own heat and electricity. In many countries different means of control have been used in order to reduce the dependency of oil in these applications.

The increasing need for energy is a problem recognized both by the US and Europe. Both these regions wish to reduce the usage of energy and both see a great potential in increased energy efficiency and energy savings. Along with the reduction in energy usage come the benefits of lower costs.

Along with the decreased use of oil comes a need for increase in other sources of energy. These different solutions will all be associated with different levels of investments cost and operating costs. Coal and natural gas along with nuclear power and hydro have for a long time been dominant over oil and are becoming increasingly important sources of energy. The problem with emissions that are related to coal and natural gas has come to take a more prominent position as many regions have agreed to the Kyoto Protocol. The use of emission rights and other regulations works towards a reduction of these emissions. Carbon capture and storage have the possibility to reduce the problem with emissions reassuring the continued use of fossil fuel. If this technique however is not up for large commercial use, as the use of coal and natural gas increases, there is a large risk that the level of emissions will increase instead of decrease as desired.

11 Identify and Analyse Key Factors

In this chapter the key factors deriving from the key areas will be identified. The key factors are described both in area specific and in general terms. The general factors are broader in description whereas area specific factors more closely focus on the key areas.



The identifying of key factors is done as Step 5 in the scenario creation model, as shown in the picture on the right. The key factors are derived from the information given in chapter 8 – 10.

In the three previous chapters the key areas have been investigated. In these chapters it has been exemplified how the different areas are affected by the increase in oil price as well as their possibilities to respond towards this increase. These different ways of responding will eventually result in second hand effects also being consequences of an increase in oil price. In this chapter the key factors deriving from each key area are presented. Key factors are factors that can have an impact on the future consequences an increased oil price will have. Only the factors believed to in general play a major role within each sector will be included in this chapter. Minor factors, or factors just acting upon one specific part within a sector, will be disregarded. The key factors are derived by analysing each key area using the six aspects; economical, technical, political, legal, social and geophysical, as shown in the scenario model in Chapter 4. When the key factors for each key area have been identified they are put in more general terms in order visualize trends and important future developments for the main problem in focus. At the end of this chapter two directions of development, due to an increase in oil price, are identified. These directions have been identified as most factors, in one way or the other, have pointed in these directions. Aspects regarding the two directions will be further explored in Chapter 12 and 13.

11.1 Area Specific Key Factors

In the following section key factors from each key area will be discussed. The key areas have many factors that are of a similar nature and therefore a presentation of general key factors will follow in section 11.2.

11.1.1 Transport

When observing the transport sector many factors can be identified that can come to affect the consequences of a high oil price.

Economical Factors

Depending on the level of the oil price different alternative fuels will become economically interesting. Which alternative fuels that will be developed will depend on which ones are the most economically beneficial. No company can be expected to invest money in a solution that will not generate a profit. Factors that can limit the economical possibility of the expansion of certain alternative fuels are: how large the initially required investment for the production is, how much further investment is needed in technical development before the fuel can be commercially available and what other operational costs there are connected to the production. The choice of alternative fuel will also depend on the access to raw material and the costs for this raw material. As soon as alternative fuels become competitive in price compared to conventional fuel they will be attractive.

Technical Factors

In order to keep up the possibility of transport as price on oil increases there needs to be a technical development of more efficient alternative solutions to the oil based fuels. There also needs to be a development of more efficient vehicles, both those running on alternative and those running on oil based fuels. The need for development of the required infrastructure is also an aspect that will to a large extent have an impact on the consequences of a high oil price.

There will be an increased need for public transport as well as commercial transport solutions as the fuel cost increases. If the current level of transportation should be sustained this will be of outmost importance for society.

Political & Legal Factors

Not only the financial and the technical development will determine the future for the transportation sector. The different political agendas in different countries will determine whether one alternative fuel will be more supported than the other. Also international environmental and national agreements will affect how different means of control are drawn up. The view on environmental politic can obstruct or push the introduction of certain fuels on the market. Fossil based transportation fuel can be discouraged by including that market into the trade with emission rights. Other means of control affecting the consumption of fuels are taxes. Either there can be an increase of taxes to further discourage the consumption or there can be a decrease of the existing ones in order to relief the increased pressure on the consumers.

Social Factors

The introduction and expansion of alternative fuels will depend greatly on the attitude of the public. It is important with acceptance and demand for alternative fuels for a successful expansion. With a higher price on oil, and the followed increased price on fuel, the willingness to pay for the current transport behaviour can be questioned. If the cost of transport increases this might change the behaviour of the public.

The access to alternative feedstock can also be affected by the public opinion. If the use of forests and agriculture changes drastically an opposition arises against the development.

Geophysical Factors

The geophysical factors that will affect the consequences of increased oil cost concerns both the availability of raw material, the adoption of distribution network and further development of infrastructure for efficient transport. If raw material is not accessible in required amount there will be a shortage of transport fuel resulting in much higher prices. If distribution networks are not developed some alternatives will have to be disregarded even if they are more energy efficient. The further development of efficient transport will be important as this factor will determine to what extent a higher cost for transport will affect the individual possibility to move.

Economical Factors:

- ➔ Investments needed in alternative production
- ➔ Investments needed in technical development
- ➔ Magnitude of cost associated with production of alternatives
- ➔ Magnitude of cost associated with raw material

Technical:

- Technical development in production of alternative fuels
- Change in transport solutions
- Access to suitable infrastructure
- Access to vehicles suited for alternative fuels
- Improved energy efficiency in vehicles

Political:

- Ambition to follow environmental agreements

Legal:

- Expansion of emission rights
- Taxation policy on fuels

Social:

- Public opinion towards utilisation of alternative fuels
- Public opinion towards change in forestry and agriculture
- Attitude towards transport behaviour
- Attitude towards environmental impact

Geophysical:

- Access to raw material for alternative fuels
- Adaptation of distribution infrastructure for alternative fuels
- Further development of infrastructure for efficient transport

11.1.2 Non-energy use

Within the non-energy use sector there is one factor that can be seen as extra important in terms of what consequences an increase in oil price will have. This factor is the willingness of investors and public to bear the cost it will imply to either keep the oil or to substitute it with other raw materials. If the price on oil reaches as high as $300/barrel oil based plastic will not be the cheap and available material that we have all come accustomed to. The benefits of the material will not be less but the cost for using it will be significantly higher. In order to keep up the availability to use this diversified product alternative raw materials and processes must come in place.

Economical Factors

The development and commercialisation of alternative feedstock will require investments both in new production facilities as well as in continued technical development. The magnitude of the required investments will affect when the companies will be prepared to carried them out and also which alternative feedstock they will go for. The magnitude of costs associated with everyday production and cost of raw materials will also have a determining factor on when and which alternatives will be profitable for the companies.

If the demand for alternative plastics increases there will be a requirement for more production capacity. The pace at which production capacity can be expanded is a factor that will influence the total cost of an increased oil price. If there is a lack of production capacity the price on existing material will be high and the consumers will have to face higher costs then otherwise necessary. If investments and preparation, to meet an increase in oil price, are made in good time the effects will be reduced.

The extra costs of both the increasing oil price and new investments and costs associated with alternatives will eventually affect both the consumer as well as the companies. The capability of transferring the increased costs for investments and/or feedstock along the value chain will have a large impact on how damaging this consequence of an increased oil price will be. If all parts in the value chain succeed in sharing the increased cost they might have a better possibility of surviving than if one part will have to take the entire cost and as a consequence is swept out.

In order to enable the non-energy use sector to be a sustainable sector the pattern of consumption must change. Plastics and other high-energy materials can no longer be regarded as waste once they have fulfilled their primary chores. It must be looked upon in continuous manner. Recycled plastic can lower the need for virgin material and the plastic "waste" used as a source of energy. Both the benefits and cost of recycling will be a factor that can determine how well this sector can meet the increase in the oil price.

Technical Factors

Since the technology to produce plastics out of alternative resources exists, the lack of technology is no valid argument why not to invest in plastics from other sources than oil. The bottom-line is, as always, that there must be an incentive for investors to invest. This incentive can be a cost advantage, the fact that the customer is prepared to pay a higher price for a product based on alternative resources or that the customer turn elsewhere or refuses to buy the old product if no alternative exist. Because of this it will be of outmost importance that improved and efficient processes are developed so that companies can still survive and make profit even though they use other raw materials. The increase of efficiency in existing processes will have to go hand in hand with the technical development of alternative raw material processes as well, this in order to ensure that resources are utilized in the best possible manner.

Political & Legal Factors

The political attitude towards environmental questions will affect the future for the non-energy use sector, one example being the attitude towards non-degradable bio-plastics. The attitude will affect taxations and recycling policies and thereby have an impact on if and when different alternatives can be economically viable.

Social Factors

The question of demand will not only be guided by price of products. It will also be guided by the opinion of the consumers towards products based on alternative resources. These opinions can be guided by political means but also through the use of media and commercials communication a message. The public opinion and behaviour will determine efficiency in recycling, importance of bio-based materials and also the availability of bio-based raw material. This will in extension affect the willingness companies and organisations have to make the necessary investments.

Geophysical Factors

The question of when investment in alternatives will be profitable for the companies is to a large extent determined by the price on production capacity and the security and price on raw material. By ensuring companies the availability of raw material, the risk connected to the investment can be lowered. New partnerships might be profitable and the present times close connection between oil and plastic producing companies can be replaced by joint ventures between farmers, regions and companies. These partnerships can be something totally new on the market but nonetheless profitable.

Economical Factors:

- ➔ Investments needed in alternative production
- ➔ Investments needed in technical development
- ➔ Magnitude of cost associated with production of alternatives
- ➔ Magnitude of cost associated with raw material
- ➔ Cost transfer within value chain
- ➔ Benefit/cost of recycling

Technical:

- ➔ Improved process efficiency in factories
- ➔ Technical development of production with alternative raw material

Political:

- ➔ Attitude towards environmental impact

Legal:

- ➔ Taxation policies
- ➔ Recycling policies

Social:

- ➔ Public opinion towards recycling behaviour
- ➔ Public opinion towards bio-based material
- ➔ Public opinion towards change in forestry and agriculture
- ➔ Willingness to invest

Geophysical:

- ➔ Access to alternative raw material

11.1.3 Heat and electricity

Oil is mainly used in the heat and electricity sector for top-load and to increase flexibility. With an increased price on oil, the use of oil in these applications will most likely be even further reduced.

Economical and Technical Factors

To ensure the possibility to reduce the oil consumption there will be investments needed in alternative production that can function as a substitution for oil. There might be a need for technical development in order to obtain a system that can replace the advantages of oil. Which alternatives that are chosen will depend on the associated costs such as the cost for raw material, production cost and price on emission rights.

The correlation between natural gas and oil will affect the development of using natural gas to a large extent. A decoupling of these prices can increase the natural gas consumption. Companies and private consumers who own a system based on oil will be directly affected by an increased oil price. Depending on how high the price goes the period of replacement might be long since it might not be economically possible to make changes or replace an already functioning system. A very high price on oil will most likely discourage the investment in a new system based on oil.

A higher oil price and the possible effect it might have on other resources, like natural gas, affect the aim of reducing the consumption by improving efficiency. There is great potential to reduce the consumption with increased efficiency and with further technical development this potential increases. Technical development will also be needed to ensure the supply of heat and electricity without using oil. This might also demand further development of alternative production units such as for example wind mills.

Political & Legal Factors

The political agenda will affect the development in the heat and electricity sector, just as it does in other sectors. Environmental agreements can strongly affect how different governments choose to react towards increased electricity consumption and the alternatives that exist to oil. The involvement and the attitude towards the environment affect how much focus is put on renewable solutions and reduction of the overall consumption. The increased concern for energy security will also affect the political guidance for the energy producers.

The political concern evolves into means of control such as emission rights and taxes which can affect the preferred resources used. Depending on the development on the price of emission rights different alternatives will become more attractive.

Social Factors

Since many households produce their own heat it is critical what the public opinion is about the use of oil or alternatives. If the price on oil increases the opinion against oil might increase but there will probably be a need for incentives to change a functioning system in the household. The opinion concerning alternatives will affect the development of these since some, such as for example nuclear power, are controversial. An increasing use of biomass can change the utilisation of forests and agriculture which might affect the publics' opinion concerning these alternatives. The question on how much money the public is willing to spend on energy from different sources and increased efficiency will be important.

Geophysical Factors

There are many different sources that can be used to produce heat and electricity. The potential for expansion is big, but there is always the concern for optimised usage of resources. The local variations in availability to alternative energy sources will come to play an important role as many regions might have a problem in producing enough energy for its own need.

Economical Factors:

- ➔ Investments needed in alternative production
- ➔ Investments needed in technical development
- ➔ Magnitude of cost associated with raw material
- ➔ Cost of emission rights

Technical:

- ➔ Improved energy efficiency in industry and society
- ➔ Access to flexible energy source for top-load generation
- ➔ Technical development in alternative energy production units

Political:

- ➔ Ambition to follow environmental agreements
- ➔ Attitude towards environmental impact
- ➔ Attitude towards energy solutions
- ➔ Attitude towards energy security

Legal:

- ➔ Emission rights
- ➔ Taxation policy on energy sources

Social:

- ➔ Public opinion towards utilization of alternative energy sources
- ➔ Attitude towards energy behaviour
- ➔ Public opinion towards change in forestry and agriculture

Geophysical:

- ➔ Access to alternative energy sources

11.2 General Key Factors

Many of the factors that have an impact on each of the specific areas can be put in general terms. The main factors that can be seen to have an effect on the consequences of a high oil price are factors such as the availability and technique to use alternative raw materials in order to replace the current oil, the technical possibility to reduce the usage of oil, the attitude among governments and the public toward the environment and the oil dependency as well as the willingness in companies to invest and develop their way out of oil based processes and products.

Economic Factors

Economical factors will decide if alternative solutions to oil can and will be further developed. The research and development of production facilities will require large investments to be made both from private investors, companies and governments. The access and magnitude of capital resources affect the path that is chosen. In connection with the fundamental investments there is also the magnitude of the extra costs that are associated with alternatives. These costs will have to be less than the effect of the increased oil price in order to guarantee the legitimacy of the alternative.

Technical Factors

Technical factors that will have an impact are the possibility to increase energy efficiency and use of oil in existing processes and industries. If less oil is needed it will be easier to substitute and the effect of the high oil price will be less. The technical development in production of alternatives will be crucial in order to ensure cheap and effective production.

Political & Legal Factors

Political factors will play an important role to direct the impact of the oil price. The environmental ambition of governments, their attitude towards environmental impact of alternatives, energy solutions, energy security as well as land utilisation can guide the evolvement of events in directions that are not presently attractive or possible. This guidance can be done through the use of legal means such as taxes, fees and subsidies.

Social Factors

One of the strongest forces can be the opinion of the public. If a high price is accepted, and no call for alternatives made, this will affect the economical prosperity. If there on the other hand is a large demand for alternative resources such as bio-based substitute, the request for increased production in agriculture and forestry will be demanded. Along with this increase of demand the public's opinion regarding a change in forestry and agriculture will also become important. The final great impact the public will have is that if a change in energy behaviour occurs this will imply drastic changes in oil dependency and thereby the possible effect of a high oil price.

Geophysical Factors

If the substitution of oil becomes interesting for companies and the public it is essential that there is access to the required raw material. The availability of land and the possibility to generate sufficient output from these areas will be crucial in the building of a new industry and oil independent economy. Likewise will the adaptation of infrastructure be an important factor that determines the possibility for expansion of alternatives to oil.

11.3 Possible directions

All of the factors mentioned in this chapter can be summarized into two main directions of development. Both of these developments will be driven by the thought that the economical consequences for the individual or company can be minimized. This minimized cost does not have to be instant but can be seen in a longer perspective as for example environmental costs. The two directions will probably not be developed on their own but parallel to each other. The two directions are:

- Development of oil replacing energy sources
- Increased efficiency

The development of oil replacing alternatives will help to keep down the effect of the increased oil price as they substitute the oil. This substitution will to some extent make it possible to sustain the current way of living and operating. The evolvements within this direction will depend on the access, availability and nature of resources that can substitute the oil. This direction is connected with both the economic, technical, political & legal as well as social and geophysical factors as previously mentioned. What possibilities there are and what choices that are made will depend on these factors. Some of the resources that currently possess the largest potential to replace oil will be further addressed in Chapter 12.

The increase in energy efficiency will not stand in the way for development of alternatives but rather be developed side by side. Along with increased efficiency the dependency and requirement for oil will be reduced making the effect of the increased oil price less. This direction will be pushed forward as companies and the public realize that money can be saved as a consequence of these efforts. Also in this direction all the factors previously mentioned will have an effect. This direction will be further addressed in Chapter 13.

12 Oil Replacing Energy Sources

In this chapter some of the possible oil replacing resources will be discussed. Depending on which alternative resources used as the oil price gets high, the consequences of a high oil price will be different. The resources discussed are both renewable and non-renewable. Some examples are given to approximate the potential for the different resources.

When the price on oil is increased, alternative resources gets more interesting. The choice of alternatives can either be renewable or non-renewable sources of energy. The choice of alternative resources to reduce the oil dependency can greatly affect the consequences a high oil price has on society. Factors such as environmental impact, security of supply and costs will differ depending on energy resource. In this chapter the energy resources with the greatest potential to reduce the dependency on oil within ten years is discussed. In order to show the extent of this potential some examples of calculation are given. These calculations are very general in the nature and only used to visualize relationships.

The potential to replace oil with other sources is great, as mentioned in Chapter 8-10. However, not all sources are possible or suitable for all applications. In Table 12.1 a summary is shown of how different resources can be transformed into different fuels. The mentioned resources are those that currently have the largest potential of being commercialized until 2015. In this chapter the different energy sources and their possibilities to replace oil is further discussed.

Table 12.1: Primary energy resources and automotive fuels.

Area of application / Resource	Chemicals	Heat & Electricity	Transportfuel				
			Synthetic diesel	DME	Ethanol	CNG	RME
Coal	x	x	x	x			
Natural gas	x	x	x	x		x	
Nuclear		x					
Solar		x					
Hydro		x					
Wind		x					
Biomass							
Wheat	x	x			x		
Soy beans		x					
Corn	x	x			x		
Willow	x	x	x	x	x		
Black liquor		x	x	x			
Wood	x	x	x	x	x		
Forest thinnings	x	x	x	x	x		
Organic waste		x				x	
Rape		x					x

12.1 Non-renewable Energy Sources

Non-renewable energy generates from sources that can not be reproduced within a reasonable time frame. This is because the source has been produced during thousands of years or is a base element. The main problem with the non-renewable sources of energy is that they contribute with non-desired waste products when combusted as well as the fact that they will eventually run out.[285]

12.1.1 Coal

Today coal provides about 22 percent of the world energy supply and is the most important fuel for electricity generation[286]. Coal can be converted into liquid transport fuels and thereby be used as a supplement to crude oil, see Section 8.5. Coal can also be used to produce other traditionally oil based products such as plastics and solvents.[287]

The world proven coal reserves are large and widely dispersed, see Figure 12.1. Over 40% of the world's coal reserves, equal to almost 200 years of current consumption, are located in OECD countries.[288] In energy equivalent terms the energy content of the coal reserves exceed the combined proven reserves of both oil and gas by a wide margin[289] even though it has lower energy content per weight unit than both oil and natural gas[290]. The retrieval of coal is also relatively simple in comparison to that of oil and natural gas.[291] The transport cost accounts for a large part of the price of coal. Therefore the coal market has traditionally been divided in two, between the Atlantic and the Pacific. These markets tend to overlap when the price on coal is high and the price on transport is low. [292]

The use of coal has extensive impact on the environment, both through the mining process and the pollution it emits when burned. An important step in reducing CO_2 emissions from coal burning has been to improve the thermal efficiencies of coal-fired power stations. A wider use of technologies to improve the environmental performance of coal will be essential if coal is to be used as a future fuel. This is particularly true in developing countries where the use of coal is thought to increase largely.[293] Currently the emissions from coal in kilograms of emission per TJ of energy consumed are 359 kg NO_x, 731 kg SO_2 and 1 333 kg particulates to be compared with 142 kg NO_x, 430 kg SO_2 and 36 kg particulates for oil.[294] When comparing the emission levels of carbon dioxide in the production of 1MWh of electricity coal emits 1020 kg where as oil emits 758 kg[295].

An example of alternative fuel

In Vancouver American Clean Coal Fuels has plans to build a € 1.14 -1,37 billion[296] CTL plant that will produce 1355 million litres/year of synthetic diesel using 4,3 million tons/year of coal.[297] This can be related to the US coal reserve of 250000 million tons of coal, see Figure 12.1, and the annual car travelling in the US of 7008 billion pkm (2003). If all this travelling had been done in a V70 using synthetic diesel the annual consumption in the US would be 0,6% of their coal reserve.

For calculations see Appendix 4.

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[285] Boyle, G. (2004)
[286] *World energy assessments: Energy and the challenge of* sustainability. (2000)
[287] Knapp, R. (2006)
[288] *World Energy Outlook 2004.* (2004)
[289] Ibid
[290] Knapp, R. (2006)
[291] *World Energy Outlook 2004.* (2004)
[292] Knapp, R. 2006-10-10
[293] Knapp, R. (2006)
[294] *Survey of energy resources.* 2006-11-01
[295] *Nuclear power and the environment. 2006*-11-08
[296] $ 1 = € 0,76, 2006-12-01
[297] *Gasification news*, 2006-11-15

Advantages

- Large proven reserves
- Different geographical pattern compared to oil and natural gas
- Can be used as an oil supplement
- Easy to retrieve
- Well known source of energy. Has been used for a long period of time

Disadvantages

- Large impact in environment by mining
- High carbon dioxide emissions
- Lower energy concentration than oil and natural gas
- Not renewable
- Great need for new cleaner technologies

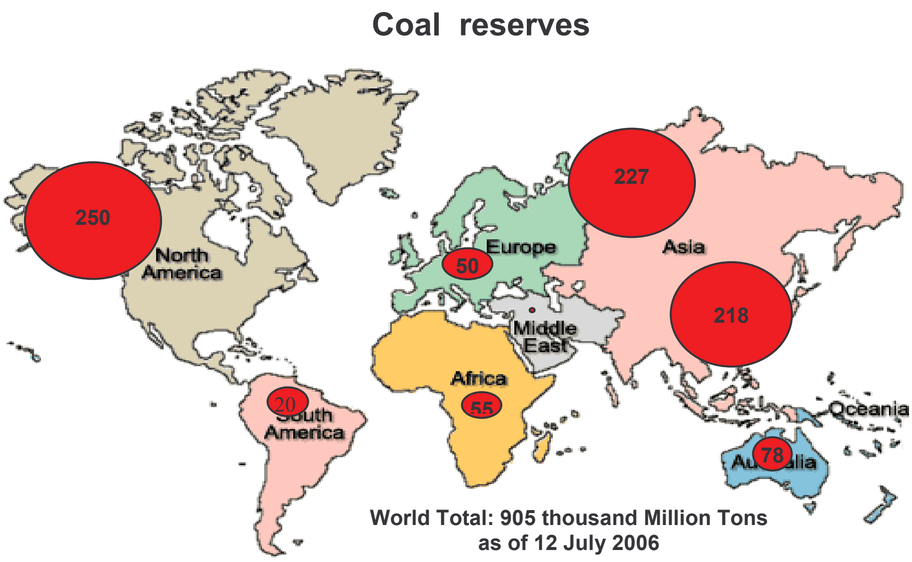

Figure 12.1: World estimated recoverable coal by region and thousand million tons.[298]

12.1.2 Natural Gas

Natural gas was in the beginning thought of as a waste product from oil production but the discovery of its potential soon made it a valuable resource. Although natural gas emits less pollution than both oil and coal, it is still a large contributor of greenhouse gases. In the natural gas industry greenhouse gases are emitted; in the processing and compression of the gas, as fugitive emissions (unintended losses of gas during transmission and distribution), as blow downs (the deliberate release of gas during maintenance operations) and during the use of natural gas during day-to-day operations such as in vehicles or heating.[299] Currently the emissions from natural gas in kilograms of emission per TJ of energy consumed are 43 kg NO_x, 0,3 kg SO_2 and 2 kg particulates with be compared to 142 kg NO_x, 430 kg SO_2 and 36 kg particulates for oil.[300] When comparing the emission levels of CO_2 in the production of 1MWh of electricity natural gas emits 516 kg where as oil emits 758 kg[301].

Natural gas can be seen as an attractive alternative to oil. It exists in large amounts and in somewhat other geographical locations, see Figure 12.2, compared to oil. It has been argued that there is enough gas for the same rate of consumption as today for another 66 to 100 years[302, 303]. The gas can be used as an almost direct substitute for oil in most processes. The

[298] *World estimated recoverable coal.* 2006-10-10
[299] Storm, P. McRae J. 2006-10-11
[300] *Survey of energy resources.* 2006-11-01
[301] *Nuclear power and the environment.* 2006-11-08
[302] *World Energy outlook 2004.* (2004)

current main use of natural gas is power generation[304] but it can also be used as feedstock in the industry, as vehicle fuel and in homes[305]. Both the availability and usefulness of natural gas combined with the decreasing cost of liquefaction and the new generation of LNG tankers makes the gas competitive in cost and availability. As natural gas gets more global due to the increased possibility of transport the gas the market also become global. This can imply a shift from long-term contracts for gas consuming countries, to a market based approach that does not necessarily ensure security of supply.[306] Due to the close link between natural gas and oil their prices are closely correlated, up to 95%. This implies that an increase in oil price also could push up the gas price.[307] Due to the low emissions El Hachemi (2006) believes that natural gas will be a possible solution for countries that wish to keep to the Kyoto Protocol. For countries like the US where coal and fuel oil can be easily replaced the role of gas will be dependent on its relative price.[308]

An example of alternative fuel

A Volvo V70 bi-fuel CNG runs on 8-9 m^3 natural gas /100 km[309]. If all pkm year 2003 in the US were to be driven by this Volvo V70 this would require $6*10^{11}$ m^3 natural gas which can be compared to the US reserve which is about $7,8*10^{12}$ m^3. Each year US would consume 7,45% of their own resources or 0,33% of the total reserves in the world.

Record fuel efficiency has been achieved for the first all-natural-gas hybrid prototype developed by IFP and Gaz de France. This vehicle uses 3.56 KG of NGV, natural gas for vehicles, for 144 km[310] equalling 4,45 m^3 / 100 km[311]. If this car was to be used instead of the V70 the annual US consumption of natural gas would be about $3,11*10^{11}$ m^3 or 3,9% of their own resources or 0,17% of the total reserves in the world.

For calculations see Appendix 4.

Advantages

- Large proven reserves
- Can be used as an oil supplement
- Well known source of energy
- Less impact on environment than oil and coal

Disadvantages

- Emissions
- Not renewable
- Need development in infrastructure

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[303] Storm, P. McRae J. 2006-10-11
[304] Mazighi Ahmed El Hachemi. (2006)
[305] *Natural gas – a fossil fuel*. 2006-11-08
[306] Mazighi Ahmed El Hachemi. (2006)
[307] Capros, P. Brussel conference (2006)
[308] Mazighi Ahmed El Hachemi. (2006)
[309] *Åtgång på naturgas.* 2006-11-15
[310] *Record fuel efficiency for the first all-natural-gas hybrid prototype developed by IFP and Gaz de France.* 2006-11-15
[311] *Åtgång på naturgas*. 2006-11-15

Natural Gas reserves

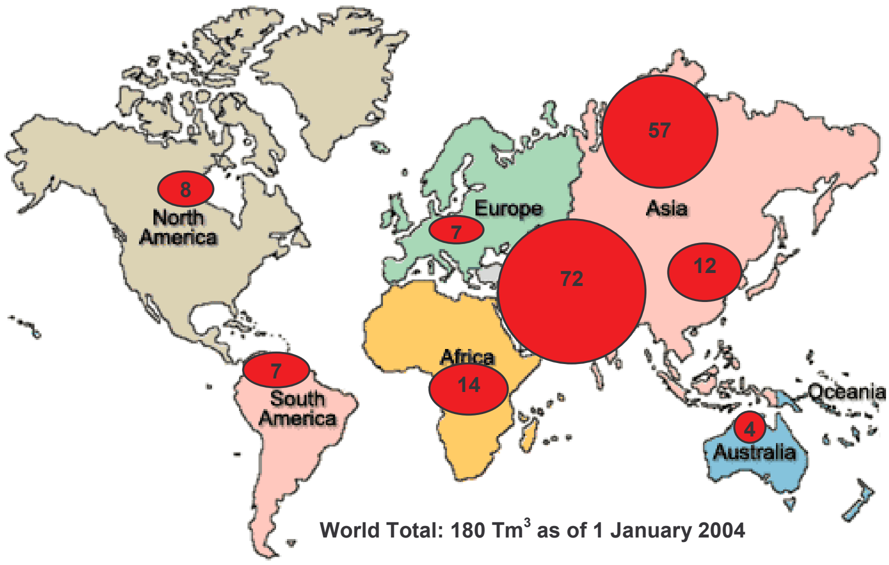

Figure 12.2: Natural gas reserves in terra cubic metres. [312]

12.1.3 Nuclear

Nuclear power is used for electricity generation and is best suited for base-load production. Currently sixteen countries depend on nuclear power for at least a quarter of their electricity. France and Lithuania get around 75% of their power from nuclear energy, while Belgium, Bulgaria, Hungary, Slovakia, South Korea, Sweden, Switzerland, Slovenia and Ukraine get 30% or more. Japan, Germany and Finland on their hand get more than 25% of their power from nuclear energy, while the USA gets 20%.[313] This indicates that the technology by now is vastly spread and that the knowledge and infrastructure exists.

Nuclear power plants have always been heavily debated. Bisconti Research Inc. performed a public opinion survey for the Nuclear Energy Institute in May 2006. This poll showed that the opinion regarding nuclear energy in the US has changed from 49% of the public opposing nuclear power in 1985 to 68% in favour of nuclear power in May 2006. 86% of the US public and 88 percent of US college graduates agree that nuclear energy will play an important role in meeting future electricity demand. Majorities also support renewal for existing nuclear power plants as well as the building of new nuclear power plants.[314] This result can be compared to an opinion survey done by the Eurobarometer for the European Union in 2006. This survey showed that 55% of the citizens in the EU oppose nuclear power but 60% acknowledge the benefits of nuclear power. If the problem regarding radioactive waste was solved 56% of the EU citizens would be in favour of nuclear power.[315] The political view of the EU is however that nuclear power as a source of energy is “less then perfect” and together with coal it is seen as an undesirable source of energy. The debate on nuclear energy is intense and the opinions of experts are often polarised which at times can make the discussions more difficult.[316]

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[312] *World Energy Outlook 2004.* (2004)
[313] *Nuclear power in the world today.* 2006-10-24
[314] Stouffer Bisconti, A. (2006)
[315] Botella, T. et al. (2006)
[316] De Esteban, F. (2002)

There are some major disadvantages with nuclear power. One disadvantage is that uranium is a limited resource however with uranium existing in vast amount this can be argued not to pose any difficulties for many decades. More evident disadvantages are the concerns for nuclear safety and waste storage. Another factor is the risk of spreading the capability of constructing nuclear weapons. The knowledge to design and fabricate nuclear bombs is available to almost every nation however the access to nuclear explosive materials has been a barrier. By spreading the use of nuclear power this material gets more available.[317]

Nuclear energy is relatively clean and cheap and the raw material, uranium, exists in large amounts. In clear cash terms the operating nuclear energy costs are about one tenth of energy produced with coal. For nuclear power plants any cost figures normally include spent fuel management, plant decommissioning and final waste disposal. These costs, while usually external for other technologies, are internal for nuclear power. The time horizon for constructing a new nuclear power plant is approximately 4-6 years which can be compared to a 2 year construction time for a gas plant. The construction cost for a nuclear plant is also larger than for gas or coal plants (3-4 000 million USD vs 412 million USD resp. 800 mill USD) but the operating cost is estimated to be less. An estimated cost for electricity production in EUR cent/kWh is 3.20 for nuclear, 3.05-4.26 for gas and 3.81-4.57 for coal. Nuclear is favourable because of the large, standardised plants used.[318]

Advantages

- Large sources of uranium
- Not geographically dependent
- Effective energy production
- Improving technology generates more energy
- Low level of emission
- Low operating cost

Disadvantages

- Large environmental impact if there is an accident
- High initial cost
- Heavily debated
- Split public opinion
- Waste problem
- Increased risk for nuclear weapons

12.2 Renewable Energy Sources

Renewable energy sources derive from the enormous power of the sun's radiation and can be defined as energy that is replenished at the same rate as it is used.[319]

12.2.1 Solar

Solar radiation can be transformed directly into useful energy through the use of various technologies. The solar energy can be used either through the form of heat or directly as electricity through photovoltaic.[320]

The solar radiation intercepted by the earth equals 173 000 TW, of which 120 000 TW hits the earth surface. Solar energy can therefore be seen as the primary energy source on planet earth and it exceeds the energy demand of man by 8,000 times. The problems with climate change and fossil fuel depletion has triggered a growing interest in solar energy as well as in other sources of renewable energies. The benefits with solar energy are the energy supply

[317] World energy assessments: Energy and the challenge of sustainability (2000)
[318] Ayres, M et al. (2004)
[319] Boyle, G. (2004)
[320] Ibid

security, the improved environment and health of people and the probable assumption that “there will be no need for war over solar energy”.[321]

However there are problems. The solar radiation that reaches the earth is very dilute (only about 1 kW (thermal) per square meter), intermittent (available only during day-time), and unequally distributed over the surface of the earth (mostly between 30° north and 30° south latitude). But these problems can be overcome with the use of different technologies.[322] Other problems connected with photovoltaic are the limited capacity of solar panels and their price. Current panels only have a conversion efficiency of 12-20% of the solar energy into usable energy.[323] A price problem arises as solar panels are getting more popular since the silicon prices are sky-rocketing. Silicon exists in vast amounts, being the second most common element in the earth’s crust but there are only a few producers that can produce the purity required of semiconductor manufacturers and solar panel manufacturers. Governments subsidise solar panels for consumers which results in that the silicon industry does not dare to invest in new production facilities.[324]

Advantages

- Unlimited resource
- Not geographically dependent
- No emissions during usage
- Low operating cost
- Can be used in small scale

Disadvantages

- Limited silicon production capacity
- Currently relatively limited energy transfer
- Expensive

12.2.2 Hydropower

Hydropower is already today a major contributor to the world’s energy supplies and is mainly used as base-load for electricity generation. The technology surrounding hydropower is well known and has been used for over a century. Hydropower is by many regarded as the best renewable source of energy. This is because it is non-exhaustible, non-polluting and more economically attractive than other options. Today hydropower creates electricity at a competitive price and provides a sixth of the world’s energy and 90% of all energy from renewable energy. The number of sites where hydropower plants can be built are finite but today only one third of the sites that qualify as economically feasible are used leaving room for further expansion. One of the disadvantages with hydropower is the local impact that they have on the river, both social and ecological.[325]

Hydropower does not only have to be used as a producer of base-load electricity. Surplus energy from for example wind or nuclear power can be used to pump up water in specially constructed hydro pump-power stations. This water can then later be released when energy is required. The hydropower can thereby function as top-load. This also means that water is pumped up when the price on electricity is low and the energy is then consumed when the price on electricity is high. As these hydropower stations are specially constructed, they are not limited by the same geophysical conditions as regular hydropower stations. The major disadvantage with these power stations is that they are expensive to build.[326]

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[321] Philibert, C. (2005)
[322] Ibid
[323] World energy assessments: Energy and the challenge of sustainability. (2000)
[324] Spencer, J. (2006)
[325] *World energy assessments: Energy and the challenge of sustainability.* (2000)
[326] Feuk, H. 2006-12-05

Advantages

- Large sources
- Effective energy production
- Low level of emission
- Low operating cost
- Renewable source

Disadvantages

- Local environmental impact
- High initial cost
- Dependant on precipitation
- Dependant on local environmental settings

12.2.3 Wind

The wind has been used for thousands of years as a source of energy. It has been used for milling grain, pumping water and other mechanical applications. Today wind turbines in an increasing amount are used to generate electricity. The uneven contribution of energy from a wind turbine makes it most suitable as a producer of base-load. Since wind energy is pollution free, it is one of the fastest growing renewable energy technologies world wide.[327]

The technical potential for onshore wind energy is large, estimated at 20-50 000 TWh a year. Studies from Europe have indicated that the offshore wind resources that are available are larger that the total electricity demand in Europe. Wind power is very attractive due to the limited impact it has on nature. During the production of a wind turbine no exotic material or manufacturing processes are required and the energy pay-back time on a large wind turbine is about 3-4 months. The main environmental aspects during normal operation of a wind turbine are the noise emission and visual impact it generates. With better design techniques the noise can be lowered but the visual impact is here to stay.[328]

Advantages

- Large domestic source
- Low level of emission
- Low operating cost
- Limited environmental impact
- Renewable source

Disadvantages

- High initial cost
- Noisy
- Visually unattractive
- Flickering shadow

12.2.4 Biomass

The potential of biomass is huge. The energy stored in terrestrial biomass has been approximated to be 25 000 EJ. The total energy consumption in the world was 14.3 TW in 2002 which can be compared to the annual rate of energy storage by land biomass that was 95 TW.[329]

Harry J. Gilbert at University of Newcastle has calculated that an estimated 10^{11} tons of plant biomass is produced each year as a result of photosynthesis. The energy content of all this biomass is equivalent to 640 billion tons of oil. The challenge is to find an environmentally friendly way to extract this energy so that is can be used to solve the upcoming energy crisis.[330]

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327 Boyle, G. (2004)
328 *World energy assessments: Energy and the challenge of sustainability.* (2000)
329 Boyle, G. (2004)
330 Proceedings of the US-EC Workshop. (2004)

Agriculture

Since the discovery of oil, farming has become more and more dependent on the energy and products produced from sources such as oil and natural gas. According to Mike Johannes, US Secretary of Agriculture, energy cost is the biggest financial problem facing farmers today.[331]

The farmers are set in the middle of the high energy cost since they face higher productions cost while shippers and food manufacturers are paying more for transportation and manufacturing and thereby reducing the prices they are willing to pay for farm products.[332] Lars Jonasson, PhD in agriculture, says that the agriculture is affected both by the oil price and the price on natural gas. He says that an increase in the price on fertilizer will have the most effect on farming and that this is because fertilizer is their biggest expense, but that the effect from an increase in oil price can not be disregarded due to the use of diesel.[333]

At the same time as the farmers struggle with higher energy costs it also presents an opportunity for extra income. By growing crops for renewable energy farmers can produce energy either for own consumption or to set up for sale. With the increase in energy cost corn ethanol and biodiesel production has become preferred raw material in energy production and is starting to become important both for a countries farmers as well as the countries energy future. [334]

In both Europe and the US[335] initiatives exist to produce renewable energy from biomass. In the case of Europe, surplus crops such as wheat can initially be used as base in European ethanol production and in thermal plants. There is currently a surplus in the European agriculture production that results in a lot of crop never being used neither as human or animal feed. This is a waste of resources that could be limited if the crops were used as renewable energy. Further ahead fallow fields can be used for growing specially fitted energy crops, but since the price on those crops is still relatively low few farmers use this possibility. In Sweden 350 000 hectares were fallow fields in 2003 out of 2,7 million hectares total (13%). From these fallow fields 20-25 TWh could be produced without affecting the current food production.[336] In 2003 there was a total of 10.6 million hectares of fallow land in EU 25.[337] Before the CAP, Common Agriculture Policy, reform in June 2003 European farmers were paid subsidiaries depending on how much crop they grew, what kinds of crops and how much farmland that was kept as fallow land.[338] With the CAP reform subsidies is paid out independently to the volume and type of crop. This opens up the farming industry to market forces and allows for the farmer to produce what is most economically viable.[339]

One of the most energy efficient crops that can be grown is *willow (salix)*. One hectare of a well-managed willow plantation can yield 10 - 12 tons of dry matter per year, with energy equivalent to about 5 000 litres of oil. This can be compared to that 1 kg of willow will generate about 1 kWh of electrical output.[340] Willow is debated because it is regarded visually

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331 Johannes, M. (2006)
332 Ibid
333 Jonasson, L. (2006-09-25)
334 Johannes, M. (2006)
335 Ibid
336 Jonasson, L. (2006-09-25)
337 *Fallow land.* 2006-10-26
338 Jonasson, L. (2006-09-25)
339 *CAP reform - a long-term perspective for sustainable agriculture.* 2006-10-26
340 *Energy from Willow*. 2006-11-01

unattractive by some. However the general opinion of both public and farmers regarding willow will probably change over time as it shows to be a good source of energy.[341]

Other examples of crops currently used as energy crops are *corn, wheat and soybeans*. These crops all have different energy yields generating various outputs as renewable fuels.[342, 343] This variation in yield indicates that it is important to optimize which crop to grow in order to generate the highest possible output. In a communication from the European Commission to the European Parliament they present figures which indicate that the maximum possibility to substitute road transportation fuel with biomass in Europe is 8% of the present European consumption. In this example the production of biofuels was restricted to 10% of agricultural land.[344] Another calculation performed by Pål Börjesson, professor at Lund University, (2005) made estimates that a 5,75% substitution of transport fuel in Europe would require 5- 15% of arable land and a 20% substitution would require 20-30% of arable land[345]. These figures can be put in relation to current fallow field in Europe which is approximately 10%[346] of arable land why this initial production would not compete with food production.

The use of biomass comes with both advantages and disadvantages. One of the disadvantages is when the price on crop increases so does the risk of unbalanced production. This increase in production often occurs in areas where the production is already high. One example is the production of soy beans in Argentina. The strong demand for soy oil to use in diesel has turned large areas of Argentina into soy bean farms. This monoculture endangers the biodiversity in the regional environment. Also the possible future use of restricted areas for farming is a problem. By letting the farmers use restricted areas such as rainforest and local reservations, important habitats and areas decrease in size.[347] This problem with the use of restricted areas for farming is most common in poor countries where the extra income from these crops is important. In the western world the discussion is mostly regarding the possible shortage of arable farmland when energy production becomes a greater challenger to food production. This however does not seem to be an immediate problem as a lot of arable land exists.[348] As the population continues to increase competition between food and energy production might however occur as a high demand for food and forest products will result in less available land for energy farming. Large scale of biomass use can only be sustainable if there is an increase in further agricultural efficiency as well as adoption in the diet of the world population. If all humans were to become vegetarians the land mass needed for food production would be much less and excess arable land could be used for energy farming.[349]

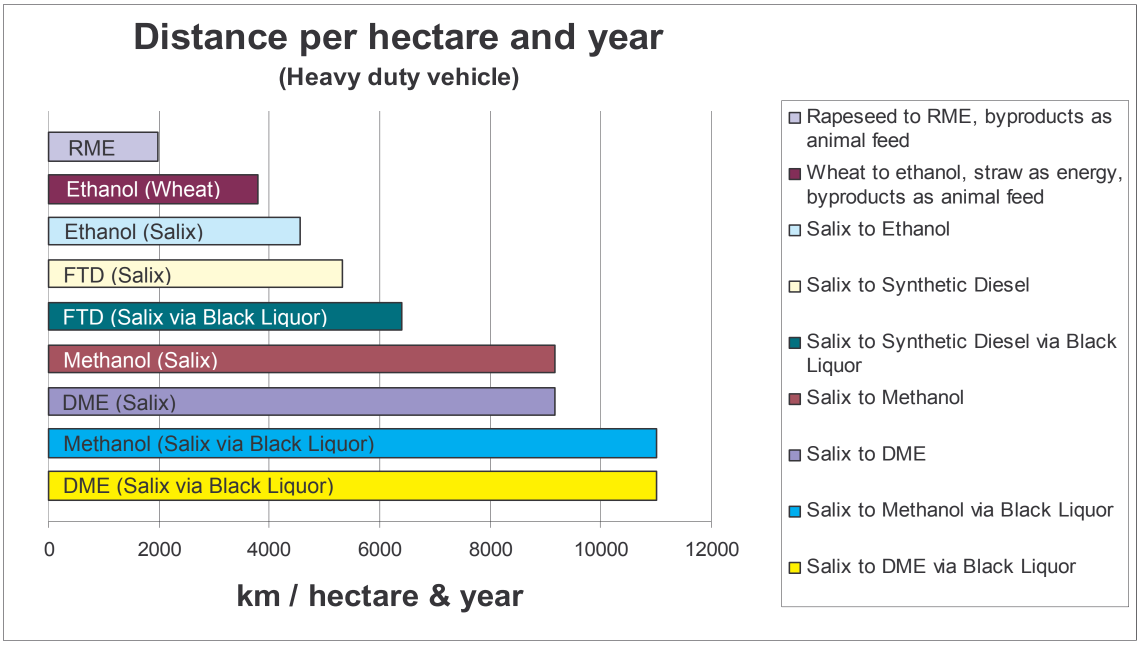
[341] Atterwall, Seminar. 2006-11-06
[342] Haaker, A. (2003)
[343] Bioenergy Feedstock Development Program. (2001)
[344] *Communication from the commission.* (2001)
[345] Börjesson, P. (2005)
[346] Holm-Nielsen, J B. (2006)
[347] *Argentina - The Environmental Costs of Biofuel.* 2006-11-07
[348] Börjesson, P. Seminar. 2006-11-06
[349] Hoogwijk, M. et al. (2003)

An example of alternative fuel

If all US pkm in 2003 were to be travelled with a Saab 9-5 Bio-power (1,27 l ethanol /10 km) which was fuelled with wheat ethanol this would require $3{,}7*10^8$ hectares, ha, of wheat plantations. This can be compared to the entire arable land of $1{,}7*10^8$ ha in the US[350]. This shows that the US can by no means produce enough wheat ethanol to cover their own need of car fuel. The situation is the same in Europe as Europe would require about 240% of arable land to fuel all pkm.

For calculations see Appendix 4.

The output of wheat ethanol for cars can be compared to the distance a heavy duty vehicle can be driven on different bio-solutions. Graph 12.1 shows that the output from different bio-solutions can vary greatly depending on crop and method used.



Graph 12.1: Distance travelled with a heavy duty vehicle depending on bio-fuel used[351].

Forestry

Forestry can be debated to be both the curse and the salvation for the world. A well-managed forest can be a great source for sustainable fuel, capturing CO_2 as it grows and then later provide a substitute for fossil fuel. The use of wood as renewable fuels can however also imply the decimation of the world's major forests and thereby a potential global environment catastrophe. If the wood is removed without control it can bring both economical and environmental problems to countries where it contributes to the industrial energy consumption. In conventional forestry today the energy production is not the main product but it is at least a part of the plan.[352]

Unlike agriculture the forests have not been pushed to maximize output. Within agriculture there has been a tradition for over a thousand years of cultivating the crops in order to increase the output. The same tradition has not been present within forestry. The finding of

[350] *United States – Total croplands.* 2006-11-16
[351] Willkrans, R. (2006)
[352] Boyle, G. (2004)

the gene that controls the blooming in some trees has however now opened up for more efficient ways for cultivation. The output in forestry can also be increased by the use of fertilizers just as in agriculture. This is currently not so common in forestry.[353] The aspect of fertilizers used in forestry is discussed between those who want to mainly increase the output of the forest and those that are concerned about the extra leakage of the fertilizers resulting in eutrophication of surrounding waters and increase in GHG.[354] These two aspects of increased cultivation and fertilizing would make it possible to increase the output of the forests but this can also be done by a higher usage of existing logging residues.[355]

Within the forest industry it is commonly believed that the increased focus on renewable energy sources will increase the request for forest products during the nest 20 years. Above all an increase in demand for small-sized round wood is expected. The factor that will have the most impact on the forest industry is the encouragement (e.g. subsidies) granted by governments to promote the use of wood as fuel. The lowest cost sources of wood for energy production are likely to be residues from the wood processing sector. These residues are already used for energy production at some sites. The next most cost-effective sources of wood fuel are likely to be forest residues and thinning, followed by tree crops grown specifically as energy crops. [356] One example from Sweden is presented in a doctorate thesis from SLU in Uppsala that states that the Swedish forest and agriculture has the possibility to produce 188,9 TWh, out of which 23% would generate from black liquor and 14,8% from agriculture. This energy would be enough to cover 40% of the electricity need in Sweden or 90% of the required fuels in the country.[357] This however must be put in perspective with the fact that Sweden has a much higher level of forest then EU and the USA on average. With the increased use of wood as biomass the competition for good quality forest products increases causing competition between traditional paper and wood industries and energy producers[358].

Black liquor is one of the most energy intense bio products that exist. Black liquor is a liquid by-product from pulping that contains water, cooking chemicals, lignin and other wood components. Approximately half the wood ends up in the black liquor and therefore the liquid is high in energy content. Black liquor has a heating value of 14 MJ/kg to be compared to 42 MJ/kg for oil. The production of black liquor is today equal to approximately 600 TWh whereof about 39 TWh is produced in Sweden and 350 TWh in North America. Converted into fuel the cost/km for methanol from black liquor would be about the same as for gasoline before tax.[359]

Advantages

- Large resources
- Not geographically dependent
- Increases possibilities for profitable agriculture
- Low level of emission
- Renewable source

Disadvantages

- Voluminous
- Low energy efficiency
- Threatened biodiversity
- Increased competition for land

[353] Linder, S. Seminar. 2006-11-06
[354] Nilsson, O. Seminar. 2006-11-06
[355] Börjesson, P. Seminar. 2006-11-06
[356] United Nations. (2006)
[357] Hagström, P. (2006)
[358] *Etanolsatsning slår mot skogen.* 2006-11-24
[359] *Black liquor gasification – the fast lane to the bio refinery.* 2006-11-01

12.3 Summary

As exemplified in this chapter there are many resources available to replace oil if desired. However, there are advantages as well as disadvantages with all of them. Coal and natural gas have the advantage of being energy efficient and easy to retrieve but at the same time they are non-renewable resources and they emit greenhouse gases when combusted. Since natural gas and oil can easily be used in the same application their prices are closely correlated, why an increased oil price probably will render in an increased price on natural gas.

Nuclear power does not have the same emission problem as coal and gas but on the other hand nuclear energy is closely connected to waste problems and the risk of large accidents. Nuclear energy is expanded but by many regarded as a “less than desirable” source of energy.

The main problem with renewable sources is that even though large amounts of energy exist, it is often hard to retrieve and store. If these problems are solved there is large potential to develop a sustainable solution. Solutions with biomass such as DME and ethanol has the advantage that they can be transported and stored but the relatively low energy efficiency, in foremost ethanol, results in that more than available land areas are required to cover even the current need.

13 Efficiency

In this chapter the potential for reducing consequences of an increased oil price through improved energy efficiency is discussed. Both investigated potential in the EU and the US is covered.

The work with energy efficiency can be seen both as a way to help the environment and a way to make the industry competitive in a situation of increasing energy costs. Still it is thought that the market alone will not enable the community to make the necessary energy savings. Today the prices of electricity and petrol do not reflect the genuine cost of this energy to our society. Neither do they encourage consumers enough to take advantage of all, or part, of the savings that are available.[360] Energy resources are becoming scarce and the EU is facing a growth in energy consumption. This makes the EU introduce goals for improved energy efficiency. As renewable resources will not be sufficient to cover present needs of oil and gas, saving energy is the easiest, most rapid and most effective way to change the energy dependence and reduce damage to the environment.[361] Also the US is looking into what potential there is to reduce the use of energy by improved efficiency.

13.1 Reduced Oil Dependency

One country that is strongly promoting the reduction in dependency on oil is Sweden. According to the Oil commission in Sweden, one of the most important aspects when reducing the consumption of oil is to become more efficient in the usage. In commission's report they propose four main targets in year 2020:[362]

- reduce energy consumption by 20%
- reduce the consumption of petroleum and diesel by 40-50%. 2/3 of this reduction is to come from an improved car pool and 1/3 through the use of bio fuels
- no oil is to be used in heating of homes and buildings
- reduce the oil consumption in the industry by 30-40%.

The commission points out that these reductions can not only come from substitutes such as biomass but must also come from active considerations regarding energy consumption. One example is the transport sector in Sweden which could be made more energy efficient through a larger use of new and energy efficient cars, route planning and an increase in train and sea transport as well as public transport.[363]

13.2 Energy Reduction in the European Union

On EU-level there is an ongoing discussion regarding energy saving and increased energy efficiency. This reduction in energy usage is not specifically targeted at oil reduction as in the Swedish case but a reduction in energy dependency will in the long run reduce the effects an increasing oil price will have on the society. The Green Paper, *Doing less with more*[364], published by the commission in June 2005 addresses many of the concerns regarding energy

[360] Saving 20% by 2020. 2006-11-10
[361] Ibid
[362] Edman, S. Seminar. 2006-11-06
[363] Ibid
[364] *Doing less with more.* (2005)

and oil dependency of the European Union but it also opens a door talking about the potential of energy savings through different initiatives and legislations.[365]

Some examples of current European legislations on energy savings are:[366]

- Directive on energy performance of buildings
- Directive on the promotion of cogeneration
- Directive for the taxation of energy products & electricity
- Directives on energy efficiency requirements for boilers, refrigerators and ballasts for fluorescent lighting
- Directives for labelling of electric ovens, air-conditioners and refrigerators and other appliances
- Regulation on Energy Star labelling for office equipment
- Directive on Eco-design requirements for energy using products
- Directive on energy end-use efficiency and energy services

The potential of energy savings in Europe is assumed by the European Commission to be at least 20%, which is equal to the total energy consumption of Germany and Finland together[367]. Table 13.1 shows estimations done by the European Commission regarding the potential energy saving in different sectors in Europe by 2020.[368] These estimations indicate a great potential to reduce the current energy need.

Table 13.1: Energy consumption and the potential for energy saving in European Union. [369]

EU Efficiency Potential

Sector	Energy consumption (Mtoe) 2005	Energy Consumption (Mtoe) 2020 (Business as usual)	Energy Saving Potential 2020 (Mtoe)	Full Energy Saving Potential 2020 (%)
Households (residential)	280	338	91	27%
Commercial buildings (Tertiary)	157	211	63	30%
Transport	332	405	105	26%
Manufacturing Industry	297	382	95	25%

The most important barrier to increased energy efficiency is a lack of information causing problems when making long term investments and also unnecessary technical obstacles. If this barrier can be overcome and energy conserved estimations made by the German Council for Sustainable Development shows that more than 2 000 full-time jobs could be created for each million tons of oil equivalent that will be saved as a result of measures and/or

[365] *Doing less with more.* (2005)
[366] *Saving 20% by 2020.* 2006-11-10
[367] *Doing less with more.* (2005)
[368] *Saving 20% by 2020.* 2006-11-10
[369] Ibid

investments specially taken to improve energy efficiency as compared to investing in energy production.[370]

13.3 Oil Saving Potential in the US

It is not only in Europe the concern for oil and energy dependency exists. In the US the American Council for an Energy-Efficient Economy, ACEEE, works towards presenting the economical and environmental benefits that can be reach through more energy efficient solutions. They state that even though investments need to be done in order to achieve energy saving there will be a relatively short payback time on these investments at the same time as the country reduces its dependency on foreign sources of energy. The ACEEE, work with three different scenarios regarding the potential for oil reduction. These scenarios represent; a modest, a moderate respectively an aggressive use of means of control and efficiency measures in order to achieve oil reduction. As presented in Table 13.2 they recognize a potential to save oil in all sectors even with modest efficiency measures taken. All in all, the ACEEE recognizes the possibility to reduce between 6-13% of the total oil consumption in the US by 2015 or between 11 – 21% in 2020. If no measures are taken the US is expected to reach a consumption of 23,3 million barrels per day in 2020.[371]

Table 13.2: Oil saving achievable with selected efficiency measures in three scenarios.[372]

US Oil Saving Potential

Sector	Modest		Moderate		Agressive	
(Million Barrels per Day)	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
Transportation	1.27	2.32	1.63	2.97	2.39	4.2
Industry	0.24	0.32	0.39	0.54	0.64	0.9
Residential and Commercial	0.02	0.03	0.08	0.13	0.13	0.19

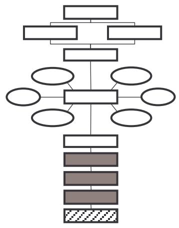
13.4 Summary

Both in the EU and in the US, studies have been made to assess the potential for improved efficiency as well as reduction in oil dependency. With improved efficiency it is possible to sustain the current way of living, but with lower consumption of energy. All the energy consuming sectors have been included in these studies and all are considered to have possibilities to improve. In the study regarding potential oil reduction, made in the US, the sector with largest potential was the transport sector. In the EU study overall energy efficiency was investigated. Basically all the different sectors had the same potential for reducing their energy consumption, but then all types of energy were included. Commercial buildings were considered to have the greatest potential for reducing their energy consumption.

[370] *Doing less with more.* (2005)
[371] Elliott, R. et al. (2006)
[372] Ibid

14 Analysis

In this chapter an analysis of the possible consequences of an increased oil price is made. The analysis is based on three possible developments; business as usual, use of alternatives and increased energy efficiency. These developments all pose challenges to the three sectors; transport, non-energy use as well as heat and electricity, causing consequences of the increase in oil price on society.



This analysis chapter includes Step 6-8 in the scenario model as shown in the figure on the right. It is followed by the scenario, which is the last step of the scenario model.

We have for some time been, and are still, living in an oil based society. Our entire economy is built on cheap and accessible energy. This cheap energy has allowed us to increase the living standard of the western world. This has led to the major role energy plays in our society, which means that a disruption or change in supply of this cheap energy, resulting in higher prices, will have major consequences. The role oil plays as a major contributor to the energy in the western world has changed since the 1970s as the western world tried to limit the use of oil due to the oil crises. As mentioned in Chapter 6 these oil crises in the 1970s were abrupt and caused by conflicts, resulting in an oil price chock, which pushed the global society into economical recession. Today there is also an increase in oil price but this time the increase has been of a more steady nature, not as high and based on other factors such as mainly shortage in production capability and increase in demand. The effects caused by the increase in oil price has not been as hazardous this time around, as the more steady increase has given the society a better possibility to cope with the increase and adjust. The effects have also been reduced thanks to the increased awareness of governments on how to deal with this issue. Today the reactions from governments are not as strong as before and the use of, for example increased taxes and "tax-cushions", has reduced the oil's ability to shock. However a substantial increase in oil price is likely to affect the society today as well, as oil is still important in many applications, foremost transport. The consequences of an oil price increase from \$60 to \$300/barrel, see Figure 14.1, in 2015 can differ greatly depending on how society reacts. The consequences will also vary between the different industries and sectors in our society.

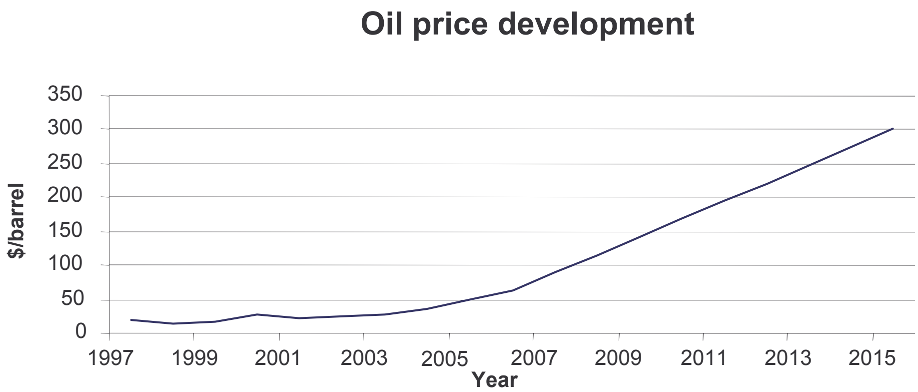
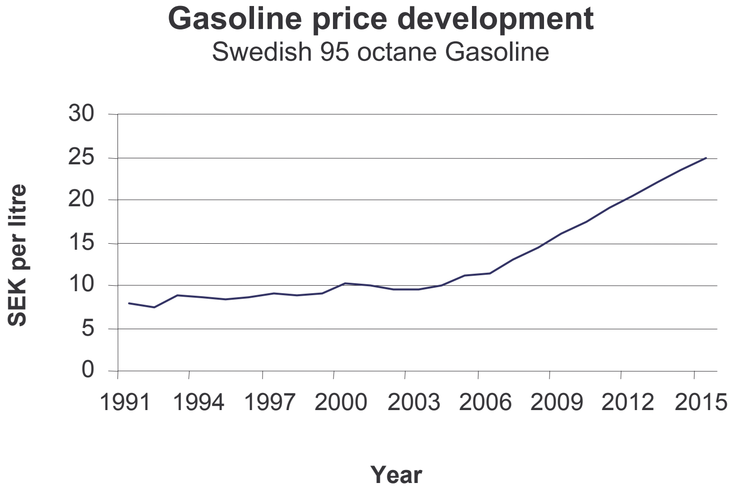


Figure 14.1: Fictive oil price development. [373,374]

[373] Fictive price development has been calculated by extrapolating current price to estimated oil price
[374] *OECD Economic Outlook No. 76 (2004)*

Along with the increase in oil price follows an increase in gasoline price, see Graph 14.1. This change in gasoline price will, in Europe, be a 118% increase between 2006 and 2015 which can be compared to the gasoline price development of 28% between 1997 and 2006.



Graph 14.1: Fictive gasoline price development.[375]

In this thesis we see three possible developments that can either act alone or be incorporated in each other. These directions are the most significant directions identified. The initial one can be considered a base case as it presumes no major change in pace to current developments. The other two developments were identified when analysing the key factors as presented in Chapter 11. They represent two possible ways to reduce the consequences caused by an increased oil price. As no other significant developments have been identified these three developments have been analysed:

1. Business as usual – No measures are taken, the increased cost for oil is incorporated in society.
2. Use of alternatives – Alternative solutions from alternative resources are developed and implemented.
3. Increased energy efficiency – The use of oil is decreased through efficiency.

14.1 Business as Usual

If business is carried out as usual no extra measures are taken to meet the increase in oil price. The ever ongoing increase in price will instead be incorporated in society. This results in that no major changes are done, either in the use of raw material or in the effort of becoming more efficient. There are, however already today actions in motion in the society working for a reduction of fossil fuel and increased energy efficiency, such as emission rights. These actions will continue but only at current rate.

If business is carried out as usual in the *transport sector,* the increase in oil price will have an immediate effect since prices for gasoline and diesel increase. An increase to $300 would imply a gasoline price of € 2,64/litre[376] in Europe and somewhat less in the US, assuming taxes are kept at present levels. The price increase on crude oil does not only affect gasoline and diesel but all sorts of transport fuels, such as fuel for air and boat transports. This means that transports, in general, become more expensive resulting in goods with a high fraction of the final price connected to transport will be greatly affected. The distance these goods can be

[375] Fictive price development has been calculated by extrapolating current price to estimated gasoline price.
[376] 1 SEK = € 0,11, 2006-12-01

economically transported will be shortened. This can result in more local production of low value and bulk goods benefiting from the natural boundaries evolving. High value goods might have a higher capability of carrying the increased cost for transport. The increase in gasoline and diesel prices will also have a major impact on the general public. A larger part of their disposable income will have to be used for transportation to ensure their present level of movement. Their flexibility and freedom to travel will be limited. With these higher expenses less money will be left for consumption of other products. The pressure on the personal economy may increase the demand for higher salaries. These increases in transport cost will probably render in lower demand for transport in the industry as well as a reduction in private transports in the general public.

In the *non-energy use sector* the price on raw material will increase. This cost can either be transferred to the customer or absorbed within the company. Already today companies such as Icopal and Borealis have chosen to absorb the higher cost on raw material instead of transferring it all to the customer. This means that the companies with possibility to further reduce their margins will be those to survive. If the price, however, increases up to $300/ barrel there is probably no possible way for the companies to absorb the entire amount which will mean an increase in the price on the products. This results in that plastics will no longer be the cheap and accessible material that we have come accustomed to. With higher consumer prices the demand for products will be lower as the disposable income is even further reduced. Along with the reduction of the disposable income comes the need for prioritising between different goods and services.

In the *heat and electricity sector* the direct connection with oil is limited, at least for the large energy companies. However as the large energy companies often use oil for top-load and marginal pricing is used, an increased price on oil will result in higher cost for heat and electricity especially in times of shortage. Industries and home owners are more dependant on oil due to the use in their own heat and electricity generation, and they will therefore probably have to endure much higher costs since a transition to alternatives can be costly and difficult to implement. The correlation between foremost oil and natural gas but also other energy sources will push up the overall price on energy. This increase in energy price will affect the overall energy consumers but probably not as much as those who are totally dependant on oil and natural gas in their individual systems. Energy-intensive industry will suffer since a large part of their production cost relates to energy cost. This will in extension result in industries closing due to no profit. Heat and electricity represents a basic need that must be satisfied. The consumption can in many parts be reduced but not eliminated which implies that electricity will always be one of the priorities for industries as well as the general public.

In general terms a business as usual approach will dampen economic growth. Depending on how the different governments react, the inflation might rise and a recession start. The flexibility of the different economies will determine to a certain extent how much the different countries will be affected. The economical transfer from oil importing countries to oil exporting countries will increase. This will in the beginning be beneficial for the oil exporting countries, but with rising price the demand will be lowered and in the longer run even those countries will experience the effect of a stagnating global economy.

Consequences of an increased oil price with a business as usual approach can be:

- increased cost for feedstock
- increase cost for heat and electricity
- reduced margins for companies

- increased costs for commodities and services
- reduced economical activity.

14.2 Use of Alternatives

If the price on oil increases the use of alternatives will expand. The increased focus on alternatives will be accepted in society and the major change in utilization of resources will be directed away from oil. This increased use of alternatives is aimed at substituting the oil to sustain current ways of living. The resources that can be used to substitute oil are many, and there are already today existing technologies that make it possible to replace oil in most applications. At a gradually rising oil price from current $60 to $300/barrel in 2015 there will be break points between the cost for oil and the cost of alternatives. Since most companies make cost efficient choices when possible it can be presumed that the oil will be substituted with alternative sources some time after this breaking point is reached.

In the *transport sector* there are numerous possibilities of replacing oil. The resource currently used for transport fuel is almost only oil which means that major changes will be necessary in a transition to alternatives. The main question here is which alternative is the most economically beneficial in terms of initial cost for production facility, production cost, cost for distribution infrastructure as well as cost and availability of raw material. The technical development will play an important role in determining which alternative will be the most available. A known and tested method might be invested in, instead of more unsure methods due to the lower risk. This might result in expansion of a solution that is not optimal with regard to net energy yield. An increased pressure for alternative fuels will increase the rate at which production capacity and infrastructure for alternative fuels is built. When it becomes possible for the public to purchase alternative fuels at a lower cost then traditional fuels the rate of transition between these fuels will increase. This implies that with an increased cost for oil targets regarding the percentage of alternative fuels consumed will be reach earlier then otherwise.

The main resources considered today for transport fuel are natural gas, coal and biomass. If biomass is chosen to substitute all oil currently used in fuels, almost all arable land will have to be used as mentioned in Section 12.2. This indicates that biomass alone can not cover even our current need for transport fuel. This further implies that coal and natural gas will come to play a big role if all transport fuel is to be substituted. Another consequence of the increased use of alternatives is that a change in infrastructure will probably be needed. Not only the distribution infrastructure will have to be changed but a change is also needed in the vehicle fleet. The cost and the extent of these changes will depend on which alternative will become the most commonly used. The local expansion of the different alternatives will depend on the different local conditions.

In the *non-energy use sector* oil and natural gas are currently the most common feedstock. As in the transport sector other alternatives are currently used to a limited extent. The increased price on oil will not only affect the oil based industries but also those who use natural gas. This is because of the close correlation between the price on oil and natural gas. The use of alternative feedstock will probably increase if the oil price goes up and stays on a high level. This will increase the amount of bio-plastics on the market. However, the timing at which alternatives starts to increase will to a large extent depend on when the willingness to invest occurs. Companies with direct relations to sources of oil and natural gas might tend to wait longer with these investments. If the correlation between the price on natural gas and oil does not continue in the same manner as today, the transition from oil to natural gas might be easier than the transition from oil to renewable resources. The possibility to switch to natural gas is dependant on the access to this resource.

In the *heat and electricity sector* many different sources of energy are already used today. This makes it easier for this sector to switch to alternatives. The large energy producers have a diverse mix between energy sources, making them less dependant on oil, than for example a smaller industry with oil based heating system. The oil used in large energy producing companies, however, fulfils a specific need through the flexibility given by oil. This flexibility can be difficult to find in other sources. If no alternative is found the consequence of a high oil price will be a considerably higher heat and electricity prices due to the nature of marginal pricing. When considering which alternatives will be used instead of oil, different means of control can affect which direction is chosen. Currently coal and natural gas are used to a large extent in this sector but there are means of control, such as company related emission rights, that can guide away from these fuels. Today the system of company specific emission rights is only used in Europe. The development of CCS can offset the limitation emission rights have on the use of fossil fuels since if implemented the need for emission rights will be diminished.

In general the approach of a transition to alternatives will raise issues concerning the use of resources. It is probable to believe that the use of natural gas and coal will increase as they exist in large amount and offers a good possibility for substituting oil. This transition will, however, be costly due to the required expansion of infrastructure. The consequences of this increased use will be that the high level of emissions of greenhouse gases will continue or even increase. This can, however, be avoided if CCS becomes a commercialized method, which is not likely before 2015. If natural gas and coal are used to substitute oil, this will allow the dependency on fossil, and therefore limited, fuel to continue. An increased price on oil can also increase the demand for biomass, which will render in competition for land. This competition will as a second hand effect raise the price both on food and on energy crops. Land is also a limited resource, in terms of that there is a maximum output that can be produced. If this limited resource is heavily utilized it can result in a decreased biodiversity and proper use of land might also be threatened. Farmers will probably gain from this transition from oil to biomass, as they become the new “energy-provider”. This can imply an upturn for a sector that today is experiencing some difficulties, as the “black” gold is replaced with “green”. Which alternatives are chosen to replace oil will depend on the cost associated with them, but also how governments choose to control the development. Since most of the resources that exist as alternative to oil are more difficult to transport in an energy-efficient manner it is probable that local energy solutions will be developed based on local conditions.

Even if both non-renewable and renewable resources are used to a maximum extent the cost for energy will be higher than the current cost for energy from oil due to the large investments needed. These investments will however help to keep the economy active. Due to these investments a consequence of the increase in oil price is that most things consumed in society will be associated with a higher cost. This increase in general cost will push for a change in consumer behaviour even with the use of alternatives. The use of transport will probably decrease or change in nature which will call for more local production and trade. However, even though there might be an increase in local production the economy of scale will also increase in importance as margins will have to be pushed pointing towards the survival of large industries on the cost of smaller ones. The limitation in resources will force industries and societies to introduce system engineering in their operations in order to utilize all available energy in the resources.

Another important consequence of the transition from oil to alternative resources will be the transitions of dependency away from oil producing countries. Through a more diverse use of energy sources the security of energy supply can be met from an increased number of locations and countries changing the political relations and trading patterns of today.

Consequences of an increased oil price with introduction of alternatives can be:

- increased use of natural gas and coal which will probably lead to an increase in emission of GHG
- increased use of biomass which will probably lead to challenge in the ecosystem and competition in the use of land resulting in higher food prices
- risk of negative economical effects due to limited access to commercialized alternatives
- investments in production capacity
- change in energy security pattern.

14.3 Increased Energy Efficiency

As the price on oil increases it will be financially beneficial to work with improved efficiency. This efficiency can involve improved usage of raw material, heat and electricity and transport fuel. The work with efficiency must be accepted both in the industry as well as by the public since this is the only way in which this approach can have a substantial effect. With improved efficiency the current way of living can be sustained to a certain degree since there will be a smaller need for oil for the same way of living.

In *the transport sector* there is large potential for reducing the consumption of oil through efficiency. This is partly due to the transport sectors extensive use of oil in fuel but there is also large potential for reducing the consumption per km driven. With increased engine efficiency, hybrid technology and reduced idling the change can be substantial and is likely to reach a total fuel reduction in the transport sector with about 20 - 25%, as mentioned in Chapter 13. These solutions are mostly a matter of better and increased use of technology, but also a change in logistics and the way of driving can reduce the transport sectors oil consumption. The consequences of a higher oil price will be that when these efficiency solutions are cost beneficial a transition will start. To obtain the possible efficiency improvements in this sector investments are needed, in some cases of substantial nature.

In the *non-energy use sector* the potential for reducing the oil consumption is not as large as for the transport sector. The non-energy use sector does not consume as much oil as the transport sector and the efficiency potential is smaller. The main efficiency potential in the US is increased recycling. This is already done in Europe which means that the additional potential is smaller here. In the US an increased recycling of plastics from 5% to 57% would mean a reduction of total feedstock needed of around 12%. Another area for improved efficiency in the non-energy use sector is the improvement of processes. With improved processes a reduction of waste products can be obtained and thereby reduce the overall consumption, but since this reduction probably is very small compared to the overall oil consumption it will not affect the possible consequences of a higher oil price.

In the *heat and electricity sector* the potential for increased energy-efficiency is large. There are large potentials to reduce the energy consumption in buildings and industries. In those industries and households that generate their own heat and electricity with oil, improved energy efficiency will directly reduce the consumption of oil. Through this reduction in oil consumption the effects of an increased oil price will be reduced with regard to the specific industry or household. The general increase in energy efficiency will however not mean a substantial decrease in oil consumption since it only represents a minor fraction of the energy sources used by large energy producers. Although the use of marginal pricing might allow the increased oil price to periodically have a substantial effect due to the use of oil as top-load. Improved efficiency can be done gradually both by considering efficiency in new investments and by changing and improving existing behaviour and equipment. With improved efficiency the consumption of oil can be reduced. This will result in a reduced dependency on oil and thereby decrease the consequences of a high oil price. This reduced dependency on oil result in a reduced dependency on countries with oil resources.

To reduce the dependency on oil through increased efficiency, investments are necessary. These investments can help to reduce the consequences a high oil price has on society by keeping up consumption and thereby reduce the risk for economical recession. When the reduction in oil usage has an effect on the private economy, a larger disposable income is free to spend on other goods. This will also help reduce the risk for a reduced economic activity. The extent of the impact a higher oil price has depends on to how quickly these changes to a more efficient society are made. If too much time is passed before the necessary investments are made, the dampening effects the improved efficiency can have will be smaller.

Consequences of an increased oil price with overall improvement in efficiency can be:

- increased investments
- general reduction of oil usage
- reduced energy dependency
- risk for economical stagnation.

14.4 General Analysis

If there is a steady increase in oil price from $60 up to $300/barrel it is most likely that a combination of the three previously mentioned developments will occur. The increasing price will make alternatives and efficiency improvements profitable. Local conditions will to a large extent affect what alternatives will be developed. This transition to more use of alternatives and improved efficiency will still result in increased costs for commodities, due to the large investments needed. The increased costs are partly due the extent of the transition needed as well as the short timeframe until 2015.

Considering the timeframe this master thesis covers, 2006 - 2015, all the potential for limiting the negative consequences of a high oil price will not be possible to implement. The construction of production facilities for producing alternatives and efficiency improvements take time, and alternatives will therefore not be able to be introduced to the full extent even if it is economical. This will increase the price on commodities since oil still will be used in many applications. People's lifestyle will not be changed drastically either within nine years, although the increased prices will affect their consumption pattern. There will probably be an increased development of means of control to ensure a reduced consumption of oil and to guide the development of alternatives. Even though there are means of control existing today which partly cover this area, more will be needed to make a large difference. It takes time to construct and implement different means of control which means that it will go by even more time before the effects of these will show. This factor contributes to why it is not reasonable to assume that all the possible reductions of oil consumption are accomplished.

Even if the western world is better equipped today to handle an increase in oil price, the raise to $300/ barrel will create instability. With an increased need for investments, reduced profit margins, higher prices on commodities, increased prices on transport fuel and energy, GDP and inflation will be affected. GDP will decrease while inflation rises.

There is a limited amount of energy resources available, both non-renewable and renewable, even if the overall efficiency is increased. The theoretical potentials for energy sources are high but it is unlikely that it can be fully utilised. The increase in population in foremost developing countries will further increase the global demand for energy, making it important with system engineering instead of considering one sector at a time. This implies that there will be increased need for recycling as well as improved use of waste material, for example straw and forest residue, as well as, garbage.

The increased oil price will play a part in triggering the use of alternative energy sources and improved efficiency. A transition period in society will occur as these changes take place and before an optimised use of energy sources is found. During this period the economy can be unstable.

Consequences of an increased oil price for the society can be:

- increased investments
- development of alternatives
- increased efficiency
- increased cost for commodities
- changes in lifestyle
- unstable economy.

15 Scenario

In this chapter the scenario is presented which is the main product of this master thesis. The scenario is based on the three analysis chapters; "Identifying key areas", "Identifying key factors" and "Analysis". The scenario reflects on a possible future in 2015 with an oil price of $300 per barrel.

After having been in steady increase since 2006 the oil price reaches the level of $300 per barrel in 2015. The high level of the oil price will cause a decoupling between the oil price and the price on natural gas, also coal is further decoupled. The decreased availability of oil will push forward an increased use of these sources, foremost natural gas. Renewable sources of energy will increase in importance, but due to limited production capacity these sources will not be able to reach their full potential in 2015. Still, the increased use of biomass will trigger a competition for land, and together with increased production cost, this causes an increased price on food and other bio-based commodities. The increased usage of more diversified energy sources has strengthened the security of supply, this through the increased number of energy types and their geographical distribution.

The increased need for natural gas and coal limits the desired reduction in GHG as carbon capture and storage has not been enough developed 2015. Europe tries to work towards fulfilling the Kyoto protocol for as long as possible, but when it is realized that renewable resources can not be commercialised fast enough, causing the direct economic consequences to become increasingly large, the protocol is abandoned.

Transport

The goal of having 20% alternative fuels in 2020 within the EU will be reached earlier and increased to 25% due to the higher oil price. A similar development will occur in the US, but not to the same extent. In Europe 15% of the total use of alternative fuels will come from biomass, and the rest will be predominately natural gas and some coal. The local variation will be significant. In some parts the production of alternative fuels will mainly be from farmland or forestry whereas in other areas from natural gas or coal. As the vehicle fleet is renewed with better and more efficient vehicles a 20 - 25% reduction in overall fuel consumption is achieved. This includes increased engine efficiency, hybrid technology, reduced idling as well as a change in driving techniques. The reason for this fast development in alternatives and improved efficiency is because these solutions will be cost efficient far below an oil price of $300/barrel.

With the increased use of alternative fuels and the improved fuel efficiency the price on fuel will result in almost a doubling of transport cost in Europe, depending on which vehicle used, compared to 2006. For the private driver this will affect the transport behaviour. If there is access to well functioning public transportation this will be used to a much larger extent to reduce the impact on the way of living. This implies that with no or limited access to public transportation, as in remote areas, the effect will be larger. This will also be the case in countries with currently limited public transportation and high average fuel consumption. Even though the utilisation of public transportation increases, this will not compensate for the entire reduction in transports which implies an overall decrease in private travelling. The need for commuting will to a large extent be sustained but the radius is shortened. This means that foremost leisure travel will be reduced. The increase in transport cost will change the priorities when buying a new car regarding aspects such as fuel efficiency and possibilities for alternatives. It will probably also result in trading in the old car for a new one earlier than otherwise.

The increased price on transport fuel will not affect commercial transport in the same extent as private transport. The fuel cost represent only a part of the total transport cost, but the price on transport will still be noticeably increased. Bulky and low value goods will be more affected by the increase in transport cost than high-value goods as transport cost represents a large part of the product cost.

The general increase in transport cost will increase the focus on improved logistic solutions with regard to fuel reduction. The changes in logistic solution will probably call for an increase in rail transport as a reduction in road transport occurs. The need for improvements in cooperation regarding transport between countries within Europe increases due to the higher demand for transports via rail.

Non-energy

Not only the price on transport is a factor that will increase the cost for products, the increased cost for oil will also affect the price on oil based products, such as plastics. Products using plastics mainly as packaging material does not increase in price as much as products entirely based on plastics. Despite this, packaging material gets more expensive why this material is minimized in products. This development is accentuated by the increased cost for transport. Other plastics products that are essential to our everyday life will continue to play an important role but as the price increases the previous pattern of increasing plastic consumption in the western world starts to curb and instead starts to decrease. The decrease in plastic use would have been greater if not bio-based plastics had helped to increase the availability of plastics. As the price on oil passes $80 per barrel an increased activity starts regarding alternative materials for plastics and other oil based products. By 2015 these techniques have provided the market with several different solutions and the price on bio-based products is somewhat lower than the cost of oil-based products. The bio-based products still have some limitations and along with limited production capacity they will only represent a limited part of the total consumption.

In some products it will be more difficult to replace the oil based raw material, such as bitumen based products. As this raw material can be seen as a waste product of oil the cost for this material does not increase as sharply as the general oil price but since no alternative emerges, many of these products will decrease in market share.

With the increased cost for oil and natural gas recycled materials becomes more cost efficient and therefore recycling increases due to both cost and environmental issues. This increased recycling will have a limited effect on the overall need for virgin material.

As the cost for raw material and production increases many companies face more pressed margins. This will make it difficult for many oil dependant companies to stay in business. The increased cost for road infrastructure and other large investments such as buildings increases the pressure also on communities, affecting the economy and thereby future investments in infrastructure.

Heat and Electricity

Other non-material commodities that will be affected by a substantially higher oil price are heat and electricity. The spot price on electricity will be occasionally affected as oil is used as top-load. The general price for heat and electricity will also increase due to the somewhat continued correlation between oil and fossil energy sources, but foremost due to the increased demand for coal, natural gas and biomass. The strong development of natural gas within electricity generation will be dampened. This is due to the increased use in other sectors such as transport and chemistry and the higher price. Natural gas, in the form of CNG, will increasingly substitute oil as top-load in electricity generation while coal even more fills up the base-load. Renewable energy sources other than just hydro will start to have a much larger part in electricity generation. Private homeowners and industries will recognize the increased profitability in renewable energy solutions.

The increasing price on oil, and thereby other fossil fuels, will direct large focus on increased efficiency in industry processes as well as electricity utilisation in households and commercial buildings. Governments will increase the request for energy efficiency in products and buildings, pushing forward the development of more energy efficient solutions. A large portion of oil based heat and electricity generators will be replaced by other diverse sets of solutions.

The increased oil price forces private homeowners and industries to invest large sums in order to break free from the oil dependent energy systems, and to lower the overall energy consumption. Those that can not afford the required investments will experience large difficulty to cope with the increasing costs.

Economical Consequences

The accumulated increased costs for fuel, chemical feedstock as well as heat and electricity will hit both companies and consumers hard forcing them to spend more money to satisfy their basic needs. This leaves less of the disposable income to be spent on non-essential products and services. This decline in consumption results in reduced economic activity and negative GDP development. The effect hits the hardest on countries that are large importers of foremost oil but also of natural gas. The necessity for the public and the industry to invest in both alternative sources to oil as well as increased efficiency keeps up a certain level of economic activity, helping the economy not to go into full depression. Also the investments in large scale production of alternative fuel, chemical feedstock and energy dampen the negative impact on the GDP.

The development of production facilities for alternatives will be delayed due to lack of qualified professionals, limited access to building materials and capital since the increase in oil price sets off many investments at the same time. The limited access to capital is partly caused by increased insecurity in the market, keeping both private investors as well as companies from investing their excess capital. Along with the investments in new production facilities that after all are made, come new job opportunities that to a limited extent can cover for the reduction of jobs in other industries. These investments will take time to fully realise why a gap between possible and required production capacity will arise.

The oil has once again come to play a major part in the transition into the future, this time not as the black gold of the industrialization but as a catalyst of the transition towards a sustainable future. The high increase in oil price from $60 until $300 per barrel during the short time period from 2006 until 2015 has a strong impact on the economy. The economic recession that initially occur is limited in time and will end as the transition into a sustainable future is fully executed.

16 Master Thesis Evaluation

In this chapter an evaluation of the work progress and experiences made are discussed. This is in order to provide the reader with an understanding of how the authors have experienced the work process.

During the work with this thesis we have had a great opportunity to explore many areas in which we previously had only limited knowledge. We have had a unique chance to meet professionals within a number of fields who have shared their knowledge with us. These discussions and interviews along with the seminars we have attended have been rewarding and even further sparked our interest in the area.

The subject of this thesis has been wide and extensive. Due to the magnitude of the main question, "What are the consequences of a high oil price?", a lot of information exists in the area. At times the information available has felt overwhelming and it has been impossible to cover all areas of interest. Because of this, there are some sections and points of this thesis that could have been further developed. Since we only possessed limited knowledge in the different sectors mentioned in this thesis, a lot of time was spent on getting to know these areas. The chapters containing data collection and empiric development have to a certain extent been allowed to picture this unprejudiced collection of information. It would have been rewarding if we had had the time to further investigate and develop some of these sections but due to the limited timeframe this has not been possible.

In the beginning of our work we built a scenario model that we intended to use as a framework for this thesis. As we continued our work it became evident that not all steps would be entirely followed as they were initially intended. This was due to the direction in which the information led us. The general structure of the scenario model has however been followed and it has outlined our work.

The scenario that was finally developed presents a picture that we have found possible with the base in our work. However, we do find it a bit difficult to believe that the price on oil will actually reach as high a $300/barrel in 2015 why it at times have been difficult to picture this image. But as these conditions were already set when we started our work we have done our best to keep this hypothesis as vivid as possible. The choice of price has however been a good assumption to base our scenario on since this has challenged our perceptions and ensured a distinct difference to the current price. One of the great advantages related to scenario creation is that we do not have to feel that the picture we have been painting is the absolute truth but rather a representation of possible events. There is always a risk however, that those reading the scenario consider it to be an exact prediction of the future, why they can feel that some statements have not been explained fully enough.

In the theory chapter it was mentioned that two common mistakes are in general made when working with scenarios; overestimation of the pace of change and underestimation of the fundamental factors, such as structures and behaviours. In our scenario we have a feeling that we might have overestimated peoples' willingness and capability to adjust to the new settings. The transition over to alternatives and the time that will pass before necessary investments are made can be much longer then we have assumed. When writing a scenario it is also possible to develop an optimistic or pessimistic view of the future. In our scenario we have tried to stay as objective as possible. At times we have felt an urge to write what we want to happen, but we have tried to keep the text to what we believe will happen. Because of this we believe ourselves to have been pessimistic but the reality might be that we have been overoptimistic.

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Seminar

EU Workshop on Hydrocarbon Prospects and Energy Futures, 6-7 September, 2006, Brussels
Speakers:
Cambell, Colin, ASPO
Capros, Pantelis, National Technical University of Athens
Champlon, Daniel, IFP
Loughhead, John, UKRC
Routti, Jorma. Cimfunds
Van Geuns, Lucia, Clingendael International Energy Programme

Biobränsle – efter Oljekommissionen, 6 November, 2006, Kungliga Vetenskapsakademien, Stockholm
Speakers:
Atterwall, Annika, Utredningssekreterare, bioenergiproducent
Axelsson, Svante, Generalsekreterare, Svenska Naturskyddsföreningen
Berglund, Hasse, Programchef, Världsnaturfonden WWF
Brandel, Magnus, VD, Svenska torvproducentföreningen
Brännlund, Runar, Professor i ekonomi, Umeå universitet
Börjesson, Pål, Docent i miljö och energisystem, LTH, Lund
Edman, Stefan, Generalsekreterare för Oljekommissionen
Fredga, Karl, Professor, medlem av KVAs Energiutskott
Fredriksson, Tage, Enhetschef, Skogsbrukets utvecklingscentral
Liljelund, Lars-Erik, Generaldirektör, Naturvårdsverket
Linder, Sune, Professor i skogsekologi, SLU, Alnarp
Lundborg, Anna, Fil.dr, Statens Energimyndighet
Nilsson, Ove, Professor i växters reproduktionsbiologi, SLU
Wachtmeister, Carl, Ordförande i LRFs energiutskott, LRF
Wirtén, Håkan, Överdirektör, Skogsstyrelsen
Wirtén, Stefan, Skogsdirektör Skogsindustrierna

Appendix 1: Questionnaire

All of the respondents were Swedish and therefore this questionnaire is presented in Swedish.

1 Personorienterande frågor

1.1 Företag/Organisation/Universitet
1.2 Titel
1.3 Specialistområde
1.4 Antal år inom företaget

2 Företagsorienterande frågor

2.1 Vad är huvudområdet för ert företag?
2.2 Vilka typer av produkter tillverkar ni?
2.3 Hur stor marknadsandel har ni inom ert område? (Sverige & internationellt)
2.4 Vilka är era största konkurrenter inom ert område?
2.5 Vilka är era konkurrenter utanför ert direkta område (substitut)?
2.6 Vilka är era största kunder och för vilka produkter?

3 Förbrukningsrelaterade frågor

3.1 Var i er verksamhet används olja?
3.2 Vilken typ av olja använder ni?
3.3 Hur stor är er årsförbrukning?
3.4 Hur köper ni in oljan?
3.5 Av vem köper ni in oljan?
3.6 Produktrelaterade frågor

3.7 Oljeberoende

3.7.1 Hur stor del av er produkt är oljebaserad?
3.7.2 Finns det idag något alternativ till olja i era produkter?
3.7.3 Finns det något tänkbart alternativ i framtiden?
3.7.4 Bedriver ni något utveckling/forskning för att hitta alternativ till olja?
3.7.5 Bedrivs det något utveckling/forskning på alternativ inom er bransch, genom tex. intresseorganisationer eller gemensamma forskningsprojekt?
3.7.6 När kan ett substitut finnas tillgänglig för produktion?
3.7.7 Vid vilket pris på olja går brytpunkten när det är lönsamt att satsa på ett alternativ?

3.8 Energiberoende

3.8.1 Hur stor del av er produktkostnad är energirelaterad?
3.8.2 Producerar ni er egen el/värme eller köper ni in den?
3.8.3 Hur stor del av denna energikostnad kan ni påverka (priset & åtgången)?
3.8.4 Hur skulle ett kraftigt ökat energipris påverka er?

3.9 Transportberoende

3.9.1 Hur stor del av er produktkostnad är transportrelaterad?
3.9.2 Vilken typ av transport använder ni er av?
3.9.3 Kan ni påverka tranportkostnaden?
3.9.4 Hur skulle ett kraftigt ökat transportpris påverka er?
3.9.5 Övriga produktrelaterade frågor
3.9.6 Använder ni er av någon typ av jordbruks/skogsbaserad komponent i era produkter?
3.9.7 Hur skulle ett förhöjt pris på denna produkt påverka er?

4 Framtidsrelaterade frågor

4.1 Vad tror ni om den framtida utvecklingen av oljepriset?
4.2 Hur känsliga är ni för en ökning av oljepriset?
4.3 Hur skulle ert företag drabbas av ett kraftigt höjt oljepris på $300/fat vid 2015?
4.4 Hur känsliga är era kunder för en prisökning på er produkt?
4.5 Hur stor del av en kostnadshöjning skulle ni kunna föra vidare direkt till konsument?

5 Konsekvenser

5.1 Vad blir konsekvenserna av ett kraftigt förhöjt oljepris ($300/fat vid 2015) för er?
5.2 Vad blir konsekvensera av ett krafigt förhöjt oljepris ($300/fat vid 2015) för era kunder?

Tillåter ni att ert och företagets namn används i rapporten?

Appendix 2: Well-to-wheels Report [377]

The WTW-report was a joint work by representatives from EUCAR (the European Council for Automotive R&D), CONCAWE (the oil companies' European association for environment, health and safety in refining and distribution), JRC/IES (the Institute for Environment and Sustainability of the EU Commission's Joint Research Centre) and assisted by personnel from L-B-Systemtechnik GmbH (LBST) and the Institut Français de Pétrole (IFP). The objectives of the report were as quoted below to:

- Establish, in a transparent and objective manner, a consensual well-to-wheels energy use and GHG emissions assessment of a wide range of automotive fuels and powertrains relevant to Europe in 2010 and beyond.
- Consider the viability of each fuel pathway and estimate the associated macro-economic costs.
- Have the outcome accepted as a reference by all relevant stakeholders.

The WTW-report only considers the production and the use of the fuel and the vehicle. It does not take the energy consumption and the GHG emissions from construction of the production facility and the vehicle into consideration. The WTW-report looks at the energy required and the GHG emitted per unit distance. It also mainly consider set-aside farmland for production, otherwise it would have to look into what kind of crop it replaced and how this would change the emissions from the farm land.

For alternative fuel based on traditional food crops estimations has been made in the WTW-report about the emission of GHG during farming. The emissions of GHG from farming stand for the major part of the total emissions for these alternatives since for example nitrogen fertiliser production releases emissions and nitrous oxide (N_2O) is emitted from the field. Nitrous oxide is about 300 times more powerful GHG than CO_2. These emissions can vary substantially depending on factors like climate and soil composition which makes the error margin larger for GHG emissions than for the energy balance for these fuels.

The WTW-report stresses the difficulties with assessing costs for alternative fuels especially when it involves not yet large-scale developed processes. Factors like the price of feedstock will depend on if the demand increases and the demand will increase if there are production facilities built. These interdependent relations increase the difficulties concerning cost estimation. Just like when it comes to energy balance and GHG emissions the costs in the WTW-report include producing the fuel, making it available to the vehicle and required changes to the vehicle.

When it comes to the pricing of the different raw materials for the fuels a relation to crude oil called an oil cost factor, OCF, was assigned each raw material. This was because the costs for especially other fossil fuels were assumed to be determined by the oil price. Natural gas was for example assigned and OCF of 1, 0 and wheat grain 0,05.

In the WTW-report, personal cars are considered and not heavy vehicles since their data only covers this area.

[377] *WTW-report.* (2006)

Appendix 2

Appendix 3: The Kyoto Protocol[378]

In 1992 the United Nations Framework Convention on Climate Change (UNFCCC) was adopted. This was the first international measure to address the problem with climate change. The UNFCCC has been ratified by 189 governments, almost all governments in the world and obliges them to establish national programmes for reducing greenhouse gas emissions and to submit regular reports. By the creation of UNFCCC it stood however clear that this effort would not be sufficient to seriously tackle the climate change and on December 11th 1997 the Kyoto Protocol was adopted. As of February 6th 2006 the Kyoto Protocol had been ratified by 106 governments and the European Community. Among those countries that have not ratified the Kyoto Protocol are the US, Australia and Monaco.

Under the Kyoto Protocol, industrialised countries are required to reduce their emissions of six greenhouse gases (CO_2, being the most important one, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) by around 5% below the 1990 level during the first commitment period of the Kyoto Protocol which covers 2008 to 2012. The reason for a five year period instead of a single target year was to smooth out the annual fluctuations in emissions due to uncontrollable factors such as weather. In the protocol there are however no emission targets for developing countries. This is because the UNFCCC recognises that industrialised countries are responsible for most of the current build-up of greenhouse gases in the atmosphere and therefore should take on a lead in reducing the emissions.

The Kyoto Protocol implies three market-based mechanisms, known as the Kyoto flexible mechanisms: emissions trading between governments with Kyoto targets, the Clean Development Mechanism and Joint Implementation. These mechanisms will allow industrialised countries to meet their emission targets cost-effectively by trading emission allowances between themselves and also opens up the possibility to gaining credits for emission-curbing projects abroad. The reason for these mechanisms is that greenhouse gas emissions are a global problem and that the place where reductions are achieved is irrelevant in scientific terms and by applying these mechanisms the reductions can be carried out where costs are lowest.

[378] *The Kyoto Protocol.* 2006-11-10

Appendix 4: Output by Selected Alternative Fuels[379]

Annual pkm 2003 (1000 million)	**US**	**EU**
	7008	4444

Coal

	Volvo V70 Diesel
consumption l/10 km	0,68
Coal reserv US (1000 million metric tons)	2,50E+11
World reserve	9,05E+11
Raw material used	
Coal (million metric tons)	4,3
Fuel output	
Synthetic diesel (million litres)	1355
litres/ton	315
km/ton	4634
Required tons/year	1,512E+09
Precent of world coal reserve needed per year	0,17%
Precent of US coal reserve needed per year	0,60%

Natural Gas

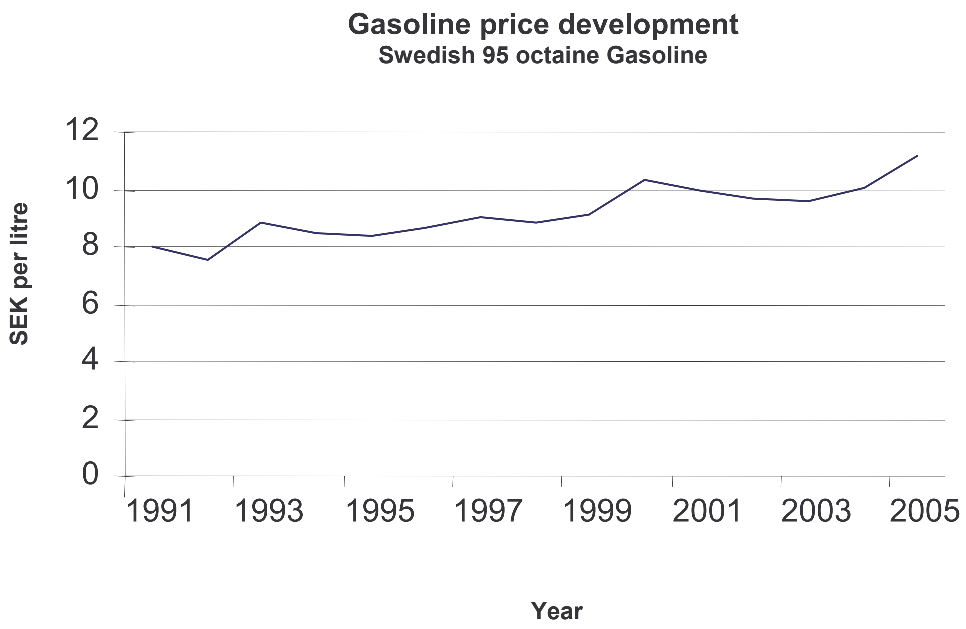
	V70 Bi-fuel CNG	**Gas hybrid**
consumption m3/10 km	0,85	0,445
Natural gas reserve US (cubic metres)	8,00E+12	
World gas reserve (cubic metres	1,80E+14	
Required m3/year	5,9568E+11	3,11856E+11
Precent of world gas reserve needed per year	0,33%	0,17%
Precent of US gas reserve needed per year	7,45%	3,90%

Biomass -Wheat

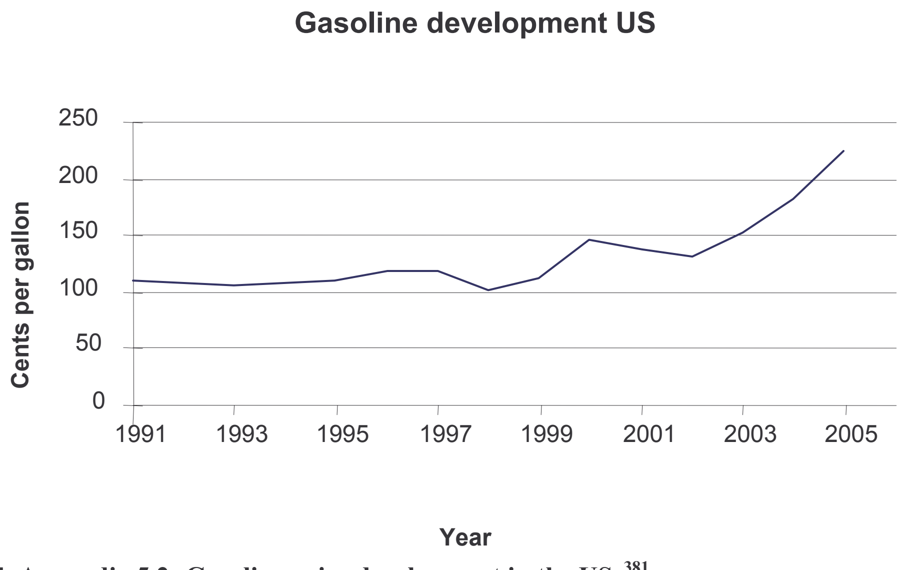
	Saab Bio-power sedan (US)	**Saab Bio-power sedan (EU)**
consumption l/10 km	1,27	1,27
US arable land (ha)	173665978	98765000
Raw material used		
tons/ha	6	6
Fuel output		
Ethanol l/ha	2400	2400
Ethanol l/tons	400	400
km/ha	18898	18898
Required ha/year	370840000	235161667
Precent of US arable land needed per year	214%	238%

[379] Zerbe, I.J. (2006) Eriksson, L. (2005) Falk, M. (2006) Graham, R.L. (1999) Biofuels and agriculture- A factsheet for farmers. (2001) National Agricultural Statistics, 2006-10-16

Appendix 5: Gasoline Price Development



Graph Appendix 5.1: Gasoline price development in Sweden (base year 2005). [380]



Graph Appendix 5.2: Gasoline price development in the US. [381]

Conditions concerning gasoline price at $300/barrel[382]:

- no change in demand
- exchange rate $ 1 = 6,81 SEK
- no change in refining process
- no change in taxation policy

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[380] *Bensinpriser 1981-2005 95 oktan.* (2006-10-27)
[381] *Weekly Retail Gasoline and Diesel Prices.* (2006-10-27)
[382] Björklund, M. 2006-12-07