Department of Development and Planning

Master Thesis

LCA on transport sector of Denmark

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Abstract

The transportation sector is seen as the major contribution to CO2 emission in the world, this is due to the fact that consumption of crude oil is high as a result of high increase number of vehicles.

A country like Denmark is obliged to reduce its CO2 emission by 21% from 1990 level according to Kyoto Protocol agreement. Many efforts have been made especially in the energy sector to reduce the CO2 emission in order to meet the set target. Some of the ways are implementation of Kyoto flexible mechanisms, increase system efficiency, increase combined heat and power technology and increase renewable technologies (biodiesel). The latter solution would be explored if it could substitute crude oil in the Danish transport sector.

Biodiesel (rapeseed) as a renewable technology fuel is a free carbon dioxide emission but the Life Cycle Assessment shows that there is significant amount of CO2 emits during the process of cultivation. The paper would then investigate how feasible to replace biodiesel with crude oil in Danish transport sector for the achievement of 21% CO2 emission reduction set target.

The result of the study identicated that the use of biodiesel to replace crude oil was not feasible for Denmark to achieve 21% of CO2 emission after analysed the three scenarios. This is due to the fact that the hectares of land needed to accomplish such target are not available.

Foreword

Thank to our supervisor Per Christensen for his kind support all along the project. We also thank friends and our loving parents for their support and valuable opinions.

Tack skal du have!

Chapter 1 Introduction

Chapter 2 Methodology

Chapter 3 ISO 14040, Impact Assessment and Land Use

Chapter 4 Construction of Scenarios SimaPro

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Chapter1

Introduction

In today’s world energy use is viewed as an important source of economic development. The energy that we produce and consume comes mostly from non-renewable sources of energy, such as oil, gas, coal etc. These resources of energy are finite and they (oil, gas, coal etc.) are dwindling at a faster rate. More over, identification of new sites of extraction are becoming too expensive or too environmentally damaging to retrieve (NREL, 2006). Another side effect of using non-renewable sources of energy is global warming and change in earth’s temperature. Currently, transportation consumes 20% of the world’s total primary energy and produces most of the world’s air pollution. The researchers also estimate that the number of cars used on road would double in just 30years time (Robert Q., 2006)

The purpose of this project is to determine the environmental impacts of using conventional fuel over bio-fuel for transportation in Denmark. Denmark has taken climate change challenge seriously and set new targets through policies and legislations (IEA Denmark, 2002). The gross energy consumption from oil for energy generation in 2004 was 370 PJ (DEA, 2005). The oil consumption had remained almost the same during 2001 and 2004. The transport sector energy consumption was approximately 205 PJ in the year 2004 (DEA, 2005). Nearly 55% of the oil being consumed in Denmark is being utilized in the transportation sector.

This project is intended to analyse the impact of replacing oil for transportation with bio-fuel in terms of land use capacity (for production on biomass) and environmental consequences.

1.1 Environmental issues

In the past two to three decades the human activities have grown and this has led to the addition of carbon dioxide and other green house gas addition into the atmosphere. The amount of emission of carbon dioxide had nearly doubled and it is expected to grow in the coming years. There are evidences that due to green house effect the global temperature is said to rise in the coming decades. Since the issue of global warming and climate change could not be restricted to few selected countries, the United Nations has initiated on United Nation Framework Convention on Climate Change (UNFCCC) at “Earth summit” in Rio de Janeiro, 1992. Now it is being addressed as conference of parties’ session (COP).

Denmark signed the Kyoto Protocol in 1997 and the agreement aimed to reduce carbon dioxide emission by an average of 21% in relation to 1990 level, between 2008 and 2012 (Danish energy authority, 2005). Relatively during the same period, political agreement was made in Denmark to increase the use of bio-mass prior to the year 2002. An average consumption of biomass energy in Denmark was 85 PJ/year during 2002 and it is expected to increase in future (DEA, 2006).

1.2 Green house gases

Some green house gases are already present in the atmosphere while other gases are added to the atmosphere due to human action. Gases that are naturally occurring in the atmosphere are water vapour, carbon dioxide, methane, nitrous oxide, and ozone. Some of the other green house gases added by human action are hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulphur hexafluoride (SF6). (US EPA, 2006)

1.3 Kyoto protocol

The United Nation Framework Convention on Climate Change (UNFCCC) called upon the developed countries (as per Annex I) on a non-binding agreement to reduce their green house gases to 1990 level. These countries are some times called Annex I countries. The UNFCCC added a clause that during the first Cop 1(Conference of the parties), the Annex I countries should review the adequacy of commitment in the convention. The first Cop1 was held in Berlin in the year 1995 and the Annex I countries declared that the commitment were inadequate so a process of appropriate action would be considered after the year 2000.

1.3.1 Kyoto mechanisms

The Kyoto mechanisms are some of the policy measures that are established to achieve the targets of emission by the countries. The Kyoto mechanisms are

- Joint implementation
- Clean development Mechanism
- Emission trading

Notwithstanding to that there are other means to achieve the Kyoto protocol target which include increase the renewable technologies, demand side management, increase efficiency of the existing energy systems, implementation of CHP technologies, just a few to mention.

1.4 Energy utilization and Energy policies

The gross energy consumption of Denmark was approximately 800 PJ for the year 2004 (DEA, 2005). As it can be seen in the figure 1, the energy consumption for the year 2004 was lesser than for the year 1996. Throughout the years from 1980 to 2004, growth in the use of renewable energy and reduction in the use of coal and oil are some positive aspects of the Danish energy scenario.

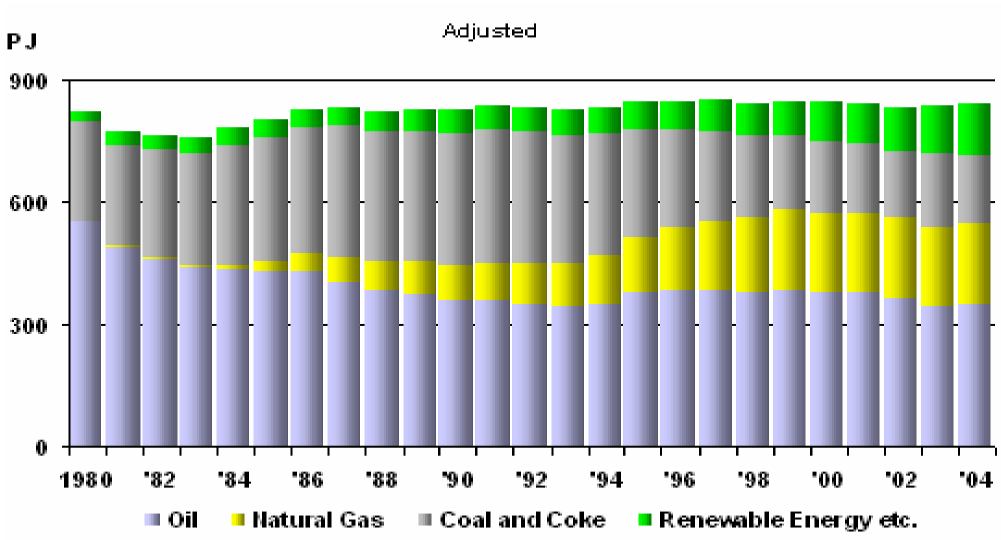


Figure 1.1: Gross energy consumption by fuel types in Denmark

Source: Danish Energy Authority, 2005

1.4.1 Danish energy policy

Denmark has long history of implementing energy policies to achieve clearly defined societal goals. Of late the energy policies are undergoing dramatic changes in both their philosophical basis and implementation details. The country has long operated under centrally managed guidelines, intended to provide the greatest benefits to society while minimizing negative environmental impacts. The country's main energy policies and their objectives have summarised in this part.

In the early 1970's Denmark, like much of the world was shocked by skyrocketing oil prices created during the Arab oil embargo. At time Denmark was still very dependent on global energy supplies with more than 90% of its energy provided by imported oil. As reaction to this crisis the Danish government issued the Danish Energy Policy 1976. The main objective was to reduce dependency of imported oil by using natural gas, coal and renewable energy.

The subsequent energy, "Energy 81", promoted domestic production of gas and oil (North Sea oil reserves). The main objectives of this plan were energy supply, security and socioeconomic issues – jobs and balance of payment (OECD/IEA, 2002).

Consequently, a new plan – "Energy 2000 Action plan for Sustainable Development"- was issued in 1990. The main objective of this plan was sustainable development of energy sector. This plan set targets to reduce energy consumption and increase the use of renewable energy (OECD/IEA, 2002).

Fourth of the Danish energy plans, "Energy 21", was issued in 1996. The sustainable development of Danish society, economically and technologically efficient energy sector and rational management of resources were key objectives of "Energy 21", The main role was given to environmental considerations especially CO2 reduction. "Energy 21" underlined the Danish government's objective to further develop energy policies that include the following targets: stabilisation of energy consumption while the economy grows; increased efficiency of Denmark's energy sectors; and a high degree of self sufficiency using domestic primary energy resources – oil, gas and renewable (DEA, 1996).

1.4.2 Energy scenario

Denmark's total energy consumption in the year 2000 was 15.24 millions tonnes of oil equivalent (Mtoe) (OECD/IEA, 2002). The energy consumption trends differ from year to year as a result of some factors. For instance, during 1973 and 1979 oil crisis the consumption level increased compared to the year 2000.

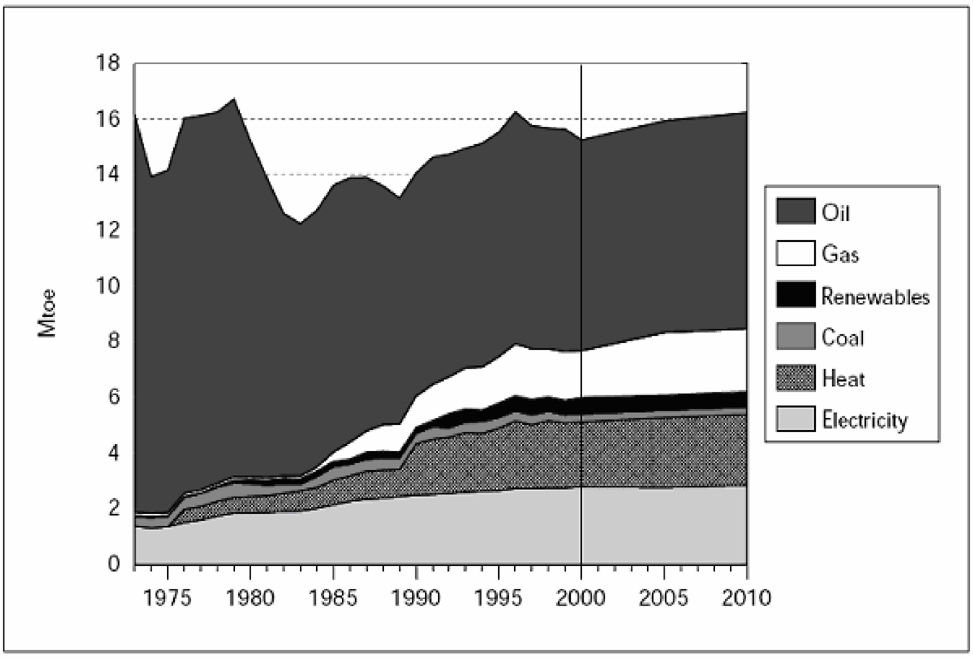


Figure 1.2: Danish total energy consumption by source
Source: IEA/OECD, Paris 2001

In 1996, there was another increased in energy consumption, this is as a result of the cold weather. Since then the country's energy consumption has been steady in some years 1999 -2000 with 2.6% negative growth (IEA/OECD 2001). All these scenarios are seen as a result of the country's highly dependency on oil which accounts 50% of energy consumption.

1.5 Transport sector

Transportation sector as the most oil consumption sector recorded 4.8Mtoe as the total final consumption in 2000 (OECD/IEA, 2002). This accounts for 31% being the highest consumption compared to other sectors, namely industries, residential/commercial and others. Oil used as the main fossil fuel in this sector means that the emission of CO2 will become the potential issue to the environment and as the matter of fact need to be addressed as the Denmark is rated as one of highest emitter of CO2 per capital. For instance, in 1999 CO2 emission level in this sector increased by 14% as compared to 1988 and even expected to increase 31% in 2010. This rise in CO2 emission in this sector means that substitution of other alternative fuels over oil has to be figured.

1.5.1 Use of biofuels for transport sector

Originally biofuel is known to be a fuel used for producing heat and electricity. With the high prices of crude oil as a result of its limited reserves and its environmental consequences, biofuel has become important commodity in recent times to be a potential alternative to crude oil. The well known alternative biofuel used for transportation in Denmark is rape seed oil. The consumption of this fuel in transport sector account for small portion as compared to the crude oil usage. Since this is new technology and need time for it to develop in terms of production and economic wise.

Denmark has potential land unused for cultivation. In 1991 the production area grew to 280,000 hectares which is 10.8% compared to the total land area of 2,672,000 hectares for cultivation (Agricultural – economic summary, 2003) which means that more than 80% is available for cultivation

1.6 Problem formulation

Denmark at present, like the entire world depends much on fossil fuel (oil) to meet its energy demands for its society. In 2000 transportation sector recorded 4.8 Mtoe, as the highest consumption of crude oil.

The sharp rise in crude oil prices in world market and ratification of Kyoto Protocol directly paved way for some countries like Denmark which has committed to reduce its CO2 emission by 21% between 2008 and 20012 relative to 1990 level; to find other alternatives solutions to limit crude oil dependency and its emissions of greenhouse gases. As oil consumption in the transportation sector has increased due to the fact that many vehicles are being used the replacement of environmentally friendly and economically feasible fuel will ease dependency of the fossil fuel and thereby can reduce the CO2 emission. The biofuel (rape seed oil) is considered clean and available in sufficient quantity in Denmark is considered as one of the alternative solution to reduce CO2 emission.

Denmark was selected as reference case for the basis of our analysis because the information regards to the land capacity for cultivating biofuel (rape seed oil) will be easier. More over the researchers performing this study are student from Denmark. The used land for cultivating is 10.8% (current usage of land for agriculture) meaning that there are lot of opportunities to explore on using land for cultivation of biofuel feed stocks in terms of land for cultivation.

Secondly biofuel has become important topic for the day considering as the alternative source of energy that emits negligible CO2.

Research question

This report attempts to answer the question "*What are the environmental impacts of using biofuels over conventional fossil fuels and its impact on land use in Denmark?*"

1.7 Objectives

The project will explore on two main objectives;

Analyzing environmental impact of using biofuel and conventional fuel: what environmental benefits will be achieved if biofuel is used instead of crude oil for transportation? How much greenhouse gases will be reduced using biofuel compared to oil and vice versa. Here four scenarios will be considered and analysis will be based on how each scenario will have impact to the current situation in Denmark transport industry.

Analyzing the land usage for cultivating rape seed: How much of land is required for cultivation of rapeseed feed stocks for the four scenarios? Furthermore, will the current land capacity be able to meet current the demand of oil consumption?

1.8 Structure of the report

The report of the project is constructed in following chapters. Chapter 1 gives the introduction and the issue to be analyzed in the report. Chapter 2 outlines the methodology adopted for the project.

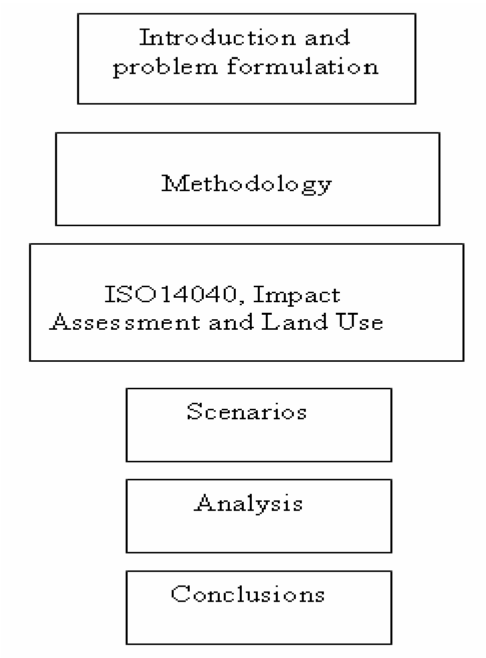


Figure 1.3: Structure of the report

Chapter 3 describes ISO 14040, land use and inventory. Chapter 4 describes the construction of four scenarios in terms of functional units and system boundary. In chapter 5 analyses of four scenarios and their impact on land use are explained. Finally in chapter 6 the result is concluded.

Chapter 2

Methodology

In this chapter research approach and data collection methods adopted are described. Chapter explains how self criticism of the work will be performed and the readers could frame their opinion about the trustworthiness of the results presented in this project. It further describes the four scenarios.

2.1 Research approach

The research approach for this project is deductive as the project started using existing theories. According to Colin (2002), a deductive approach works from a more general to a more specific issue. This process of doing research is also called as top down approach.

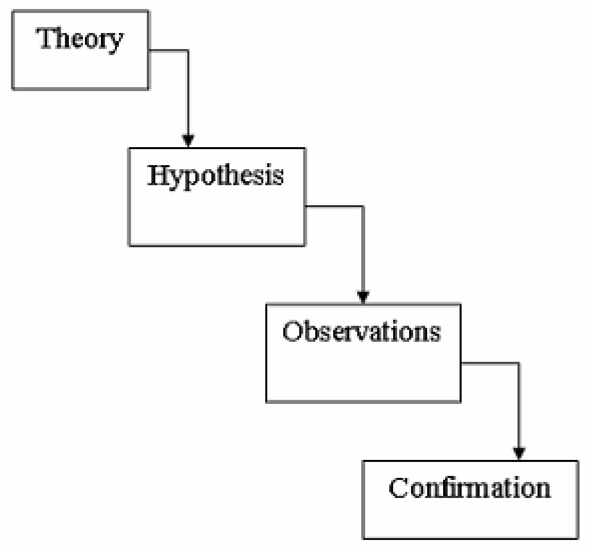


Figure 2.1: The figure above show the deductive approach of research. It is also call top down approach

After studying the existing theories, hypothesis of the project is set. Then observations are made to address the hypothesis. Finally with the observation and theories it is possible to test the hypothesis.

In this case, the project uses ISO 14040 for determining the goal, scope and performing the inventory data collection. Further, to conduct the inventory analysis SimaPro 6 version is used. ISO 14040 and SimaPro 6 are the theories employed in this study. Hypothesis or assumption of the project: The environmental impact of using biofuel is minimal over conventional fossil fuels in the transport sector of Denmark. Data are collected and modelling of the data is performed in SimaPro to replicate the current scenario. Tradeoffs are made and analysis is performed to understand the environmental impacts of using two different types of fuel for transportation. Using the results of the analysis the hypothesis for this study is addressed. Then suggestions for improvement and possible policy measures are suggested to Denmark's transport sector.

Next come, what type of research data are required? Whether qualitative or quantitative? Since the aim of our work is to gather details of production and consumption of bio and conventional fuel types, we decided that quantitative data collection method would be more appropriate.

2.2 Data Collection

Quantitative data collection method is adopted in this study. Quantitative method involves counting, measuring and analysis of events (Smith, 1988). The main concerns of quantitative method are the performance of these measurements, their validity and prediction of cause and effects (Cassell & Symon, 1994). Some of the advantages of quantitative methods are

- Independent and dependent variables can be determined precisely (Alexei, 2002)

- Eliminating or minimizing subjectivity of judgment (Kealey & Protheroe, 1996)

- Research problem can be set very specific (Frankfort-Nachmias & Nachmias, 1992)

Disadvantage of quantitative data according to Camille (2005)

- Formulation of an advanced and specific hypothesis is very important in a quantitative method (Huysamen, 1997)

- The disadvantage of a quantitative research according to Edwards (1998): *"the disadvantage that the resulting theory often fails to take account of the unique characteristics of individual cases"*

Qualitative data collection methods are not employed in this project, rather the readers are given brief idea about this method. According to Denzin (1971), qualitative method hold good for natural setting where natural setting implies to the study focus on every day activity. Qualitative method is less driven by very specific hypotheses and categorical frameworks and more concerned with emergent themes and idiographic descriptions (Cassell & Symon, 1994).

2.3 Data types

There are two types of data collection methods, primary and secondary. Secondary data are referred to as data that already exist which have been collected for different purpose (Colin, 2002). The secondary data being used in this project encompassed books, articles, scientific journals and information found on the web. Key words used for collecting data were: Energy use of Denmark, Transport sector of Denmark, Biofuel usage in Denmark, Process of extraction of biofuel, Process of extraction of conventional fuel.

The primary data collection involves performing of observation and interviewing methods. Primary data can be defined as data collected by research intended for his study purpose (Colin, 2002). In this project there is no primary data collected involved.

2.4 Self criticism

According to Teresa and Sarah (2004), data being collected during the research process need to be checked for validity and reliability by the researcher. So accordingly, the knowledge we obtained during the process of data collection is subjected to validity and reliability as these data being collected are key issues during analysis and drawing conclusions.

2.4.1 Validity

Kvale (1996, p 238) defined validity as, "*Validity is often defined by asking the question: Are you measuring what you think you are measuring?*" Answering to this type of question determines to the validity of the research process.

2.4.2 Reliability

Quality is a key word in determining the reliability of a qualitative or quantitative research method. David (1997) point's out that reliability is synonymous with repeatability. A measurement that could give the same value over repeated intervals or time is said to be reliable.

2.4.3 Generalization

Polit and Hungler (1991) define generalization as the degree to which the findings of the study sample could be generalized to the entire population. This is the statement for the word *generalization* in common terms of research.

2.5 Using LCA as a methodological tool

In this report LCA methodology is applied to determine the impacts of the four scenarios and find out what are the impacts corresponding to each of the individual scenario.

This will further lead us to the main focus of our project, where analysis on the impact of using biofuel (rapeseed oil) instead of conventional fuel for transport sector of Denmark. For this purpose four different scenarios are built in SimaPro 6 to analyse the impact of rapeseed on environment. The four different scenarios are:

3. Using 100 % oil (diesel and petrol)
4. Using 79% oil (diesel and petrol) and 21% from biofuel (rapeseed)
5. Using 50% oil (diesel and petrol) and 50% from biofuel (rapeseed)
6. Using 100% biofuel (rapeseed)

Some of the assumptions made in performing the analysis are

- Oil was consumed by Cars (diesel and petrol), trucks, busses and van
- The consumption level was set to remain the same
- Rapeseed oil replaces both petrol and diesel for automobiles
- The disposal of vehicles are not considered
- The numbers of vehicles are set to remain the same during the entire analysis
- The numbers of vehicles and the kilometres driven by vehicles considered for study are exact numbers for the year 2003 (Danish ministry of transport, 2004)
- Electricity usage and irrigation of crops in rapeseed production are omitted
- CO2 emission values on biofuel production process are marginalized

The different scenarios are explained with the help of diagram

Scenario 1: Using 100 % oil (diesel and petrol)

The scenario one considers the transport sector of Denmark to be completely depended on oil for firing its automobiles. The diagram below shows the usage of petrol and diesel for automobiles

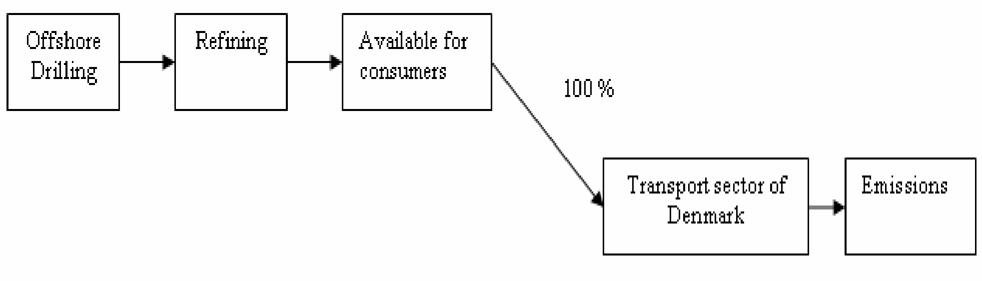


Figure 2.2: Flow diagram for scenario 1

The model built in SimaPro will involve drilling of oil from the North Sea to transportation to nearby refineries. When the oil is refined, diesel and petrol is made available to the customers. Finally the emission level is estimated from the output generated by the SimaPro.

Scenario 2**:** Using 79% oil (diesel and petrol) and 21% from biofuel (rapeseed)

In scenario 2, there is a gradual shift in the usage of biofuel in the transport sector. The scenario considers the usage of 21% of biofuel for transport sector, in accordance to the Kyoto protocol the Danish government has agreed. According to the agreement the Danish government should reduce CO2 emissions level by 21% by the year 2012.

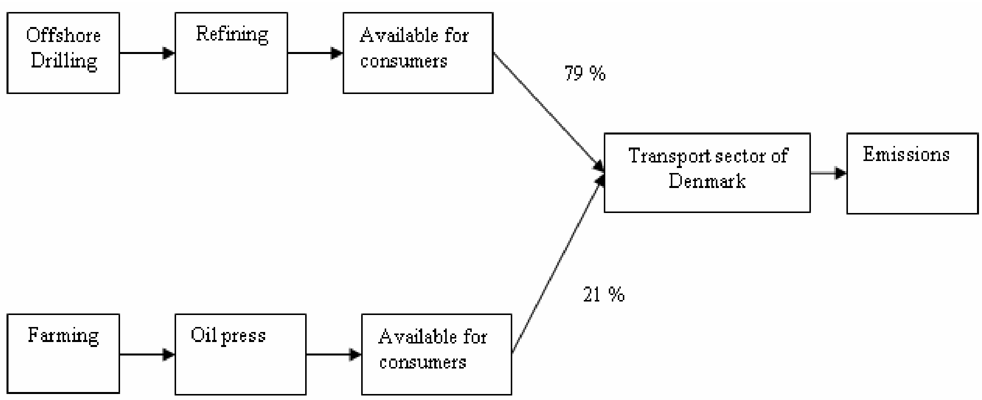


Figure 2.3: Flow diagram for scenario 2

In this scenario, the feed stock is send to the oil press for production of bio diesel. The bio diesel produced is used as a substitute for diesel and petrol. In this case the bio diesel is assumed to replace 21% of conventional fuel

***Scenario 3*:** Using 50% oil (diesel and petrol) and 50% from biofuel (rapeseed)

In scenario 3, there was an increase in biofuel usage in the transport sector from 21% to 50 %.

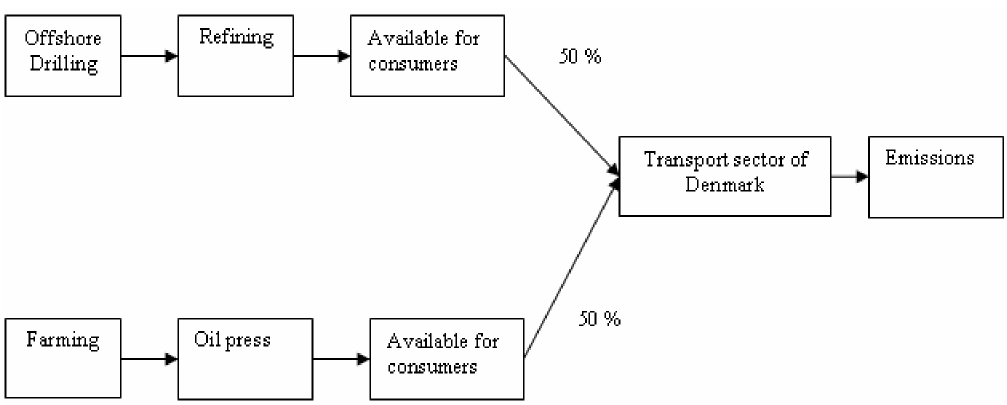


Figure 2.4: Flow diagram for scenario 3

There was an equal contribution from oil and biofuel.

***Scenario 4*:** Using 100% biofuel (rapeseed)

In scenario 4, the biofuel is assumed to completely replace conventional fuel for transport sector of Denmark.

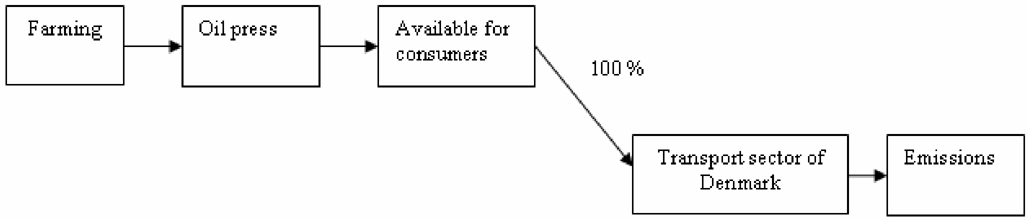


Figure 2.5: Flow diagram for scenario 3

In this scenario the effect on environment by using biofuel instead of conventional fuel is identified. The emission levels are compared with the other scenarios to conclude whether replacing conventional fuel with biofuel is worth an alternative.

Chapter 3

ISO 14040, Impact assessment and Land use

This section of the report describes the ISO 14040 phases or stages and the various stages that are applied in this particular report. It further explains the how impacts assessment could be used as a theoretical framework and how the use of land is described as an impact to the environment.

3.1 Why ISO 14040?

With the current trend of economic and technological development in the world, the environmental issues and its related impacts on products, process and service to the environment has been seen as problematic and therefore need to be addressed beforehand. The use of international standard to address this issue has been identified though there are many complexities regards to the use of the standard. ISO 14040 was then introduced as the main recognised standard to address the environmental impacts of a product, process or service. The International Standard 1SO 14040 is a worldwide environmental management approach by many governmental bodies and companies for policy making and regulations because it is well approved standard by Western countries. Another reason of using ISO 14040 in this study is that it is recognised as only standard for life cycle assessment (LCA).

In addition to that it is only standard that clearly defines the goal of the project carried out and expected audience the project is addressing to, scope that gives the various parameters of the project such as functional units, boundaries of the project and the inventory that also deals with the data collection and how they are used in a model known as SimaPro to determine the impact of that particular product or service.

3.2 What is ISO 14040?

ISO 14040 is an abbreviation represents International Organization for Standardization that provides principles, framework and methodological requirements for conducting Life Cycle Assessment (LCA) studies. The international standard on LCA has been adopted as part of ISO development of Environmental Management Standard of ISO 14000 series. This standard is sub-divided in stages according to the interpretation of their definition. These stages are defined based on ISO 14041 – 14043 that give the details of the product or service being assessed and possible potential impacts that related to the product or service on life cycle basis. The stages are categorised into four main different phases

Goal and scope definition (ISO 14041: 1998), Life cycle inventory analysis (ISO 14041: 1998), Life cycle impact assessment (ISO 14042: 2000), Interpretation (ISO 14043: 2000)

3.3 General descriptions of ISO 14040 and various elements

ISO 14041: Goal

Aims/reasons for taking up the study
Intended target group or audience the study address to

ISO 14041: Scope

Functional systems of the product and their functional units
The system boundaries
Data quality requirements
The type of critical review
Dealing with multiple outputs- allocation procedures

Assumptions and Limitation

Type of impact assessment methodology and interpretation to be performed

ISO 14041: Inventory

Life cycle inventory according to EPA is defined as a *process of quantifying energy and raw materials requirements, atmospheric emissions, waterborne emissions, solid wastes, and other releases for the entire life cycle of a product, process or activity* (EPA, 1993). It contains the following elements as mentioned below.

Description of all the processes in a life cycle phases
Data collection on each process step
Calculation of the inventory table with all raw material depletion and emission

Life cycle impact assessment

Impact assessment is a process of identifying, analysing and concluding the future consequences of a proposed action or an event. In this project, impact assessment is conducted for transport sector of Denmark, studying scenarios of replacing conventional fuel with biofuel (Rapeseed). LCA software tool called SimaPro was deployed for the purpose of construction and analysis of different scenarios.

Impact assessment is defined as "*A study of the potential future effects of resource development on other resources and on social, economic and/or environmental conditions*" (British Columbia, 2001). The impact assessment studies are performed by different means which may include (University of Westminster, 2006):

- Focussed groups and feedbacks
- Analysis of data review

- Conducting survey to collect data
- Trying new form of investigation

Impact assessments are made on different levels, Environmental impact assessment, retail impact assessment, Life cycle impact assessment etc. and are performed according to the kind of situation under investigation.

Importance of impact assessment

Impact assessment is an important step followed in a LCA approach, where the input to the system and its subsequent translation of output are analyzed. Impact categories are predefined in an impact assessment and the inventory is converted into potential contributors of the impact using the predefined impact categories (Curran, 1991, *S.E. Daniel et al. / Ecological Indicators 4 (2004).*

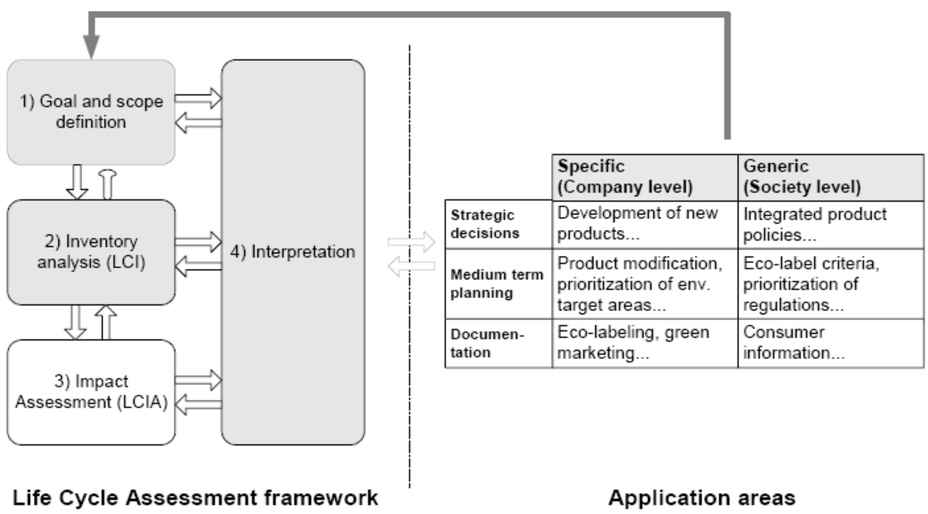


Figure 3.1: Phases in a LCA
Source: Jerlang et al (2001), Thrane (2005)

Impact assessment is also a popular way of analysing and identifying the hazards of a new product before it is launched in the market, prioritizing and correcting them to obtain best results. Figure 1 gives the phases of an entire LCA process.

The two way arrow sign between different phases represents the interaction between them. The LCA methodology as a whole cannot determine the ‘real’ impacts of a product or a process but only ‘potential’ impacts.

Tools for performing impact assessment

This project analyses the environmental impact of using conventional and biofuel (rapeseed) for the transport sector of Denmark. There are a wide range of tools available in the market for conducting environmental impact assessment. Some of them are (Finnveden et al., 2004)

- Environmental impact assessment
- System of Economic and Environmental Accounting(SEEA)
- Environmental Auditing
- Material Flow Analysis (MFA)

In addition to above mentioned tools, software tools like: ECO-it, EDIP (Environmental Design of Industrial Products), EIOLCA (Economic Input Output LCA at Carnegie Mellon University), GaBI product family, SimaPro, TEAM (Tool for Environmental Analysis and Management) are available in the market (LCA, 2006).

Steps in Impact assessment

There are three steps involved in performing Impact Assessment (PRe, 2006).

- Classification and Characterization
- Normalization
- Evaluation or Weighting

Classification and Characterization

In classification, all elements are arranged or sorted according to the effect they create on the environment. The effects are classifies as classes, for example the elements that contribute to green house effect are classified as one class and the substance that contribute to ozone layer depletion are classified as another class (Pre, 2006).

Characterization

The elements that are classified are weighed to produce an effective score. The weighting factor is applied to the elements to identify their exact effect on the environment, as some elements have more effect than others. Some advantages of characterization are

- Helps in differentiating the relative size of one effect compared with another effect
- Bring out the importance of various environmental effects
- Interpretation in terms of effects is less confusing than interpreting in terms of element list

Impact categories used in EDIP/UMIP 97 method are: Global warming, Ozone depletion, Acidification, Eutrophication, Photo chemical smog, Ecotoxicity water chronic, Human toxic air, Bulk waste

Normalization

Normalization helps in understanding the relative size of one effect over another effect. For example, the effect that is caused in manufacturing of a particular product is compared with the known total effect for this class (Pre, 2006).

Evaluation or Weighting

Weighting helps in identifying the most important effect on the environment for study conducted, from the normalized effects. In this stage, the normalized sores are multiplied with a weighting factor to clearly show the element's relative effect on the environment (Pre, 2006).

3.4 What phases or stages are applicable in this research?

This study will not apply all the ISO 14040 stages but it is limited to the first three stages which include the goal, the scope and the life cycle inventory. The impact assessment step was performed using SimaPro (software tool on LCA) and the results obtained are analyzed and concluded to answer the research question.

3.4.1 Goal and scope of the study

The goal of the study is supposed to include a statement of the reason for taking up the study and intended application of the results and the intended target group. In this case, the goal of the project is defined as investigating the environmental impact of using biofuel (biodiesel) in relative to conventional fuels (petrol and diesel) in the transport sector of Denmark. This study tries to address the Danish Transportation Sector as a target group which is known to consume more than 50% of the total crude oil of the country.

Scope of the work is viewed from the functional units, system boundaries, and some assumptions of the products and process being studied. Here the functional units are of three folds vehicles, conventional fuel and biofuel. The Danish transportation sector is divided into four groups namely; cars, trucks, buses and vans and the total kilometres covered for the year 2003 remains at 46.30 billion Km (35.56 billion Km by petrol and 3.22 billion km by diesel). For every 1km a vehicle is driven it consumed 0.064kg of petrol and 0.104kg of diesel and biodiesel respectively.

Some of the basic assumptions made are:

Oil (petrol and diesel) is consumed by cars, trucks, busses and van
The consumption level is set to remain the same
Rapeseed oil replaces both petrol and diesel for automobiles
The disposal of vehicles are not considered

The numbers of vehicles are set to remain the same during the entire analysis

The system boundaries are of two fold; the biodiesel (rapeseed) production and conventional fuel (petrol and diesel) extraction. For biodiesel production, the land use, feedstock, oil mill and finally to the consumer. In each of the stages the emissions are taken into consideration. With the conventional fuel, crude oil extraction from the North Sea, transportation of oil to the refineries, refining of oil (production of petrol and diesel) and finally to the consumers.

3.4.2 Inventory

This phase of LCA describes the quantification of raw materials required, atmospheric emissions, waterborne emissions, soil emissions and other solid waste for the entire life cycle process. For example, crude oil extraction to the final consumer where emissions to the air, water and soil were categorised in the appendix. These emissions determined the impacts of the overall life cycle of the crude oil (petrol and diesel).

Since we were comparing biodiesel with petrol and diesel, we find it difficult to get reliable data for emissions as associated with burning biodiesel. The data of diesel were used to increase or decrease the emissions based on US EPA inventory from diesel. The following emissions data were used; carbon monoxide (48%), nitrogen oxide (10% more), sulphur dioxide (20% more), hydrocarbons (67% low) and particulate matter (47% low). (US EPA, 2006).

Most of the other data used in the model were adopted from the SimaPro 6 standard data base available with the software. The numbers of vehicles used in calculation are given in table 1

	Cars	Buses	Trucks	Van
Petrol	1,736,917			
Diesel	157,537	14,132	34,896	365,112

Table 3.1: Numbers of vehicles and fuel types for Danish transport sector
Source: Danish Ministry of transport, 2004

The country's road transportation sector was categorized into four main groups namely; cars, buses, trucks and van with the numbers relating to the individual groups as in table 3.1. For the base case scenario all the vehicles uses petrol and diesel.

3.4.3 Impact assessment

In this project SimaPro 6 is used in conducting the impact assessment. SimaPro stands for "System for Integrated Environmental Assessment of Product". The reasons for choosing SimaPro 6 as a tool for doing the impact assessment study are (Pre, 2006)

- The tool is available in the Aalborg University labs
- Classes were handled to train students in the use of SimaPro 6
- Proven, reliable and flexible tool
- Its user interface following ISO 14040
- Easy modelling
- Results appear in one Window
- Reliable data base built within SimaPro

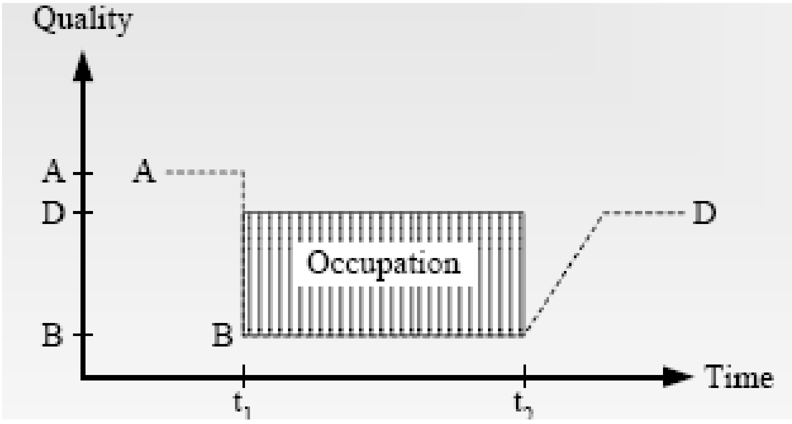
The impact assessments were performed by two methods: Eco indicator 95 and EDIP/UMIP 97. As there are no specified methods stated to determine the environmental impact on fuel usage, the two impact assessment methods stated above are applied and tested to compare the deviations in the results. In addition to the above analysis, impact on land usage due to increase in land acquisition for rapeseed production is performed.

3.5 Land Use

The use of land has great impact on the life cycle assessment. Many life cycle assessment projects exclude the land use as an impact to the environment due to the fact that researchers find it uphill task to include. For example allocation of land erecting of buildings, crops planting and just a few to mention has impact to the individual functional units. Some of the impacts associated with land use include substantial reduction of regional biodiversity, changes natural landscapes, disturbances in fresh water circuit and thereby leading to degradation of the natural environment (Lindeijer E, R Müller-Wenk and B Steen (2002)).

Land use is defined as the in the web dictionary as the *way land is developed and used in terms of the types of activities allowed (agriculture, residences, industries, etc.) and the size of buildings and structures permitted. Certain types of pollution problems are often associated with particular land uses, such as sedimentation from construction activities*. [2]

But in this context land use is referred to intensive human activities aiming at exclusive use of land for certain purposes and adapting the properties of land areas in view of these purposes (Lindeijer E, R Müller-Wenk and B Steen (2002)). The figure below shows how the area of land use has significant impact of the quality of the land but can regain it quality if the land is allowed to fallow for specific period of time.



Lindeijer et al. (2002), *Impact Assessment of Resources and Land Use*. SETAC

Figure 3.2: Impact of land use and the effect on quality
Source: Lindeijer et al., 2002

3.5.1 Reasons why land use were not included in impact assessment

- Land-use impacts seem very dependent on the regional or even local situation, which is generally not known in LCA
- Land use as an environmental intervention is more complicated than only emission of carbon dioxide. Rather it might include many different elementary activities such as excavating, ploughing, draining, or fertilising.
- Describing types of land use and studying the corresponding impacts on the nature is herculean task for developers of LCA methodology.
- Land use data are not added in traditional environmental data collection schemes because such data are not easily available.

(Lindeijer E, R Müller-Wenk and B Steen (2002))

3.5.2 LCIA methods for land use

There are five different methods of evaluating land use in Life cycle impact assessment (LCIA). These are:

- Simplest: Inventory data
- Simple: Qualitative/Functional approach (Mattson et al., 2000).
- Medium: Land use classes
- Medium/Heavy: Key indicators/ Land use classes (Kollner, 2000)
- Heavy: Key indicator (Weidemer and Lindjeir, 2001)

These methods are well known and used in this current situation for many LCIA model. The most widely used among the five is the simplest method which will applicable in our case. We would look into how land use is included in this case especially where cultivation of rapeseed on specific area of land will have impact on the natural environment. The four scenarios:

- 100% of conventional fuel used for transportation
- 21% of rapeseed oil and 79% conventional fuel
- 50% rape seed oil and 50% conventional fuel
- 100% rape seed oil

The last three scenarios will be the focus since land acquisition for the production or cultivation of rapeseed is important and has to be incorporated in the in the LCIA model.

3.5.3 The Simplest Method of LCIA

In this method two different interventions are considered namely; occupation and transformation interventions. These interventions are defined based on land occupation and land transformation. This method is defined according to occupation of the area of land use for certain period of time or transformation of area of land use for particular activities or purposes. Mathematically, it can be expressed as

Land occupation = m^2 a

Land transformation =m^2

m^2 represents area of land used and
a represents time frame in annually (yearly)

With this method, it is identified how the three scenarios of biodiesel (rapeseed) cultivation can be calculated in terms of the land use for the cultivation and its impacts or influence on the Danish total land area and the environment.

Chapter 4

Construction of Scenarios in SimaPro 6

This chapter explains how the four scenarios are built in the SimaPro using the data set available in the data base. This chapter is meant to give the readers a clear idea of how the scenarios are setup and some of the assumptions and calculations upon which the model is based on.

4.1 Basic Model structure in SimaPro

The LCA wizard in SimaPro is classified into the following category, the goal and scope, Inventory, Impact assessment, Interpretation and General Data as shown in the figure 1. The SimaPro's user interface follows ISO 14040.

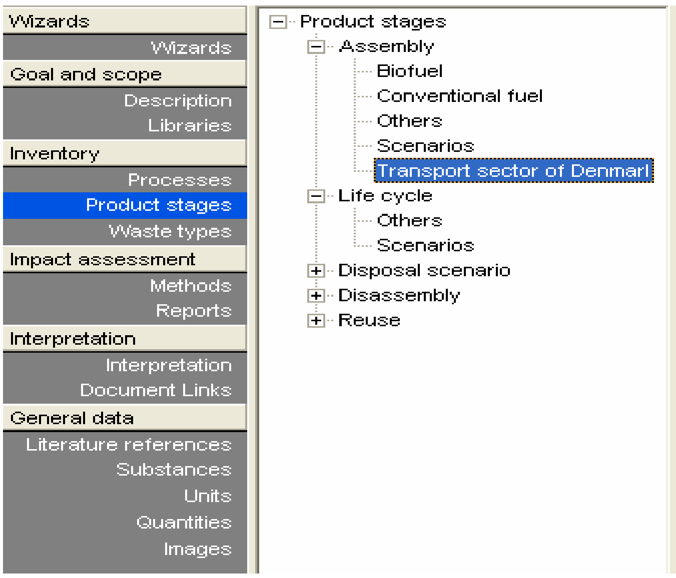


Figure 4.1: LCA wizards in SimaPro

The process wizard in the inventory represents the collection of all data that are available with the SimaPro. The data provided in the process wizard ranges from material, energy, transport, processing, use, waste scenario and waste treatment. Each set of these process consists of many data related to there particular category. For detail understanding of how the data and wizard works please refer to the SimaPro software and it's manual.

From the figure 1, the product stage wizard is sub divided into assembly, life cycle, disposable scenario, disassembly and reuse.

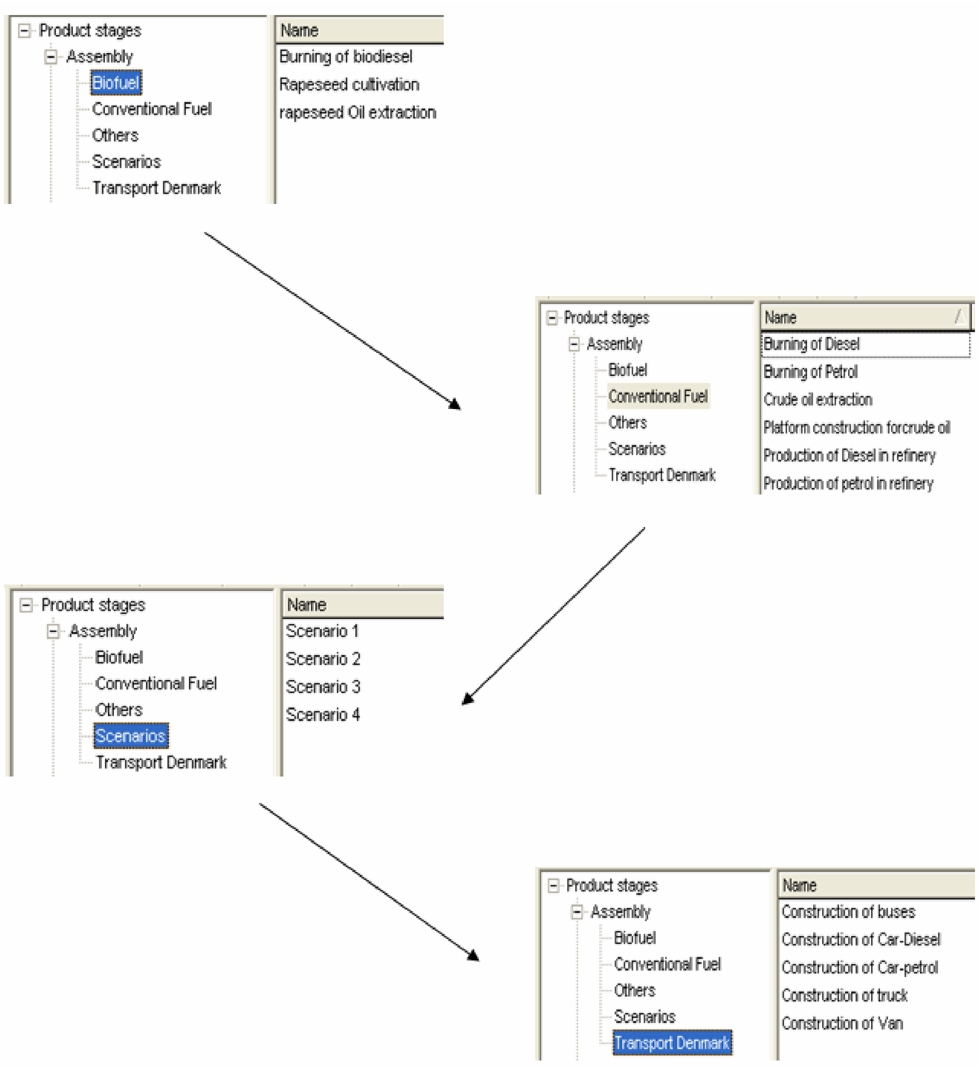


Figure 4.2: Shows various assemblies (Biofuel, conventional fuel, scenarios and transport sector of Denmark) and subassemblies.

In this project, only assembly and life cycle stages were used in constructing the scenarios. As seen from the figure 1, the assembly stage are classified into

- Biofuel
- Conventional fuel
- Scenarios
- Transport sector of Denmark

The figure 2 gives a very brief overview of how the different elements (subassemblies) are established within the wizard's product stage assemblies for creating the scenarios.

4.2 Scenario 1

The building of scenario 1 is explained in terms of functional units, system boundaries and basic assumptions for the scenario 1. The Functional Unit (FU) of scenario 1 is conventional fuel for the transport sector of Denmark.

Transport	Number of vehicles	Billion Km per year
Car (Petrol)	1,736,917	35.56
Car (Diesel)	157,537	3.22
Van (Diesel)	365,112	5.9
Truck (Diesel)	34,896	1
Bus (Diesel)	14,132	0.625
Total	**2,308,594**	**46.30**

Table 4.1: Functional units for the scenario 1

The above table gives the details of different functional units and translating them back to the number of Km driven by 2,308,594 vehicles in Denmark. The number 2,308,594 is the number of vehicles on the road in Denmark for the year 2003 and the number of Km driven are the vehicle kilometres for the year 2003.

<table>
<tr><th>Billion Km per year</th><th>Kg of diesel used per Km</th><th>Kg of petrol used per Km</th><th>Kg of diesel produced in billion</th><th>Kg of petrol produced in billion</th><th>Total crude oil extracted in billion Kg</th></tr>
<tr><td>35.56</td><td>-</td><td>0.064</td><td>-</td><td>2.27</td><td rowspan="6">3.38</td></tr>
<tr><td>3.22</td><td rowspan="5">1.104</td><td rowspan="5">-</td><td rowspan="5">1.11</td><td rowspan="5">-</td></tr>
<tr><td>5.9</td></tr>
<tr><td>1</td></tr>
<tr><td>0.625</td></tr>
<tr><td>46.30</td></tr>
</table>

Table 4.2: The amount of crude oil to be extracted in accordance to the Km driven

To give an example of the above calculation

Number of Car (Petrol): 1,736,917

Km driven by petrol car per year (2003): 35.56 million Km

Petrol consumed for a Km drive: 0.064 kg

Therefore:

Petrol used by 1,736,917 cars: 35.56*0.064=2.27 billion Kg of petrol

Similarly diesel consumption is calculated (Car (diesel), van (diesel), Bus (diesel), and truck (diesel)) and the total crude extraction in Kg was found to be 3.38 billion Kg

System boundaries

The system boundaries are the defined boundaries of an event or a scenario. The system boundary for scenario 1 is given in figure 3. The system boundaries cover from extraction of oil from the North Sea to the emission to the environment on burning of diesel and petrol. The system boundaries explained below underlines the assumptions and constraints taken into account in building each system boundary in SimaPro.

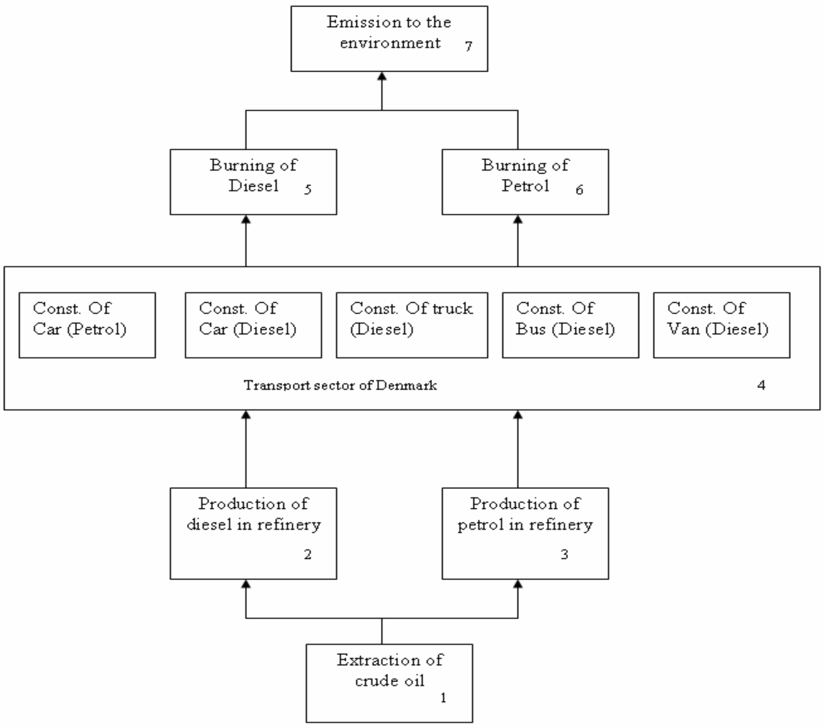


Figure 4.3: System boundaries for scenario 1

Extraction of crude oil (Included processes): Exploration and production of oil and gas on the Norwegian Continental Shelf (offshore). Data doesn't include combusted fuels for turbines, motors etc. It includes well testing (fuel requirements and emissions). Natural gas is partly dried on the platforms, the rest is dried in a special production plant (For detailed reference on data and its emission content refer appendix 1).

Production of diesel in refinery (Included processes): Transportation of product from the refinery to the end user. Operation of storage tanks and petrol stations. Emissions from evaporation and treatment of effluents. Excluding emissions from car-washing at petrol stations (For detailed reference on data and its emission content refer appendix 1).

Production of petrol in refinery (Included process): All processes on the refinery site excluding the emissions from combustion facilities, including waste water treatment, process emissions and direct discharges to rivers.

Transport sector of Denmark: The transport sector of Denmark (assumed for this study) falls under the following five vehicle types on Danish roads. Car(Petrol), Car(Diesel), Truck(Diesel), Bus(Diesel), Ferry(Diesel)

Car (Included process): The inventory includes processes of material, energy and water use in vehicle manufacturing. Rail and road transport of materials is accounted for. Plant infrastructure is included, addressing issues such as land use, building, and road and parking construction.

Truck (Diesel), included processes: The inventory includes processes of material, energy and water use in vehicle manufacturing (final assembly, engine production and manufacturing of metal parts). Rail and road transport of materials is accounted for. Plant infrastructure is included, addressing issues such as land use, building, road and parking construction.

Bus (Diesel), included process: The inventory includes processes of material, energy and water use in vehicle manufacturing (final assembly, engine production and manufacturing of metal parts). Rail and road transport of materials is accounted for. Plant infrastructure is included, addressing issues such as land use, building, and road and parking construction.

Van (Diesel), included process: The inventory includes processes of material, energy and water use in vehicle manufacturing. Rail and road transport of materials is accounted for. Plant infrastructure is included, addressing issues such as land use, building, road and parking construction.

Burning of Diesel (Included processes): Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Also heavy metal emissions to soil and water are estimated.

Burning of Petrol (Included processes): Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Also heavy metal emissions to soil are included. For petrol cars platin emissions are accounted for.

Emission to the environment: Finally using the results obtained from SimaPro, the environmental impact of using conventional fuel is analyzed.

While building the system boundary model (scenario 1), data for the processes 1 to 4 were used from the database provided with the SimaPro (An example of data input is shown in appendix). The data for process 5 and 6 were modified from the original set of data for the burning of fuel (petrol and diesel) in the SimaPro.

4.3 Scenario 2

The building of scenario 2 is explained in terms of functional units, system boundaries and basic assumptions for the scenario 2. The Functional Units (FU) for scenario 2 is 79 % conventional fuel and 21 % biofuel for the transport sector of Denmark. The functional units for the scenario 2 are

Transport	Number of vehicles	Billion Km per year
Car (Petrol)	1,736,917	35.56
Car (Diesel)	157,537	3.22
Van (Diesel)	365,112	5.9
Truck (Diesel)	34,896	1
Bus (Diesel)	14,132	0.625
Total	**2,308,594**	**46.30**

Table 4.3: Functional units for the scenario 2

The total kilometres driven by the vehicles was 46.3 billion Km. In this scenario 21 % of 46.3 billion Kilometres is replaced by biodiesel/biofuel.

<table>
<tr><th>Billion Km per year</th><th>21 % replaced by biofuel in billion Km</th><th>Diesel produced in billion Kg</th><th>Petrol produced in billion Kg</th><th>Total crude oil extracted in billion Kg</th></tr>
<tr><td>35.56</td><td rowspan="5">9.7</td><td>-</td><td>1.80</td><td rowspan="5">2.66</td></tr>
<tr><td>3.22</td><td rowspan="4">0.86</td><td rowspan="4">-</td></tr>
<tr><td>5.9</td></tr>
<tr><td>1</td></tr>
<tr><td>0.625</td></tr>
</table>

Table 4.4: Total amount of Crude oil to be extracted for scenario 2

To give an example of the above calculation

21 % is replaced by Biofuel (21 % of 46.30 billion): 9.73 billion Km
Total number of diesel vehicles: 571,677
Total number of petrol vehicles: 1,736,917
Total number of vehicles: 2,308,594
Total Km on diesel: (571,677/2,308,594)*9.73=2.40 billion Km;
10.74-2.4=8.34 billion Km
Total Km on petrol: (1,736,917/2,308,594)*9.73=7.3 billion Km;
35.56-7.3=28.26 billion Km
Kg of diesel needed to be produced (8.34*0.104) = 0.86 billion Kg
Kg of petrol needed to be produced: (28.26*0.064) = 1.80 billion Kg
Total Crude to be extracted: 2.66 billion Kg

21 %replaced by Biofuel in Billion km	**Kg of Biofuel used per Km**	**Billion Kg of Biofuel needed**	**72 % more of feed stock in billion kg**
9.73	0.104	1.01	1.737

Table 4.5: 21 % bio fuel for the transport sector of Denmark

21 % of the total driven Km in Denmark is replaced with the biofuel. This number equals 9.73 billion Km. The amount of biofuel required to supplement 21 % conventional fuel was 1.01 billion Kg.

The above number is multiplied with a factor 1.72 because, 72% more feedstock of rapeseed is needed for every unit of biodiesel produced as 72% of feed stock used for producing a unit biofuel goes as fodder. The total feed stock needed for scenario 2 was 1.737 billion Kg.

System boundaries

The system boundaries are the defined boundaries of an event or a scenario. The system boundary for scenario 2 is in figure 4. The system boundaries cover from extraction of oil from the North Sea to the emission (of gases) to the environment on burning of diesel and petrol. The additional system boundaries for this scenario include burning of biodiesel, biodiesel production and feed stock cultivation.

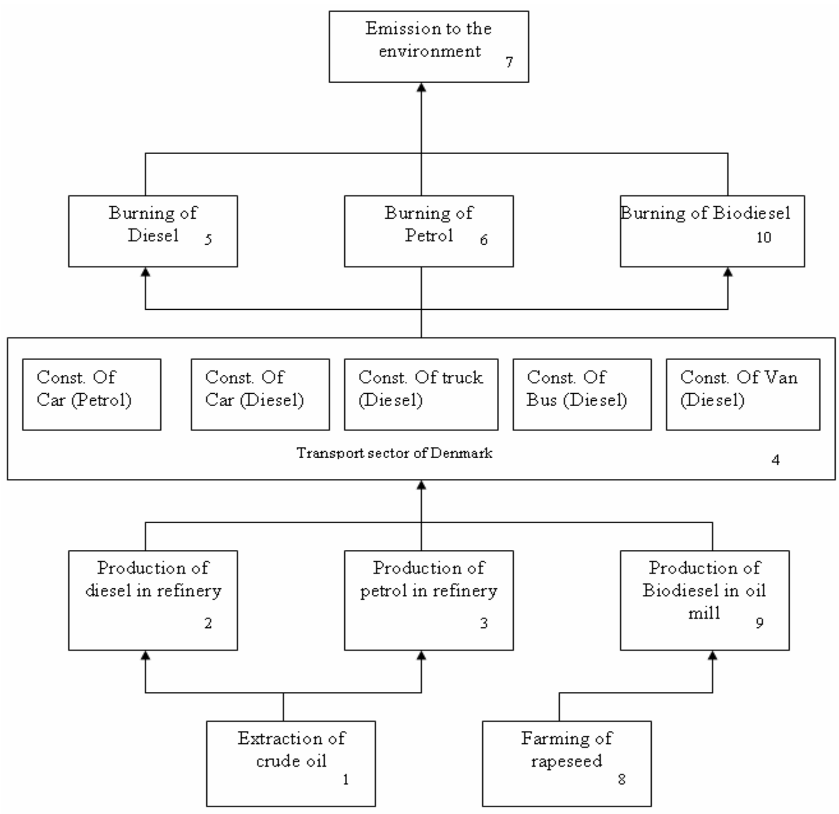


Figure 4.4: System boundaries for scenario 2 (21 % biofuel supplements conventional fuel for the transport sector of Denmark)

The system boundaries for the process from 1 to 7 are the same as explained in scenario 1. The additional system boundaries: production of biodiesel, burning of biodiesel and rapeseed cultivation are explained below

Production of Biodiesel in oil mill (Included process): In this process Soya oil production is taken into account because of the unavailability of data on rapeseed oil production. Manufacturing process starting with drying of Soya beans is considered, plus consumption of auxiliaries, energy, infrastructure and land use, as well as generation of emissions into air and water. Transport of the raw materials and auxiliaries is also included. The generation of the co-product soya scrap is considered. Transport and storage of the final products are not included. Transient or unstable operations are not considered, but the production during stable operation conditions. Emissions to air are considered as emanating in a high population density area. Emissions into water are assumed to be emitted into rivers.

Burning of biodiesel (Included process): Burning of biodiesel data were added to the SimaPro data base due to the unavailability of this particular data. The data were modified for the diesel (burning) data with the input obtained from the US EPA source on emission of biodiesel on burning. Refer appendix for detail on emission of biodiesel.

Farming of rapeseed (Included process): The inventory includes the processes of soil cultivation, sowing, weed control, fertilisation, pest and pathogen control, harvest and drying of the grains. Machine infrastructure and a shed for machine sheltering is included. Inputs of fertilisers, pesticides and seed as well as their transports to the farm are considered. The direct emissions on the field are also included.

4.4 Scenario 3

The building of scenario 3 is explained in terms of functional units, system boundaries and basic assumptions for the scenario 3. The functional units for scenario 3 is given below

Transport	Number of vehicles	Billion Km per year
Car (Petrol)	1,736,917	35.56
Car (Diesel)	157,537	3.22
Van (Diesel)	365,112	5.9
Truck (Diesel)	34,896	1
Bus (Diesel)	14,132	0.625
Total	**2,308,594**	**46.30**

Table 4.5: Functional units for the scenario 3

The total kilometres driven by the vehicles was 46.30 billion Km. In this scenario 50 % of 46.30 billion Kilometres is replaced by biodiesel/biofuel.

<table>
<tr><th>Billion Km per year</th><th>50 % replaced by biofuel in billion Km</th><th>Diesel produced in billion Kg</th><th>Petrol produced in billion Kg</th><th>Total crude oil extracted in billion Kg</th></tr>
<tr><td>35.56</td><td rowspan="5">23.15</td><td>-</td><td>1.16</td><td rowspan="5">1.681</td></tr>
<tr><td>3.22</td><td rowspan="4">0.521</td><td rowspan="4">-</td></tr>
<tr><td>5.9</td></tr>
<tr><td>1</td></tr>
<tr><td>0.625</td></tr>
</table>

Table 4.6: Total crude oil required for scenario 3

To give an example of the calculation

50 % is replaced by Biofuel (50 % of 46.30 million): 23.15 billion Km Total number of diesel vehicles: 571,677 Total number of petrol vehicles: 1,736,917 Total number of vehicles: 2,308,594 Total Km on diesel: (571,677/2,308,594)*23.15=5.73 billion Km; 10.74-5.73=5.01 billion Km Total Km on petrol: (1,736,917/2,308,594)*23.15=17.41 billion Km; 35.56-17.41=18.15 billion Km Kg of diesel needed to be produced (5.01*0.104) = 0.521 billion Kg Kg of petrol needed to be produced: (18.15*0.064) = 1.16 billion Kg Total Crude to be extracted: 1.681 billion Kg

50 % replaced by Biofuel in Billion km	Kg of Biofuel used per Km	Billion Kg of Biofuel needed	72 % more of feed stock in billion kg
23.15	0.104	2.407	4.14

Table 4.7: 50 % biofuel for the transport sector of Denmark

50 % of the total driven Km in Denmark is replaced with the biofuel. This number equals 23.15 billion Km. The amount of biofuel required to supplement 50 % conventional fuel was 2.407 billion Kg.

The above number is multiplied with a factor 1.72 because, 72% more feedstock of rapeseed is needed for every unit of biodiesel produced as 72% of feed stock used for producing a unit biofuel goes as fodder. The total feed stock needed for scenario 3 was 4.14 billion Kg.

System boundaries

The system boundaries are the defined boundaries of an event or a scenario. The system boundary for scenario 3 is given in figure 5. The system boundaries cover from extraction of oil from the North Sea to the emission (gases) to the environment on burning of diesel and petrol. The additional system boundaries for this scenario include burning of biodiesel, biodiesel production and feed stock cultivation.

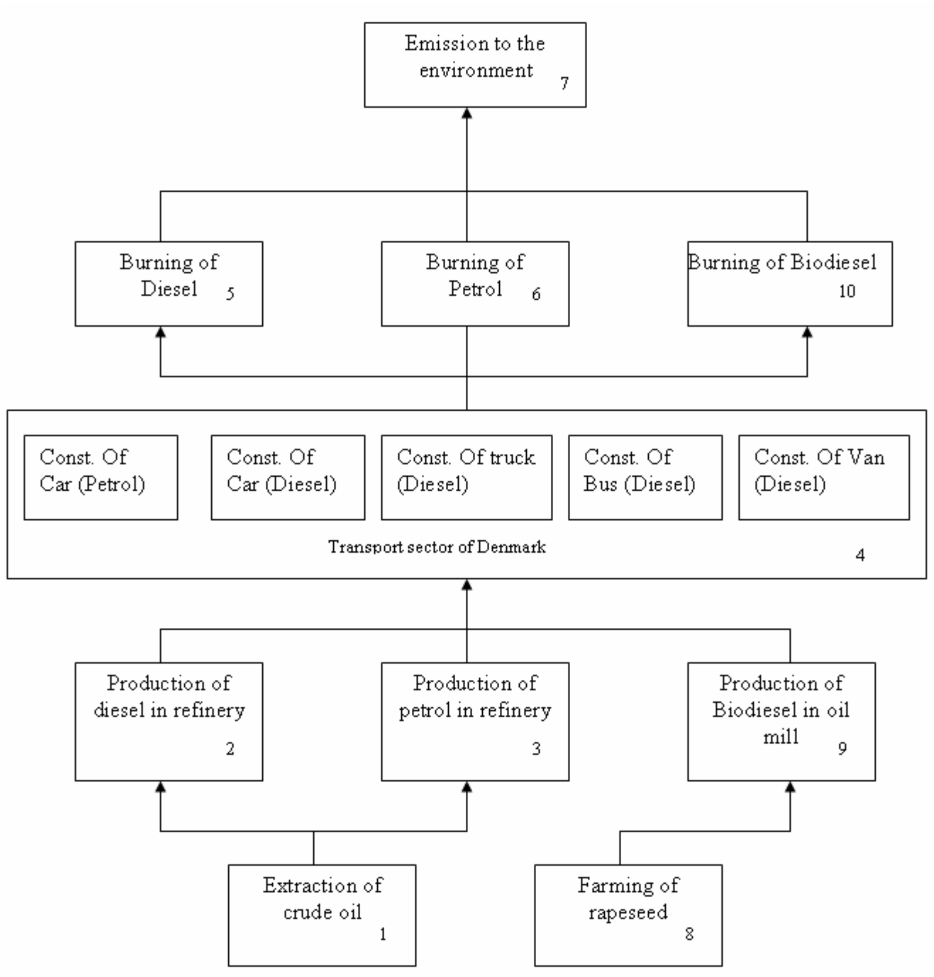


Figure 4.8: System boundaries for scenario 3

The system boundaries for the process from 1 to 10 are the same as explained in scenario 2. The system boundaries are built using the assumptions relevant for scenario 3.

4.5 Scenario 4

The building of scenario 4 is explained in terms of functional units, system boundaries and basic assumptions for the scenario 3. The functional units for scenario 4 is given below

Transport	Number of vehicles	Billion Km per year
Car (Petrol)	1,736,917	35.56
Car (Diesel)	157,537	3.22
Van (Diesel)	365,112	5.9
Truck (Diesel)	34,896	1
Bus (Diesel)	14,132	0.625
Total	**2,308,594**	**46.30**

Table 4.9: Functional units for the scenario 4

The total kilometre driven by the vehicles were 46.30 billion Km. In this scenario, the transport sector of Denmark uses 100 % biofuel replacing the conventional fuel.

Billion Km per year	Kg of biofuel used per Km	Kg of biofuel needed in billions	Total feedstock to be cultivated in billion Kg
35.56			
3.22			
5.9	0.104	4.815	8.28
1			
0.625			

Table 4:8 Total feed stock required for scenario 4

To give an example of the calculation

100 % is replaced by Biofuel: *46.30 billion Km*

Kg of biodiesel needed to be produced: 46.30**0.104=4.81 billion Kg*

100 % of the total driven Km in Denmark is replaced with biofuel. This number equals 46.30 billion Km. The amount of biofuel required to supplement 100 % conventional fuel was 4.815 billion Kg.

The above number is multiplied with a factor 1.72 because, 72% more feedstock of rapeseed is needed for every unit of biodiesel produced as 72% of feed stock used for producing a unit biofuel goes as fodder. The total feed stock needed for scenario 4 was 8.28 billion Kg.

System boundaries

The system boundaries are the defined boundaries of an event or a scenario. The system boundary for scenario 4 is given in figure 6. System boundaries for this scenario include burning of biodiesel, biodiesel production and feed stock cultivation..

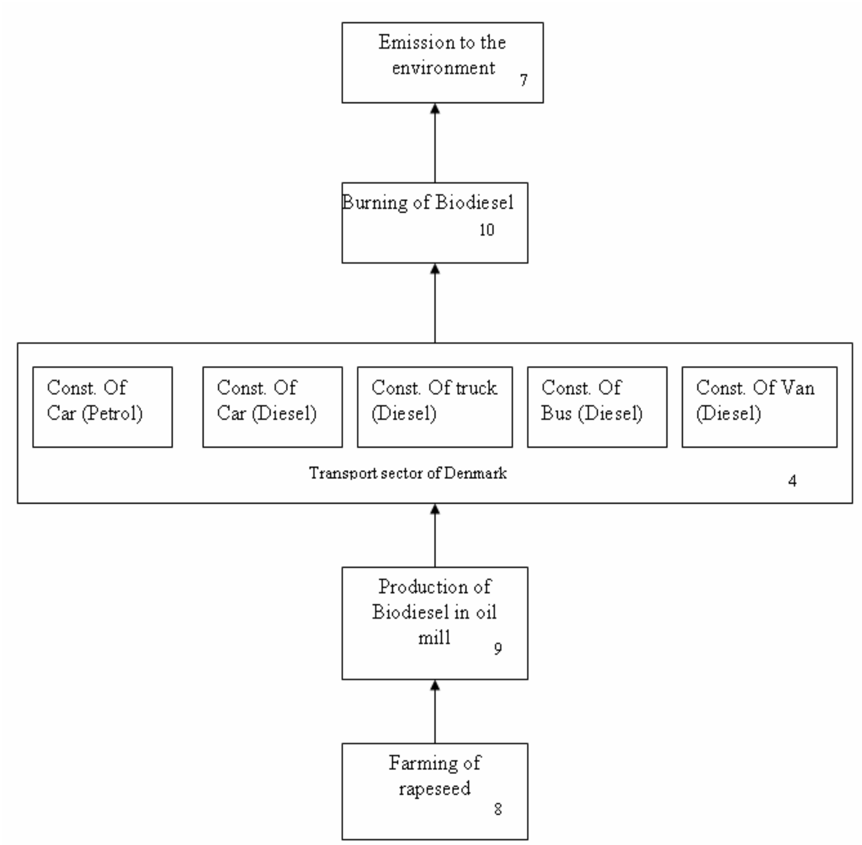


Figure 4.9: System boundaries for scenario 4 (100 % biofuel supplements conventional fuel for the transport sector of Denmark)

The system boundaries for the process are the same as explained in scenario 2 and 3.

Chapter 5

Analysis

The results obtained from the SimaPro 6 are analyzed to conclude on the environmental impact of shifting from conventional to biofuel use in the transport sector of Denmark. In this process the results of different case scenarios are obtained in SimaPro using two selected methods available within the SimaPro. The two methods used in obtaining the results for the scenarios are: Eco Indicator 95 and the Danish EDIP/UMIP 97 method. As there are no specified methods stated to determine the environmental impact on fuel usage, the two impact assessment methods stated above are applied and tested to compare the differences in the results. In addition to the above analysis, impact on land usage due to increase in land acquisition for rapeseed production is performed.

5.1 Environmental impact

The emission accounted in the transport sector is narrowed down to four emission categories that will be considered for analysis. The four emission categories are: GHG (Green House Gas), CFC (Chlorofluorocarbon), Acidification and Eutrophication. The units for the four categories and the contribution to the impact category are outlined in the table 1 below.

Scenarios with EI 95 method	**GHG (Kg CO2) in billion Kg per year**	**Ozone (Kg CFC) per year**	**Acidification (Kg SO2) in million Kg per year**	**Eutrophication in million Kg per year(PO4)**
Scenario 1	23.4	17900	142	15.5
Scenario 2	19.6	14600	169	23.4
Scenario 3	14.3	10000	206	36.4
Scenario 4	5.15	1890	269	57.2

Table 5.1: Emission results of the four impact categories using Eco Indicator 95 method

According to the table 1, the CO_2 emission has clearly reduced by going from scenario 1 to other scenarios. The reduction in CO_2 emission is from 16 to 78 % moving from scenario 2 to 4. The reasons for the reduction in CO_2 level is due to the replacement of conventional fuel (diesel and petrol) with biofuel (rapeseed oil). The biofuel (rapeseed oil) has zero CO_2 emission on burning, but there are some considerable emissions during the process of feed stock cultivation, transportation and production of biodiesel. The table 2 shows the set of results obtained for the same scenarios using EDIP/UMIP 97 method.

Scenarios with EDIP/UMIP method	**GHG (Kg CO_2) in billion Kg per year**	**Ozone (Kg CFC) kg per year**	**Acidification (Kg SO_2) in million Kg per year**	**Eutrophication in million Kg per year (NO_3)**
Scenario 1	25.3	13600	142	14.3
Scenario 2	21.6	11100	169	23.4
Scenario 3	16.4	7720	206	36
Scenario 4	7.56	1620	269	57.7

Table 5.2: Emission results of the three impact categories using EDIP/UMIP 97 method

The figure 1 and 2 shows the decrease in CO_2 level relative to different scenarios.

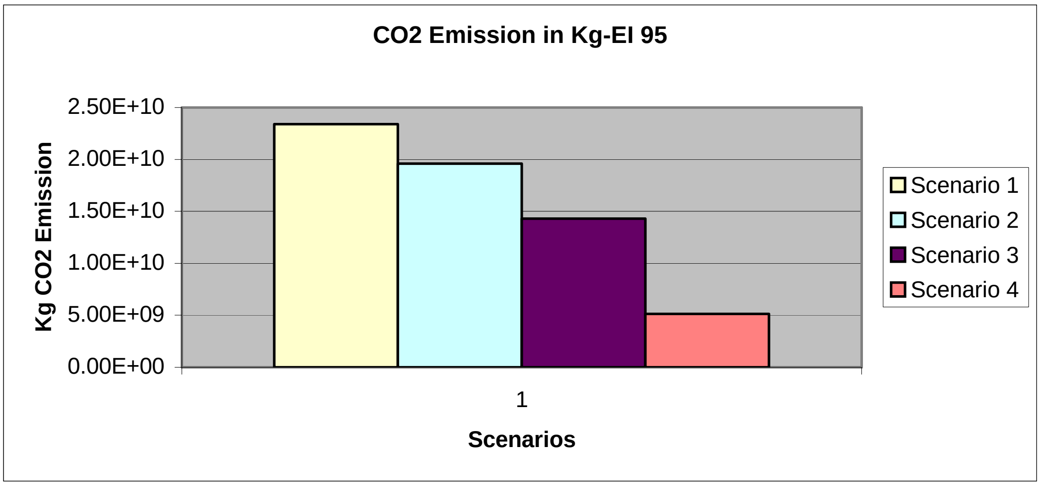


Figure 5.1: CO_2 emission using Eco Indicator 95 method

From figure 1(using Eco Indicator 95 method), comparing scenario 1 and 2, 16 % reduction of CO2 is achieved. Similarly for scenarios 1 and 3, 39 % CO2 emission reduction is achieved and finally scenario 1 and 4, 78 % reduction level.

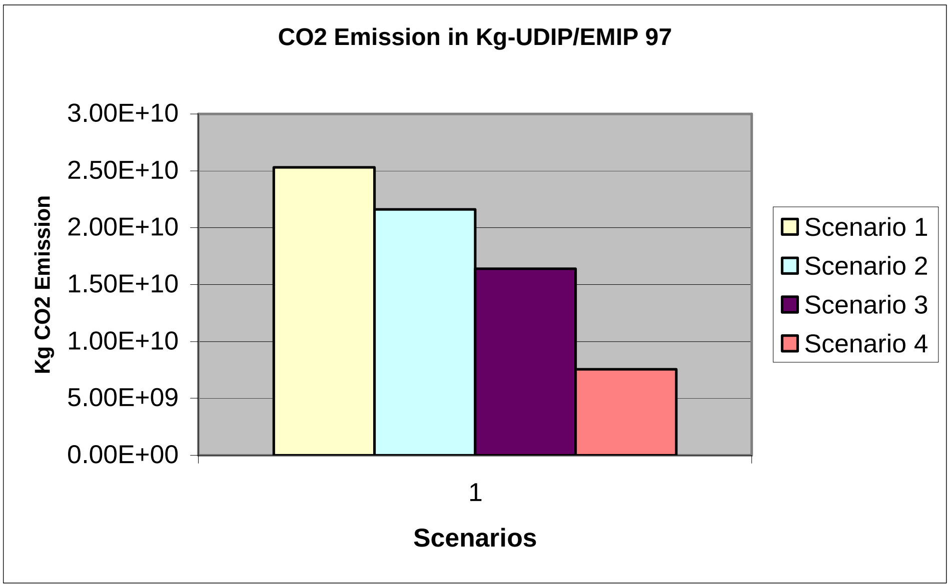


Figure 5.2: CO2 emission using EDIP/UMIP 97 method

Figure 2 shows the CO2 emission reduction for the scenarios using the EDIP/UMIP 97 method. The percentage decrease in CO2 emission was 70 % comparing scenario 1 and 4. The table 3 outlines the CO2 emission decrease relative to scenario 1 using the two methods stated (EI 95 and EDIP/UMIP 97).

	Kg CO2 decrease in % (EI 95)	**Kg CO2 decrease in % (EDIP/UMIP 97)**
Scenario 1 v 2	16	14.5
Scenario 1 v 3	39	35
Scenario 1 v 4	78	70

Table 5.3: CO2 emission in percentage by comparing scenarios using EI 95 and EDIP/UMIP 97 method

From the table 3, it is deduced that there is a possibility to reduce CO2 emission between 70 and 78 percent if the Danish transport sector replaces conventional fuel with bio fuel. Empowering scenario 3 in Danish transport sector, 50 percent conventional and 50 percent biofuel can help the Danish government to achieve the Kyoto protocol agreement, to reduce CO2 emission by 21 % by 2012.

Ozone Depletion (CFC emission)

Comparing scenarios 1 and 4, CFC gas emission is reduced by 89 % and 88 % (EI and EDIP/UDIP 97). The table 4 shows the CFC emission.

	Kg CFC decrease in % (EI 95)	**Kg CFC decrease in % (EDIP/UMIP 97)**
Scenario 1 v 2	18	18
Scenario 1 v 3	44	43
Scenario 1 v 4	89	88

Table 5.4: CFC emission increase in percentage

The decrease in CFC emission is due to supplementing conventional fuel with biofuel in the scenarios. Comparing the two methods, CFC emission can be reduced by 88 to 89 percent going from conventional to biofuel.

Acidification

There is an increase in emission of SO_2 going from scenario 1 to 4. Acidification is mainly caused by sulphur dioxide, nitrogen and ammonia which are released during the growth of rapeseed. The increase in acidification content is outlined in table 6 for the two methods (EI and UDIP).

	Kg SO2 increase in % (EI 95)	**Kg SO2 increase in % (EDIP/UMIP 97)**
Scenario 1 v 2	19	19
Scenario 1 v 3	45	45
Scenario 1 v 4	89	89

Table 5.5: Percentage increase of SO2

Reducing the fertilizer usage which carries ammonia and sulphur dioxide can considerably reduce the acidification.

Eutrophication

The use of phosphate and nitrate as fertilizers has negative impact on streams, lakes and rivers due to the facts these chemicals enrich the soil and thereby drain to water bodies to cause harm for drinking, fisheries and recreational purpose. In the case of rapeseed cultivation the use of these compounds are high as a result of the fertilizer application. From the table 7 below, comparing the scenario 1 with other three scenarios the percentage increase is relatively high. This indicates that the phosphates and nitrate content in biodiesel especially rapeseed is higher than crude oil (petrol and diesel).

	Kg PO4 increase in % (EI 95)	**Kg NO3 increase in % (EDIP/UMIP 97)**
Scenario 1 v 2	51	63,5
Scenario 1 v 3	135	151,5
Scenario 1 v 4	269	303

Table 5.6: Percentages increase of PO4 and NO3

To summarise, it will be feasible for Danish transport sector to move from scenario 1 to scenario 3, where 50 percent fossil fuel is replaced by biofuel. In this case there will be a CO2 reduction between 35-39 % and the Kyoto agreement to reduce 21 % CO2 emission can be achieved.

5.2 Land Use as part of LCA

In the quest for replacing conventional fuels (petrol and diesel) with biodiesel in the Danish transportation sector, it was deduced that different scenarios required different land area for cultivation of rapeseed.

The results of the calculations shows different measure of land need for the rapeseed cultivation for the three different scenarios as in Table 7 below. The LCA method used for the calculation was the simplest method. With the formulae below the various figures in hectares were obtained to determine the impacts of the three scenarios.

Land occupation = $\mathbf{m^2\ a}$

Land transformation =$\mathbf{m^2}$

	Scenario 2	Scenario 3	Scenario 4
Percentage of Rapeseed Cultivation	21%	50%	100%
Area of land use million (hectares)	0,67	1,59	3,18

Table 5.7: Area of land use for rapeseed cultivation in million hectares

In the calculation it was shown that for every hectare, 2.6 tonnes of rapeseed can be cultivated. Since several tonnes of rapeseeds were needed to produce required amounts of biofuel fuel for the three different scenarios, land acquisition need to be considered. Also in the calculation it was defined that, for any production of rapeseed oil, 72% of the product goes as fodder which is believed to be used for different purposes and the remaining 28% as the fuel. In this analysis allocation is made for the 72% by-product or fodder from the rapeseed as economically worth product and is assumed very important if considered economic feasibility because rapeseed is dependent on the income of the by-product. In this analysis the fodder was taken into consideration as part of the inventory

Looking at the three scenarios as compared to the current situation in Denmark it would be discovered that the land needed to meet the cultivation of rapeseed is a huge task. The total land area of Denmark is 4,308,000 ha area of Denmark and of this 2,653,000 ha was used for agriculture. With these hectares, 334,000 ha which consisted of 130,000 hectares already for rapeseed cultivation and the remaining 204,000 ha are set-aside according to EU schemes. The current available land allocated for rapeseed cultivation when compared with scenario 2 of land area of 668,077 ha which represents 21% of rapeseed cultivation means that the country's oil demand (21 % by rapeseed) could not be met. However, this scenario seemed promising if compared with the total agriculture land available within Denmark, but the problem is cultivation of other food crops and cattle grazing which are probably more vital for the country's food needs. Rapeseed is not the only crop cultivating in the country but the role of the Danish Government can have significant influence to allocate or convert additional land for cultivation in order to meet the reduction target. The 21% CO2 emission reduction according to Kyoto Protocol agreement cannot be met due to the fact that only 14-16% CO2 reduction could be achieved when substituted by 21% of biodiesel relative to conventional fuel.

Moreover, comparing the scenario 3 of 1,592,308 ha of rapeseed cultivable land with the baseline case of 334,000 ha the difference is large. For the country to be able to meet this set target for rapeseed oil production a more than half of the country's agriculture land has to be converted to rapeseed cultivation. This actually is difficult for the country as the there are scarcity of land available for cultivation rapeseed and even if there are, they can be used for other purposes such as food crops, cattle and pigs rearing.

Furthermore, comparing the baseline case of 334,000 ha for the production of rapeseed relative to the scenario 4 with 3,184,615ha the difference is substantial for the country to accomplish. For Danish Government to achieve this intended target according to this scenario then the country has to either invest in other countries for the production of biodiesel or import of rapeseed feedstock from Eastern Europe or other countries.

From the analysis, it can be concluded that the land available to meet the rapeseed cultivation requirements are a daunting task. As previously stated the rapeseed is not the only crop of great importance, since other crops especially food crops are essential commodity for the Danish Government.

Chapter 6

Conclusions

This project took its point of departure from Danish Transportation sector where the focus is replacing the conventional fuel (petrol and diesel) with biodiesel such as rapeseed oil as the main substitute. According to Kyoto Protocol agreement, Denmark has to reduce its CO2 emission by 21% from 1990 level. Many measures have been taken by the Danish government to carry out the reduction process. Such measures include the adaptation of Kyoto Flexible Mechanisms (Joint Implementation, Clean Development Mechanism and Emission trading), increasing energy efficiency, increasing CHP implementation, increasing renewable technologies, just a few to mention. The latter solution was taken critically and analysed using LCA as a main tool to derive answer to our research question:

"What are the environmental impacts of using biofuels over conventional fossil fuels and its impact on land use in Denmark''?

To answer our research question, four scenarios were taken into accounts

3. Using 100 % oil (diesel and petrol)
4. Using 79% oil (diesel and petrol) and 21% from biofuel (rapeseed)
5. Using 50% oil (diesel and petrol) and 50% from biofuel (rapeseed)
6. Using 100% biofuel (rapeseed)

In the first scenario it was considered using 100% oil (petrol and diesel) for firing the vehicles in Danish transport sector. This scenario was the baseline case scenario and was used to compare other three scenarios, where biodiesel is considered as substitute fuel for conventional fuel, in order for Denmark to reduce its CO2 emission by 21%.

With the second scenario, 21% of biofuel was assumed to replace the same amount of oil for the transport sector and the result deduced was CO2 emission reduction of 14.5-16 % compared to scenario 1 (using EI 95 and EDIP/UMIP 97 method). The reduction loss of biodiesel was as a result of transportation (using petrol and diesel) used for the rapeseed between processing unit, irrigation processes, electricity use during cultivation. This indicates that the Denmark target to achieve 21% emission reduction cannot entirely be met by moving from scenario 1 to scenario 2. In accordance to scenario 2, land needed for the cultivation of rapeseed cannot be attained, since the land allocated for agriculture is 2,653,000ha and are allocated for other agriculture purposes. This could be possible if and only if land used for other purposes are converted for rapeseed production. Even when converting other land available to the required land area of 668,077ha the 21% CO2 emission reduction target by Danish Government only 14.5-16% could be achieved with this scenario

In analysing scenario 3, whereby 50 % conventional fuel is replaced by 50 % biofuel for CO2 emission reduction in Danish transport sector, it was identified that the CO2 emission reduction was 35-39% using the two different impact methods. This scenario can lead the country to achieve the target CO2 emission reduction with even excess quota but the problem is land acquisition to meet such demand is a question. To meet such a demand 1,592,308ha of land is needed for rapeseed oil production which is more than the total land area allocated for rapeseed (108,000ha) and set-aside EU scheme for rapeseed cultivation (204,000ha).

Last but not the least, scenario 4 has the highest CO2 emission reduction with 70-78% compared to other two potential scenarios. This shows that the target for Denmark to achieve the 21% as of 1990 level according to Kyoto Protocol agreement would be overwhelmed and can even earn abundance CO2 surplus which would be a credit for the country in the future. However, the land needed for such accomplishment is difficult and highly impossible if compared to the available land for agriculture which is less below the land needed to meet this scenario.

Obtaining the 21% of the CO2 emission reduction target mathematical calculation is used to find a number between the scenario 2 and scenario 3. The result was 18.45 billion kg of CO2 saved but the corresponding land needed to accomplish this task was 870,000 ha which is practically not possible for Denmark. Judging from the three scenarios for the Danish Government to achieve the reduction of CO2 emission, all the three scenarios will not be feasible for the Danish society viewing it from the present land available.

Since the research question highlighted on the environment impacts of biofuel usage over conventional fuel, other impacts such as acidification, eutrophication and ozone depletion were analysed. Based on the results of the analysis using the two method of impacts assessment, acidification impact was due to the presence of ammonia, sulphur dioxide and nitrogen dioxide in the biodiesel. The cause of this impact is as a result of the fertilizers used during the cultivation of the rapeseed. Comparing the baseline case scenario for scenario 2 the SO2 emission increased by 19%, 45% with scenario 3 and 89% with scenario 4 respectively. If the fertilizer application is marginalized during cultivation, there will be significant change on percentage and can reduce acidification. For eutrophication, the presence of phosphate and nitrate chemicals in the fertilizer application on rapeseed cultivation gave rise to the high percentage increase when comparing the baseline case scenario with the three scenarios using biodiesel as substitutes.

With ozone depletion, CFC content was reduced when comparing scenario 1 with scenario 2, scenario 3 and scenario 4. The huge reduction of CFC is a result of less carbon monoxide emission when burning biodiesel as compared to conventional fuel.

In a nutshell, according to the assumptions made for the scenarios (CO2, CO emissions on burning of oil, generation of electricity; emissions assumed on burning of biofuel); the use of biodiesel over conventional fuel for the transport sector of Denmark will not have a major effect, considering the land available for cultivation of rapeseed. If Denmark can obtain rapeseed feedstock by some other means (cultivating in Eastern Europe and transporting them for process within Denmark), still question arises whether a solution like that can really reduce the environmental impact as a whole, which need to be addressed further. Within the scope of this project and the assumptions outlined, biofuel is not the best alternative solution for Danish transport sector for reducing CO2 emission, due to unavailability of land required for rapeseed cultivation. Moreover biodiesel usage has negative impacts such as acidification and eutrophication as a result of fertilizer application, which is known to contain ammonia, sulphur dioxide, nitrogen oxide, phosphate and nitrate.

6.1 Self criticism

To evaluate our work, the data collection needed has to be checked for its validity and reliability because most of these data are essential for our analysis and are used to draw our conclusion.

Validity

Most of the data collected are from SimPro 6 version and US EPA which are considered valid sources of information because they are well known and used sources. Since most of the data obtained were from well known sources it’s believed that the work was valid to a certain point and can used as reference study for any future work.

Reliability

The reliability of data and results are measured by the quality of data obtained. The data on number of vehicle and the vehicle km cover are Danish road transport data from the year 2003. These data are very reliable and can be had from the Danish Ministry of Transport. Using reliable data like these have subsequently improved the reliability of work.

Generalization

The data gathered for the goal of the study had been referred and verified with many internet pages that provide similar data. Therefore the data used in the scenarios of this report are generalized data for biofuel and conventional fuel usage in Denmark transport sector. The results of the study can be generalized to some extend, but there are some limitations with regard to the construction of specific processes for scenarios. Emissions for process were used from the SimaPro data base, which in some cases were specific to some countries other than the country of study, Denmark. In this case there is a possibility to experience a change in emission values when the same process is performed and measured in Denmark. For example, the emission data on rapeseed cultivation used was for Switzerland, but it is not certain that the same level of emission will be achieved if the process (rapeseed cultivation) is carried out in Denmark.

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