CHALMERS

Development of an evaluation model for environmental sustainability of waste transports at Renova

Master of Science Thesis in the Master Degree Programme Industrial Ecology

MAGNUS ANDERSSON

EMIL JANSSON

Department of Technology Management and Economics
Division of Logistics and Transportation
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2011
Report No. E2011:086

REPORT NO. E2011:086

Development of an evaluation model for environmental sustainability of waste transports at Renova

MAGNUS ANDERSSON
EMIL JANSSON

Department of Technology Management and Economics
Division of Logistics and Transportation
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2011

Development of an evaluation model for environmental sustainability of waste transports at Renova

MAGNUS ANDERSSON
EMIL JANSSON

Report No. E2011:086
Department of Technology Management and Economics
Division of Logistics and Transportation
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2011
SE-412 96 Göteborg
Sweden
Telephone +46 (0)31-772 1000

Chalmers reproservice, Göteborg 2011

Abstract

Over the past decades environmental issues, and especially climate change, have been getting more and more attention both in public debate and governmental policy. As a large consumer of fossil fuels, and consequently a substantial source for emissions of CO_2, the transport sector is a big contributor to climate change.

As people get more and more aware of environmental issues transport companies have seen the business opportunity to offer environmentally preferable services associated to their transports, commonly known as “green” services, making it possible for customers to actively contribute to a sustainable development. These services are often seen among companies in the logistic sector but have not yet been introduced in the waste management sector. Renova, a waste management company owned by 11 municipalities in and around Gothenburg, is now interested in investigating the differences between their vehicles from an environmental point of view as a first step towards a construction of a “green” service associated to their transports.

This thesis is aiming at developing an evaluation model for environmental sustainability of waste transports at Renova. A framework for environmental sustainable transports (EST) has been developed listing the negative impacts transports are having on environmental sustainability. The EST framework is based on a systems perspective and acknowledges the principles of sustainability. The impacts listed in the framework are affected by both technical and logistic efficiency, in this thesis symbolised as a three layered structure with the EST framework at the bottom being affected by a technical and a logistic layer lying above it. An LCA like method of assessment has been used in order to evaluate the environmental impacts caused through the technical layer for all the heavy vehicles employed at Renova. The model uses operational data of the vehicles together with the most reliable and accepted sources for data and calculation factors that are freely available. The logistic layer has been less investigated, but is strongly recommended to further analyze in order to improve the result and use of the model.

The result of this thesis is a comprehensive evaluation model for environmental sustainability of transports that includes the entire chain of activities that affect the transports’ environmental performance. In contrast to other environmental assessments made for transports today that are heavily focused to emissions of CO_2 and climate change, the evaluation model made in this thesis includes several other aspects important to acknowledge in terms of environmental sustainability.

The model is made operational through a software tool enabling Renova to internally compare the different vehicles in terms of environmental sustainability. The tool is designed in a way that Renova can perform updates of the comparisons in case the conditions surrounding their transport activities change in the future.

Keywords: Sustainability, EST, waste transport, environmental assessment.

Acknowledgements

This Master of Science thesis has been initiated by the waste management company Renova AB, located in Gothenburg, Sweden. It is performed with supervision at the Division of Logistics and Transportation of Chalmers University of Technology as the final element of examination from the master programme of Industrial Ecology. The thesis has been accomplished through supervision, guidance, help or input from a number of people that the authors wish to thank:

RENOVA AB
For creating the opportunity of the thesis and for their trust, collaboration and commitment:
Viktoria Edvardsson
Magnus Bäckström
Martin Thörnqvist

CHALMERS UNIVERSITY OF TECHNOLOGY
For their kind commitment to the project and evaluable guidance, knowledge and time:
Vendela Santén
Magnus Blinge
Maria Grahn
Ulrika Lundqvist

NTM
For valuable input and discussion on the issues of environmental performance modeling:
Magnus Swahn

LUND UNIVERSITY
For providing valuable assistance and documentation:
Pål Börjesson

Table of contents

Abstract....IV

Acknowledgements....V

Table of contents....VI

List of figures....IX

List of tables....IX

List of abbreviations....X

1 Introduction....1

1.1 Background....1

1.2 Purpose....2

1.3 Research questions....2

1.4 Scope and limitations....2

1.5 Outline of the report....3

2 Methodology....4

3 Introduction to Renova....5

4 Literature review....7

4.1 The concept of sustainability....7

4.2 Sustainable transports....8

4.3 Environmentally sustainable transports....9

4.3.1 Air pollution....12

4.3.2 Noise and vibrations....15

4.3.3 Energy consumption....15

4.3.4 Fuel production....16

4.3.5 Electricity production....17

4.3.6 Other environmental impacts....18

4.3.7 Logistic management....18

4.4 Assessing sustainability....19

5 Market survey....21

5.1 What does the concept of ‘sustainability’ or ‘sustainable transports’ mean to the company?....21

5.2 What kind of green services or green products are on offer from the company?....22

5.3 How are the green services or products offered to the customers? ... 25
5.4 How do the companies quantify or estimate the environmental impact of their activities? ... 27
5.5 What sources of reference are used to support claims and calculations made by the company? .. 28
5.6 What is the level of transparency of results and statements from the company? ... 28
6 Application of theory ... 29
6.1 Defining an environmental sustainability framework for transports ... 29
6.2 Analysis of market survey ... 31
7 Creating an evaluation model ... 32
7.1 Methods of evaluation ... 34
7.1.1 Emissions from fuel combustion ... 36
7.1.2 Emissions of PM from road surface, tire, and breaking system wear ... 40
7.1.3 Emissions from fuel production and distribution ... 40
7.1.4 Emissions from electricity production ... 41
7.1.5 Vehicle noise ... 41
7.1.6 Fossil fuel use ... 42
7.1.7 Bio fuel use ... 42
7.1.8 Electricity use ... 42
7.1.9 Energy input during fuel production ... 42
7.1.10 Use of vehicle maintenance products ... 43
7.1.11 Use of scarce vehicle construction materials ... 43
7.1.12 Land use for bio-fuel production ... 43
7.1.13 Soil and water contamination ... 44
7.1.14 Environmental intrusion and barrier effect ... 44
7.2 Developing software tool ... 44
7.3 Influence of logistic efficiency ... 46
8. Evaluation of model ... 48
8.1 Sensitivity of model ... 48
8.2 Reliability of model ... 50
8.3 Model usefulness on market ... 53
9 Conclusions ... 54
10 Recommendations to Renova ... 56
11 References ... 58

Appendix A 67
DSV 67
Geodis Group 68
Posten Norden 69
UPS 70
FedEx 71
IL Recycling 71
Ragn-Sells 72
RenoNorden 73
SITA 74
Stena Recycling 75
DB Schenker 76
Green Cargo 77
DHL 78
Dachser 80
Appendix B 82
Appendix C 83

List of figures

Figure 4.2: An illustration of sustainable transports
Figure 4.3.4: Simplified illustration of main steps in a WTW study for a biofuel
Figure 4.3.7: The logistic organization funnel
Figure 6.1: The correlation between the four principles of sustainability and the EST framework
Figure 7.1: A visual representation of the EST model
Figure 7.2: The technical layer of Renova
Figure 7.1.1: Categorization of vehicles
Figure 7.2.1: The inputs needed from the user in order to perform calculations.
Figure 7.2.2: View of a results sheet
Figure 7.3: Schematic view of the transport types at Renova.
Figure 8.1: Standard deviation in fuel consumption between different vehicle types, averaged together for each vehicle group

List of tables

Table 3.1: Vehicle presentation
Table 5.2: Summarized categorization of the companies according to their green services
Table 6.1: The EST framework
Table 6.2: Market focus compared to literature focus on EST
Table 7.1.1: Energy content in fuel
Table 7.1.1.1: Emission factors from fuel combustion for heavy vehicles
Table 7.1.1.2: Emission standards for Euro I-VI for heavy diesel vehicles
Table 7.1.1.3: Emission standards for Euro III-VI for heavy gas
Table 7.1.1.4: Calculated emission factors per Euro class and fuel type
Table 7.1.3.1: Emission factors for fuel production and distribution for heavy duty vehicles
Table 7.1.4.1: Emission factors for electricity production and distribution, Swedish average energy mix
Table 7.1.9.1: Energy input factors for fuel production
Table 7.1.12.1: Land efficiency for growing rapeseed in the south of Gothia, and Swedish land availability for growing rapeseed for RME production
Table 8.2: Comparison of Euro class percentage changes from Euro I for EcoTransIT and evaluation model
Table 9.1: The EST framework
Table C.1: Sources for electricity production. Swedish average energy mix
Table C.2: Emission factors for different sources of energy
Table C.3: Calculated emission factors for Swedish mix of electricity

List of abbreviations

CCU	Cargo Capacity Utilisation
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
CONCAWE	Conservation of Clean Air and Water in Europe
CSR	Corporate Social Responsibility
EPoN	Expert Panel on Noise
EU	European Union
EUCAR	European Council for Automotive R&D
EST	Environmentally Sustainable Transport
GRI	Global Reporting Initiative
HC	Hydrocarbons
IEA	International Energy Agency
JRC	Joint Research Centre
KTH	Royal Institute of Technology
LU	Lund University
LCA	Life Cycle Assessment
NGO	Non-Governmental Organisation
NO	Nitric oxide
NO_x	Nitrogen oxides
NO	Nitrogen dioxide
O_3	Ozone
OECD	Organisation for Economic Co-operation and Development
PM	Particulate matter
RME	Rapeseed Methyl Ester
SGS	Société Générale de Surveillance
SPI	Swedish Petroleum Institute
UN	United Nations
WCED	World Commission on Environment and Development
WHO	World Health Organisation
WTT	Well-To-Tank
WTW	Well-To-Wheel

1 Introduction

Renova is a company in the waste disposal industry, owned by 11 municipalities in the area around Gothenburg. The main activities for the company are transports and treatment of waste aimed for recycling, energy production or land filling. The waste treatment facilities are currently successful in complying with governmental environmental goals and the transports are continuously improved to meet ever-stricter demands. To improve the environmental work already done, the company is interested in making it possible for costumers to actively contribute to a sustainable development. One way of doing this to offer so called "green services" as compliments when selling products or services. Examples of green services are H&Ms collection of organic cotton or the ability to buy climate compensation with transport services from DHL.

To establish the environmental load of a product and to be able to compare it to other products, it is necessary to perform an environmental assessment on it. This thesis report is focused on developing a model for such an environmental assessment with regards to the transport services provided by Renova. The company uses several types of vehicles and fuels that are interchanged frequently, the model therefore needs to be designed to reflect this and still deliver proper assessments.

1.1 Background

The work done by Renova to improve its transport services can be seen as a part of the increasing focus on environmental issues in general as well as a response to the ever increasing environmental demands on the transport sector in specific. Transports are considered an essential part of economic and societal development, as such transport operations have a tendency to grow with economic growth. As noted by the European Statistical Office, Eurostat, this is the case in Europe, which has an increasing amount of road traffic every year (Eurostat, 2009). As road traffic is also a contributor to environmental problems such as air pollution and global warming, the transport sector has been subjected to strict regulations. The transport sector emitted almost 20% of the combined GHG emissions in EU-27 in 2006, about 93% of those emissions came from road transport according to Eurostat (2009). In terms of energy, transport activities stood for roughly 30% of the total final energy consumption in EU-27 in 2005.

A key concept often used in the debate on environmental issues is 'sustainability'. The meaning of it will be discussed in detail later in this report, but as one would expect, it deals with making activities sustainable over time. The pollution and the use of limited resources like fossil fuels in the transport sector can be seen as unsustainable.

1.2 Purpose

The purpose of the thesis is to investigate the concept of environmental sustainability in relation to transports, to investigate how the concept is used on the current market, and to develop an evaluation model for the concept that will aid Renova in their efforts to further their environmental work. The model should guide Renova in knowing which environmental issues of sustainability that are of importance, and enable them to compare their vehicles in respect to those issues. The model should be designed as a software tool that enables Renova to perform updates of the comparisons in case the conditions surrounding their transport activities change in the future. The tool should also be designed in such a way that results can be communicated on the waste management market.

1.3 Research questions

By completing the purpose the thesis will answer the following questions:

- What defines environmental sustainable transports and which factors causing environmental impacts are of most importance?
- What is the market view on environmental sustainability and are the methods of assessment used in industry today in line with the research of the field?
- How can literature on environmental sustainable transports be translated and applied in order to develop the environmental performance of a specific company like Renova?

1.4 Scope and limitations

The thesis is limited to the subject field of environmental sustainability of transports and logistics. It does not take into account economic or social aspects related to these subjects by request from Renova, as the company is mainly interested in developing their environmental work at this point. A substantial part of the project is scoped around the literature review and the market survey, this is because both the literature view and market view on environmental sustainability needs to be understood and combined. Focus is put on environmental impacts and resources needed to perform transport operations and will not take into account aspects other than the use of vehicles such as production of vehicles and road infrastructure, unless specific issues of importance to do so arise. This is derived from LCA methodology where production of machinery and transport vehicles are often excluded from the studied system because the majority of the environmental impacts come from use. As an example described by Jones (2002), roughly 10% of GHG emissions from the lifecycle of a normal petrol-engine car come from the production of the vehicle, 15-20% come from the production of its fuel and the remaining 70-75% can be attributed to use. Environmental impacts from organisational issues regarding logistic management of vehicles will be treated in general terms, as the evaluation needed by Renova revolves around the technical environmental performance of their vehicle fleet. This also means that the software tool for evaluation will be based technical issues.

Data used within the project is limited to what can be supplied from Renova, no measurements or quantifications will be performed. This is because Renova is interested in a model that uses current data capabilities of the company in order to reach a high level of usability. The model itself is geared towards performing comparisons of the environmental performance of vehicles and will be designed to work with the data supplied. Note that the data and internal organisation of Renova is confidential, no evaluation results from Renova can be printed in this report. As a consequence the thesis revolves around the issues of sustainability, evaluation, modelling and market capabilities and not the specific outcome of the evaluation itself. Regarding other kinds of data, it will be confined to what is available in research literature, and to data which is free to be used in a commercial context as the results are intended for Renova.

The market survey will include a number of leading companies within the transport sector. As environmental and sustainability issues are often picked up by larger companies, some of the companies have been selected based on their size. Other companies have been selected because their activities are similar to those of Renova, or because they have a strong environmental profile which makes them interesting to study. The included companies are the following:

- Companies operating in the waste disposal industry: IL Recycling, Ragn-Sells, RenoNorden, Stena Recycling and SITA.

- Companies working with transport services: DHL, DB Schenker, Green Cargo, DSV, Dachser, Geodis Group, Posten Norden, FedEx, and UPS.

1.5 Outline of the report

The report starts out with the methodology chapter to conclude how the project work is conducted. It then supplies the reader with an introduction to Renova and its vehicles and fuels in order to establish the context in which the project is performed. The following chapter four and five deal with the empirical findings of the literature review and market survey, and will provide the reader with the foundations for the rest of the report. Chapter six is the starting point for objective three and will analyse the empirical findings as well as be used in preparation for chapter seven, which describes how the model and tool is developed. The subsequent chapter eight evaluates the workings of the model in order to complete objective five. Answers to the questions stated in section 1.3 will be given in chapter nine, which also describes the contributions of the project and suggestions for how to develop it further. The last chapter is geared towards Renova, and entails relevant observations and recommendations to the company. At the end of the report the reader will find appendices for full documentation on empirical findings from the market survey as well detailed calculations referred to in the text.

2 Methodology

To fulfil the purpose of the thesis, the following series of objectives will be completed:

1. A literature review concerning the meanings and assessment methods of ‘sustainability’, ‘sustainable transports’ and specifically ‘environmentally sustainable transports’ in order to pinpoint relevant aspects to take into account for the model, and to subsequently establish how they can be evaluated.

2. A market survey of how environmental sustainability, environmental assessment methods, green services and green working methods are currently used in the transport industry. The objective being to investigate the view of sustainability and how environmental impacts from transport services are quantified and communicated on the market. This is of importance in order to establish if existing commercial methods are in line with research, and also in order to design the model so that results can be communicated to the market.

3. A structured comparison of the relationship between literature and market view of sustainability in order to set up the foundations of an evaluation model.

4. Based on the literature review, a development of a model that has the possibility to quantify relevant environmental impacts from the Renova transport system that affect sustainability, as well as to allocate them to each specific vehicle types being used. In addition a conversion of the model into a usable software tool that fits the needs of Renova, and that can be easily managed and updated by Renova if needed.

5. An analysis of the robustness of the model in order to examine and understand its strongpoint’s and drawbacks from a sensitivity, reliability and usability point of view.

The first objective will be performed by reading books and scientific articles on the subjects discussed in sections 1.3-1.4. The starting point of the review will be reading material from courses taken in the Industrial Ecology program at Chalmers, such as ‘Sustainable development’, ‘Science of environmental change’, ‘Environmental management’ and ‘Environmental aspects on logistics and transportation’. The courses and the programme provide an overview of important aspects relating to sustainability at large. Second, literature recommended by researchers and specialists at Chalmers and other relevant research bodies will be used to gain deeper knowledge into specific fields such as environmental logistics and fuel production. Thirdly books and scientific articles from the library and extensive databases of Chalmers will be used to broaden the literature base. Lastly websites and published reports by both governmental and non-governmental organisations will be reviewed in order to get input from stakeholders outside academia. Examples of such stakeholders are the different regulating bodies of EU and the Swedish government, organisations with special interests such as the OECD as well as independent research institutes. The literature study will be an iterative process in order to gain sufficient knowledge to complete objective one.

The second objective is the market survey. It will be performed as an external review by studying annual reports, homepages and public information provided by the selected companies. In case any question or uncertainties arise from the collected information, additional information will be collected via e-mail to relevant company employees. The market survey revolves around six questions that have been developed to meet the description of the objective:

1. What does the concept of 'sustainability' or 'sustainable transports' mean to the company?
2. What kind of green services or green products are on offer from the company?
3. How are the green services or products offered to the customer?
4. How does the company quantify or estimate the environmental impact of their activities?
5. What sources of reference are used to support claims and calculations made by the company?
6. What is the level of transparency of results and statements from the company?

The third objective will be solved by gathering the results from the literature and the market sources, compiling the most common aspects mentioned by both sources, and comparing the aspects in order to establish the position of the market in relation to literature. The fourth objective of designing the model and software tool will be made with the aspect of the literature as a base. Each of the aspects will be assigned an evaluation method based on relevant literature recommendations or by developing a new method with guidance from thesis supervisors and relevant experts. The combination of the literature aspect and evaluation methods will constitute the model. The model will then be converted into software by coding it into Microsoft Excel with design input from Renova in order to facilitate a fitting solution. Initial user input data to the Excel tool will be collected on each vehicle from the Renova database and supplied with the tool. The results from the tool, based on the initial user input data, will then be evaluated by performing a sensitivity analysis of the data as well as by discussing reliability of data sources, evaluation methods and the tool's output in order to complete objective five.

3 Introduction to Renova

Renova is a company in the waste disposal industry, owned by 11 municipalities in the area around Gothenburg. The main activities for the company are transports and treatment of waste aimed for recycling, energy production or land filling. The company employs several types of heavy vehicles in their operations running on different fuels and using different technologies. To be able to make an adequate environmental assessment of the transports a mapping of the different vehicles, fuels, and logistic operations used by each vehicle class across the fleet is needed. The vehicles included in this study are listed in Table 3.1, together with a short explanation of their type of waste collection, logistic operations, and types of fuel. Rear and front lifting refers to if waste containers are lifted into the truck from the rear or the front, compression operations are performed by some vehicles to reduce the cargo volume, crane lifting refers to the operation of loading or unloading cargo with a crane arm mounted on the vehicle and hook lifting is used to pick up large containers.

There are basically three types of logistic operations at Renova; Pick-up/Drop-off, 'Milk round pick-up'/Drop-off and Pick-up/'Milk round drop-off'. A milk round is a transport operation where one vehicle performs a number of pick-ups or deliveries along a route. Each of Renova's operations can be performed several times a day or only once depending on vehicle. These logistic operations are coupled with the collecting operation. Some vehicles empty several containers before drop-off while others operate by transporting entire containers between points. In the case of the 'Crane/Hook lift truck' and the 'Tipping/Crane truck' the vehicles can perform two types of logistic operation since they can be used both as collecting waste as well as delivering bags of soil "portion-by-portion" with their crane arm.

Table 3.1*: Vehicle presentation*

Type of vehicle	**Type of collected waste**	**Collecting operation**	**Logistic operation**	**Type(s) of fuel**
Rear loader	Household and company waste	Rear-lifting, emptying and compressing	Milk round pick-up/Drop-off	Diesel, gas, RME/gas, RME, electricity
Pick-up	Hazardous waste (oils, chemicals, paints)	Manually collecting and transporting	Pick-up/Drop-off	Diesel
Front loader	Combustible waste and corrugated fibreboard	Front-lifting, emptying and compressing	Milk round pick-up/Drop-off	Diesel
Heavy rear loader	Material from construction sites	Rear-lifting, emptying and compressing	Milk round pick-up/Drop-off	RME
Crane / Hook lift truck	Big bags and small containers. Also used for delivering soil.	Crane-lifting and emptying/transporting	Pick-up/Drop-off, Pick-up/Milk round drop-off	Diesel, gas
Crane truck	Waste from recycling stations, e.g. glass	Crane-lifting and emptying	Milk round pick-up/Drop-off	Diesel, RME
Hook lift truck	Large and heavy containers	Back-lifting and transporting	Pick-up/Drop-off	Diesel, RME
Skip loader	Small and medium sized containers	Back-lifting and transporting	Pick-up/Drop-off	Diesel
Van	Hazardous waste (oils, chemicals, paints)	Manually collecting and transporting	Pick-up/Drop-off	Diesel, RME

Pneumatic collector	Sludge	Emptying through suction and transporting	Milk round pick-up/Drop-off	Diesel, gas, RME
Tipping / Crane truck	Big bags and small containers. Also used for delivering soil.	Crane-lifting and emptying/transporting	Pick-up/Drop-off, Pick-up/Milk round drop-off	RME

As can be seen from Table 3.1 the different types of fuels used by the vehicles employed at Renova are diesel, RME, gas, and electricity. The diesel is of Swedish type MK1 blended with 5 % RME, the RME is 100 % RME, while the gas is a mix of biogas and natural gas.

A large part of the gas used by the vehicles is biogas through the implementation of the "Green Gas" principle in Gothenburg. The Green Gas principle ensures that when an amount of CNG is refuelled at a filling station corresponding amount of biogas is refuelled to the gas system (FordonsGas, 2011). Renova buys a quota of Green Gas each year and gas exceeding the quota constitutes of CNG that in Sweden is a mixture of biogas and natural gas. The quota of Green Gas is quite large making biogas the most commonly used fuel for the gas vehicles.

Other differences among the vehicles are the denomination according to Euro classification. Emissions of CO, HC, NO_x, and PM are regulated through Euro classification that engines need to fulfil before being sold. Since the introduction of the Euro classification the limits for the regulated emissions have become more and more stringent for each new Euro class (DieselNet, 2009). Since there are differences in Euro classification among the vehicles in the fleet, levels of the different regulated emissions will vary inside it.

4 Literature review

This chapter will start with a short introduction to the areas of sustainability and sustainable transports, followed by a study of the field of environmental sustainable transports. The environmental impacts related to the subject will be examined as well as methods for assessing sustainability.

4.1 The concept of sustainability

The concept of sustainable development first gained attention through the report *Our Common Future*, published by the World Commission on Environment and Development in 1987 (WCED, 1987). The report, also known as the Brundtland Report defined sustainable development as (WCED, 1987):

...development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WBSCD, 1987).

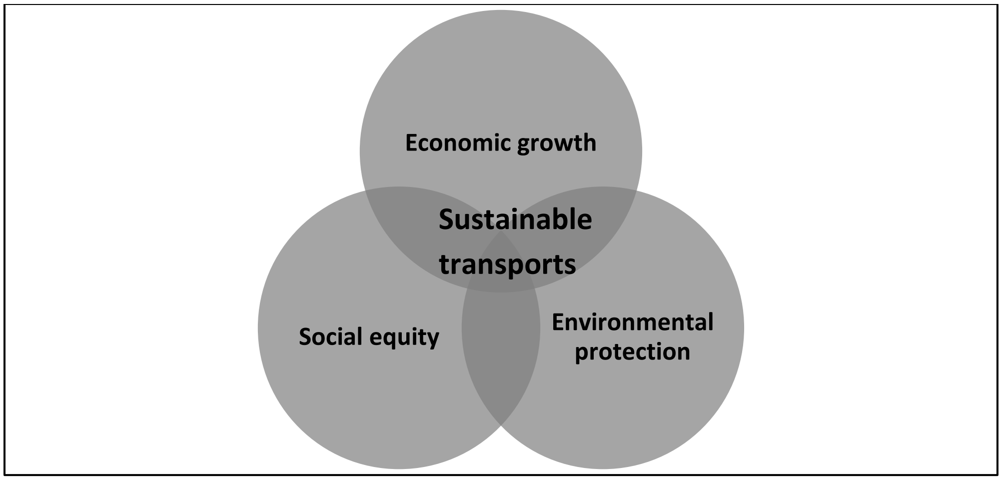
This definition is supported by four fundamental principle of sustainable development; ‘futurity’, ‘equity’, ‘public participation’, and ‘environment’ (Mitchell et al., 1995). The first principle, ‘futurity’, which is also known as inter-generational equity, describes that if future generations should be able to meet their needs and aspirations the current generation need to ensure that they have the environmental capital (resources and ecological support systems) to do that. The second principle, ‘equity’, which is also known as intra-generational equity, describes that the current generation should share the costs of human activity, e.g. pollution, and that the access to environmental capital should be more equally distributed. The third principle, ‘public participation’, describes that individuals should have the possibility to participate in and affect the decisions that affect them and the process of sustainable development. The fourth principle, ‘environment’, describes that a wider ecosystem is worthy of conservation since it has, besides the value as a resource of use for humans, also an intrinsic value.

These principles are included in the more commonly used approach of the *triple bottom line* by highlighting the three components of sustainability; economic growth, social equity, and environmental protection, all of them need to be considered if the *needs* of both present and future generations are to be met (Behrends et al., 2008).

Since the definition of sustainable development was coined the concept of sustainable development has gained increasing attention. In 2001 the concept was incorporated into high decision making levels when the EU established a strategy that the principles of economic, social, and environmental effects of all policies should be examined and taken into account in the decision making processes (European Commission, 2001).

4.2 Sustainable transports

A common way of defining sustainable transports is to apply the Brundtland definition of sustainable development to transports and is seen in several of the reviewed studies (Black, 1996; OECD, 2002; Richardsson, 2005; Behrends et al., 2008). As a natural consequence, the aspects of the triple bottom line approach are often applied to definition of sustainable transportation as well (Richardsson, 2005; Behrends et al., 2008). In Figure 4.2 an illustration of this is seen.



. *Figure 4.2: An illustration of sustainable transports*

The EU Transport Council has through three basic principles adopted the following definition of what a sustainable transport system does (European Commission, 2004):

- Allows the basic access and development of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.

- Is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy as well as balanced regional development.

- Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes while minimizing the impact on the use of land and the generation of noise.

4.3 Environmentally sustainable transports

Environmental issues related to transports have traditionally been connected to mainly exhaust emissions. By employing the triple bottom line approach to sustainability and sustainable transports, environmental issues are put into a much wider context. From the definitions noted in section 4.2 the environmental part of sustainable transports should not only connect to traditional environmental impacts but to resource use and equity over time. As with the issue of defining sustainability, defining environmentally sustainable transports (EST) is not a clear-cut matter as opinions differ on what the concept should entail. By studying literature about sustainable transports from several societal bodies, and taking note of the environmental issues raised, a relevant set of issues can be developed. The following paragraphs review such literature published by academia, regulatory bodies, research institutes, and non-governmental organisations (NGOs).

Academia is a source of great value since it is constantly engaged in research. The literature on sustainable transports mainly comes from Europe, North America and Australia as noted by Richardsson (2005). The American researcher William Black (1996) describes why current transportation systems are unsustainable. His focus is put on the use of non-renewable resources, emissions causing impact to the global environmental, depletion of the ozone shield through use of coolants in motor vehicles, and on urban air quality. He argues that some of the impacts causing short-term costs or issues (impacts affecting present generation), should not be included in the concept of sustainable transports since they do not create long-term problems of unsustainability, i.e. they do not compromise the ability of future generations to meet their transport needs. Examples of environmental impacts that he considers are outside the framework of sustainable transports are noise pollution, water pollution due to runoff from streets and highways, loss of wetlands, loss of open spaces and structural damage from vibration. More recent research has expanded the view on sustainable transports and EST by including these short-term costs and issues as well. Gudmunsson (2004) has reviewed studies of sustainable transports and compiled a list of major economic, social and environmental issues raised in those studies. The author presents the issues in two categories in an attempt to visualize which impacts that affect the present generation, noted as 'Development', and which impacts that affect future generations, noted as 'Sustainability'. The approach is similar to that of Black (1996), with the difference that the short-term costs or issues that affect the present generation are included in the scope. Presented here are the environmental issues related to EST compiled by Gudmunsson (2004):

- Development (Present)
  - Healthy air quality
  - Acceptable noise
  - Limited pollution/Waste
  - Visual quality/liveability

- Sustainability (Future)
  - Climate stability
  - Protecting ecosystems/biodiversity
  - Land conservation
  - Resource conservation

The issues by Gudmunsson are echoed by several researchers such as Richardson (2005) and Piecyk and McKinnon (2010). A lot of attention is given to comparisons of how vehicle technology, such as different fuels and engines, contribute to unsustainable development. Researchers within the field of logistics recognise these issues but often put them into a logistic organisation context, such as increased environmental load because of poor logistic organisation (Aronsson & Huge Brodin, 2006; Chapman, 2006; Wu & Dunn, 1995; Behrends et al., 2008).

Regarding regulating bodies the EU is a key player for the European countries. It also works as a valuable source of information as it publishes environmental reports through the European Environment Agency (EEA) as well as statistics on the development of traffic, pollution, energy and much more through Eurostat. Annual reports from EEA (2007, 2009, 2010a, 2010b) and Eurostat (2009) highlight a number of areas of importance for environmental development of road transports:

- Air pollution.
- The production, efficiency and use of different fuel types.
- The energy efficiency of different vehicle technologies.
- Vehicle noise and vibrations.
- Planning and management of transport operations.
- Planning and utilisation of infrastructure.

For Swedish conditions, the Swedish Environmental Protection Agency, Swedish EPA, is in charge of implementing solutions for meeting domestic environmental goals. Tied to their work are several research institutes. The Swedish Environmental Research Institute is its main collaborator. It is connected to research on external costs in the transport sector. Focus is put on the issues of air pollution and noise, but also how these issues are influenced by results of poor logistic management such as congestion, which increase idling emissions in traffic (Belhaj & Fridell, 2008).

Turning to research institutes, many of them work as advisors for regulating bodies as well as in collaboration with academia. As a consequence the issues raised by research institutes are often more extended versions of those of regulating bodies. The Dutch independent institute CE Delft work as a key advisor for the EU and the Swedish National Road and Transport Research Institute, VTI, works for Swedish EPA. The EU view on sustainable transports is repeated by CE Delft researchers den Boer et al. (2009) and Maibach et al. (2007), as well as by Swedish EPA researcher Tapani (2003). Den Boer et al. (2009) also note the issues of transports having a negative effect on biodiversity. The Swedish research institute TransportForsK AB goes further by assigning more aspect to EST than others in their environmental handbook for transport purchasing (TFK, 1998). It picks up on issues regarding chemicals used in connection to vehicles, like spills of cleaning agents, glycole, oil and lubricants. It also notes the importance of discarding residual products like used tyres, oil filters and batteries in a proper way as well as purchasing replacements from sources with low environmental impact. Beyond that it mentions ground vibrations, and the negative barrier effect of preventing access to different parts of a physical space that roads and vehicles imply.

Non-governmental organisations like the WBCSD, the OECD and one of its main bodies, the IEA, have done extensive research in the area of environment, transports and sustainability. Although the organisations have been criticised for being favourable towards the business sector and the oil, gas and nuclear industries (Murray, 2009), they are committed to several large-scale research projects connected to sustainable development. Their main publications are similar to those of the EU and can be said to raise issues in line with other research (OECD, 1997; WBCSD, 2004; IEA, 1999). A notable research project is the EST project initiated in 1994 by the OECD, with the goal of defining the EST concept. Six countries were selected as case studies for which scenarios of sustainable transport societies were envisioned and projected for 2030 based on local conditions. All scenarios included a future with great increase in population and use of goods and services. By applying today's recommendations on health and environmental welfare to the projected circumstances of the future, the project was able to define the areas of environmental concerns where the biggest improvements had to be made in order to reach the envisioned scenarios. Finished in 2002, the project concluded that six environmental concerns should be put in focus; emissions of CO_2, NO_X, VOC:s, noise, particulates as well as land use occupied by different parts of transport operations (OECD, 2002)

In summary the literature can be seen as describing both technical and organisational issues related to EST. Much attention has been given to air pollution, renewable fuels, improved vehicle technology and logistic management. A lesser part of the literature picks up on noise and vibrations, although they are noted as upcoming problems of great concern as exemplified by the EEA (2007). Issues of visual and geographical barriers that transport activities impose on ecosystems are often mentioned but rarely treated in detail. The same goes for the issue of resource use during vehicle maintenance. To conclude this section, environmental impacts and constraints that affect the environmental sustainability of transports come from several sources and include the following:

Environmental concerns related to vehicle use:

- Air pollution
- Noise and vibrations.
- Energy consumption.
- Other issues such as use of vehicle maintenance products.

Environmental concerns related to the transport sector at large:

- Air pollution, resource constraints and energy consumption when producing renewable fuels and energy.
- Logistic management.
- Efficient construction and use of infrastructure.

Except for the last bullet regarding infrastructure which lies outside the scope of the thesis, the coming sections will discuss each area in more detail.

4.3.1 Air pollution

Air pollution includes a variety of substances having different properties and thereby different environmental impacts. The impacts caused by these substances differ depending from which perspective they are studied; locally, regionally or globally (Ericsson & Ahlström, 2008). Emissions of CO_2 and SO_X are depending on contents of carbon and sulphur in the fuels while the emissions of CO and

NO_X are more depending on aspects such as driving styles and combustion aspects (Uppenberg et al., 2001).

4.3.1.1 Local perspective

In a local perspective air pollution causes impacts in the vicinity of the source of emissions, generally as impact on human health but also on plants and buildings. Substances usually causing local air pollution from road transport include PM (particulate matter), CO (carbon monoxide), NO_2 (nitrogen dioxide), HC (hydrocarbons) and O_3 (ozone) (Ericsson & Ahlström, 2008).

PM can be described as fine particles of dust containing a large number of chemical substances and is usually classified into two classes depending on size; $PM_{2,5}$ (particle diameter < 2,5 µm) and PM_{10} (particle diameter 2,5-10 µm). Emissions of PM from the transport sector come from exhaust emissions (mainly from heavy diesel vehicles) and wear of road surface, tires and breaking systems (Ericsson & Ahlström, 2008). Inhalation of the particles can have different effect on human health depending on the composition of chemicals and size of the particles. Known health effects associated with exposure of PM are illness and deaths through heart and lung diseases (Ferrand, 2006).

CO forms when combustion of carbon is incomplete, i.e. in a combustion engine if there is not enough oxygen presence to form CO_2. Inhalation of CO will reduce the ability for the blood to transport oxygen since CO molecules will attach themselves to the haemoglobin with greater tenacity than the oxygen molecules (Ferrand, 2006). Babies and people suffering from cardiovascular diseases are more sensitive to this effect than others (Ericsson & Ahlström, 2008).

NO_X is a collective term for both NO and NO_2. NO_2 is formed during combustion causing N (nitrogen) and O_2 (oxygen) in the atmosphere to form NO (nitric oxide), which is then (to some part) oxidized further to form NO_2 (Ferrand, 2006). In a local perspective emissions of NO_X causes health effects and exposure to concentrations above normal levels in the atmosphere can cause damage to lung tissue (Ferrand, 2006), and can worsen the condition for people suffering from asthma or impaired lung functions (Naturvårdsverket, 2010 b). NO_2 is also a part in the formation of the secondary pollutant O_3 (Ericsson & Ahlström, 2008).

HC is a collective term for chemical compounds containing hydrogen and carbon. Hydrocarbons causing environmental impacts and health effects are VOC/NMVOC (volatile organic compound/non methane volatile organic compound) and PAH (poly aromatic hydrocarbons) which are emitted through incomplete combustion of gasoline and diesel fuels (Trafikverket, 2010). Some of the VOCs and PAHs can have serious health effects as they can be carcinogenic and can cause damage to the central nerve system (TFK, 1998). VOCs are also contributing in the formation of O_3 (Naturvårdsverket, 2011).

O_3 is one of the most hazardous pollutants from the transport sector and can be regarded as both a local and regional air pollution (Ericsson & Ahlström, 2008). Its persistency allows it to be transported in the air for long distances and thereby causing impact far away from the source (Naturvårdsverket, 2009). High concentrations of O_3 cause impact on both human health and on plants. Humans can experience irritation on mucous membranes and lungs and asthmatics can experience breathing problems (Naturvårdsverket, 2009), while plants can age prematurely because O_3 impacts both photosynthesis and growth causing large yield losses to the agriculture industry (Ericsson & Ahlström, 2008). O_3 is a secondary pollutant and is not emitted directly from combustion. The formation of O_3 is complex but can in a simplified way be described through following reactions as explained by Ferrand (2006): When NO_2 has been formed it can through the photochemical effect of sunlight form NO and O, where the O can react with the atmospheric O_2 forming O_3. If no competing molecules are present the hazardous O_3 can be removed through a rapid reaction with NO forming NO_2 and O_2. However, in presence of competing molecules, e.g. VOCs, the removal of O_3 will be limited since VOC can remove the NO through the reaction of VOCs and NO forming NO_2 and organic nitrates. The concentration of O_3 is higher in rural areas than in cities since concentration of the O_3-removing molecule NO is higher in cities due to larger emissions of NO_x from e.g. traffic (Ericsson & Ahlström, 2008).

4.3.1.2 Regional perspective

In a regional perspective the local air pollution has been transported by wind and cause impact on ecosystems like forests and lakes in an entire region, either through airborne or deposited pollution (Ericsson & Ahlström, 2008). The environmental impacts caused by air pollution in a regional perspective are mainly increased acidification and eutrophication through the pollutants NO_x and SO_2.

NO_x is emitted during combustion as explained earlier causing the nitrogen and oxygen in the air to react and form NO_x (NO and NO_2). In a regional perspective pollution of NO_x causes both acidification and eutrophication (TFK, 1998). When NO_x molecules react with H_2O acids are formed which at deposition contribute to acidification while the deposition of nitrate ions contribute to eutrophication (Trafikverket, 2010).

SO_2 is emitted through combustion of sulphur containing fuels, e.g. fossil fuels. In contact with water SO_2 forms sulphuric acid, which at deposition causes acidification (TFK, 1998). Emissions of SO_2 from the transport have decreased significantly during the last two decades as a result of lower content of sulphur in motor fuels (Swedish Environmental Protection Agency, 2011).

4.3.1.3 Global perspective

In a global perspective air pollution is causing global warming through emissions of infrared absorbing gases. From the transport sector the emissions of CO_2, CH_4, and N_2O are seen as gases contributing to global warming (Uppenberg et al., 2001). In the atmosphere the gas absorbs much of the infrared radiation from earth, of which some are emitted back to earth that otherwise would escape into outer space (Mason, 2006). The effect is increasing the average temperature on earth, which is believed to cause a series of serious impacts to ecosystems and human settlements (Uppenberg et al., 2001). The transport sector is a big contributor to emissions of CO_2.

4.3.2 Noise and vibrations

Using vehicles give rise to noise and ground vibrations that can have a negative impact on human health. According to estimations from the EEA (20009) close to 67 million people in Europe is exposed to daily noise levels from road transports that exceed the EU guidelines for excessive noise. According to Brambilla (2001), who has studied noise measurement techniques, more than 50% of the European population was exposed to noise levels higher than those recommended by the WHO in 2001 because of transport activities. As population and road transport services are growing as noted by Eurostat (2009), both the source of noise and the recipient base of it is increasing. Other than causing annoyance, exposure to high level of noise can cause concentration and communication difficulties, stress and disturbance of cardiovascular and mental health. Night time exposure can also cause sleeping disturbances, especially for young babies (Schade 2003; EEA 2009).

According to EEA (2009) the noise issue has been on the agenda since the 1970's and is a growing concern that is often overshadowed by the debate on air pollution and global warming. The EEA report identifies a number of technical factors that can improve noise levels like using silencers, low noise tires and noise absorbing materials, but also discards them as somewhat inefficient as they are often expensive and have limited effect. Instead reducing traffic levels is put forward as a more straightforward way of limiting noise as it is noted that each car makes only a small contribution to perceived road noise; an eight-fold reduction of cars is needed to halve the noise.

Measuring of noise is done either at source point or at recipient point and subsequently comparing it to compliance with local authoritative noise exposure levels. As road noise varies with time, measurements are usually performed during longer time periods and expressed as averages over a 24 hour period, separating them into day and evening or night time because the difference in health effects (Brambilla, 2001). Apart of the EEA is the Expert Panel on Noise (EPoN) that is responsible for developing an effective noise policy for Europe, according to their research a noise level of 50dB is considered a good average noise quality (EEA, 2010c), which can be compared to a low voiced conversation or bird twitter (Ericsson & Ahlström, 2008).

According to TFK (1998) noise is closely related to driving speed, with trucks producing the most noise at 60-70 Km/h. Vehicle noise is mainly produced by the vehicles cooling fan, engine, drive-train and exhaust pipe as well as interaction between tire and road and by wind resistance at high speeds (EEA, 2009). However, noise levels cannot be attributed to specific types of vehicles since they are heavily affected by local conditions such as road conditions and driving styles (Ericsson & Ahlström, 2008; Althaus et al., 2009)

4.3.3 Energy consumption

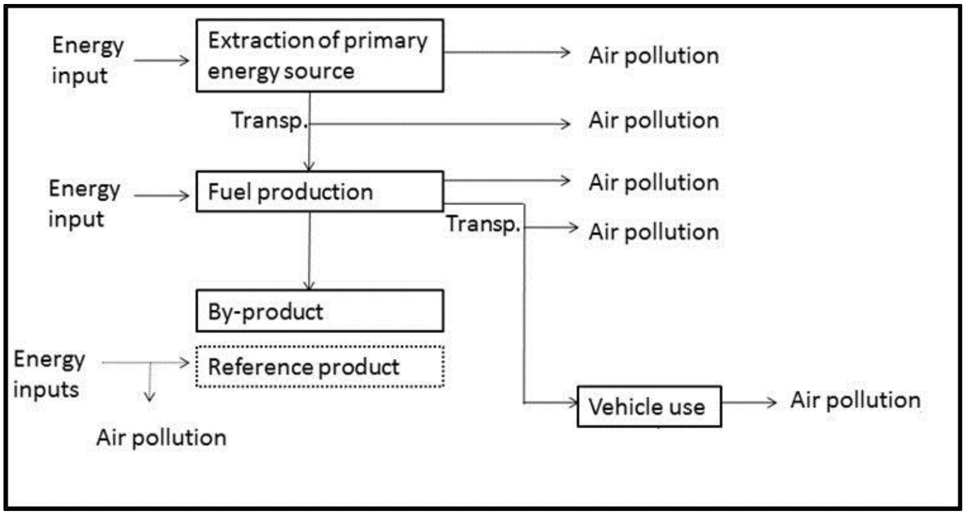
Energy consumption by itself does not cause a direct environmental impact, but is closely connected to the principles of sustainability. The access to energy and the amount of energy readily available is limited and the use of it should therefore be managed. According to Giddens (2009) energy scarcity, price, and security are among the most immediate challenges our society is facing today. It is assumed that in a near future, when most of the older vehicle fleet has been replaced, considerably reductions in air pollution will be seen, making other environmental driving forces, such as energy use, a higher priority (Ecotraffic, 2010). Energy efficiency is therefore an important measure to take into consideration when evaluating transports from an environmentally sustainable perspective (Halldordsson, 2010). Another important factor regarding the fuels and the importance to lower fuel consumption is the resource constraints put upon the production side of fuels and energy, most notably on renewable fuels. To be able to meet the sustainability principles of inter- and intra-generational equity the use of resources and thereby the energy and fuel consumption must decrease.

4.3.4 Fuel production

Vehicle fuel is a topic of that has gained a lot of attention and research. At its core is the issue of how to direct the transport sector away from fossil fuels towards renewable fuels in order to avoid global warming and climate change. As fossil fuels are so infused with modern society, this is daunting task. There are a large number of renewable fuels today, they are generally not as readily available as fossil fuels, and often not as energy efficient. With renewable fuels comes the question of how to produce and use them so that the total environmental impact is lower than that of fossil fuels. How to do this, what aspects to consider, and how to compare environmental impacts of different fuels is complicated and a vast topic.

There are countless types of renewable fuels, particularly biomass based fuels have been in focus because of their ability to be used in today's transport infrastructure. Large organisations like the EU and IEA have been involved in extensive research in the field. In Sweden a research imitative called “f3”, derived from “fossil free fuels”, have been launched to provide the government, industry and third party organisations with scientific research. F3 consists of scientists from KTH, LU, Chalmers as well as other research groups, governmental bodies and energy and transport companies (Swedish Energy Agency, 2011). There is a common consensus that evaluating environmental impact from fuels needs to take into account both the production and use phase of the fuels, this is usually done with so called well-to-tank (WTT) or well-to-wheel (WTW) studies, an approach similar to performing a LCA. WTT studies takes into account environmental impacts starting from the production site (the well) of any raw material needed to produce the fuel, through production of the fuel itself, as well as any transports needed along the production chain. WTW studies also include the vehicle use phase (Alvfors et al., 2010).

Performing a WTT/WTW studies struggles with many of the problems related to an LCA, like what operations in the production system that are to be included as well as allocation dilemmas when more than one product is produced by the system. In general, five stages are taken into account in a full WTW study as illustrated in Fig. 4.3.4: Extraction of primary energy source, primary energy source transportation, fuel production, fuel distribution transportation, and energy consumption in vehicles.



. Figure 4.3.4: *Simplified illustration of main steps in a WTW study for a biofuel.*

The EU is a commonly used source of information for these types of studies because of its extensive JEC Biofuels Programme reports. The reports are the results of a continuing project between the EU and the oil companies of Europe; the Joint Research Centre of the EU (JRC), the European Council for Automotive R&D (EUCAR) as well as the oil industry organisation Conservation of Clean Air and Water in Europe (CONCAWE). The JEC reports are focused on quantifying energy use and emissions of CO_2, CH_4 and N_2O for a large number of fuels. As noted by Alvfors et al. (2010) however, there are additional concerns that can be attributed to biofuels. Notably the limited ability to grow feedstock, which has been studied in several reports by LU and f3 researcher Pål Börjesson (2007a; 2007b; 2008), where the restrictions on land and feedstock yields are put in focus as an important restraint that need to be taken into account.

In general WTT/WTW is a complicated task and involves many variables that needs to be taken into account, often with the use of several assumptions because specific circumstances connected to producing the fuels are unknown or vary greatly between fuel types, local conditions and time periods. These assumptions may influence the end results to a great extent, and therefore it is impossible to put exact numbers on environmental loads in any specific system. This is noted by *(*Alvfors et al., 2010), where the feedstock production and fuel production stages are pointed out as large contributors to the overall environmental load of a biofuel, as well as being the stages that include the most assumptions. As a consequence of this dilemma quantifying environmental loads of biofuels are rough estimates and can be treated in a general manner at best.

4.3.5 Electricity production

Establishing environmental impact from electricity use is related to the system in which the electricity is produced. Depending on the source of the electricity the environmental impact will differ, wind power produces electricity with relatively low impact while coal power is a heavy polluter etc. The electricity production system is made up of a great many sources and as a result the environmental impact of a certain amount of electricity consumption is made up of contributions from each source. There is currently no way of establishing the specific origin of electricity other that knowing the distribution of the sources that produced it. As with fuel production, with electricity production it is relevant to evaluate what parts of the system to include when allocating environmental impact. This is often country specific since different countries have different strategies for meeting electricity demand. According to IVL (2009), which have produced a guidance report for how to deal with environmental assessment of Swedish electricity, the Swedish electricity system is relatively domestic with few inputs from European sources and mainly constituted of hydro and nuclear power. They therefore conclude that using the Swedish average energy mix is recommended for situations when evaluating existing electricity consumption. The IEA (2000) has done extensive charting of country specific electricity mixes and evaluated the environmental impacts from a life cycle perspective, and can be seen an organisation of great importance when comparing electricity production impacts of different countries.

4.3.6 Other environmental impacts

Besides environmental impacts mentioned in previous sections there are others related to road transports that need consideration. Soil and water contamination is one of these impacts and is caused by road runoff of anti-skid treatment substances, spills of oil and glycol, leakage of hazardous vehicle maintenance products such as solvent-based degreasing agents and vehicle care products containing tensides. Others are barrier effects and intrusion of natural environments caused by roads and vehicles dividing areas that functionally belong together and taking up space that could be important areas for plants and animals. The use of scarce vehicle construction materials is also put forward as a potential problem for future transport operations, especially the use of scarce metals in batteries when moving away from fossil fuels to electric based propulsion (TFK, 1998).

4.3.7 Logistic management

Organisation of logistic operations is a key factor for moving towards sustainability as it is the societal need of logistics operations that creates the subsequent need for vehicles and their associated environmental impacts. From a logistic point of view environmental concerns can be seen as one of many efficiency variable of any logistic operation. Examples of other important variable are costs, time, customer satisfaction, flexibility in operations and capital occupation in cargo (Jonsson et al. 2008). The variables are often contradictory and need to be managed to work together. The opportunities to do so are largely laid during the planning stage, as the potential to change organizational structure is greatly diminished on a vehicle level. This view is symbolized by an organizational funnel by Aronsson and Brodin (2006), where each level in the funnel creates opportunities for the level below in the form of a logistic operation but also limitations for how the operation can be performed, see figure 4.3.7.

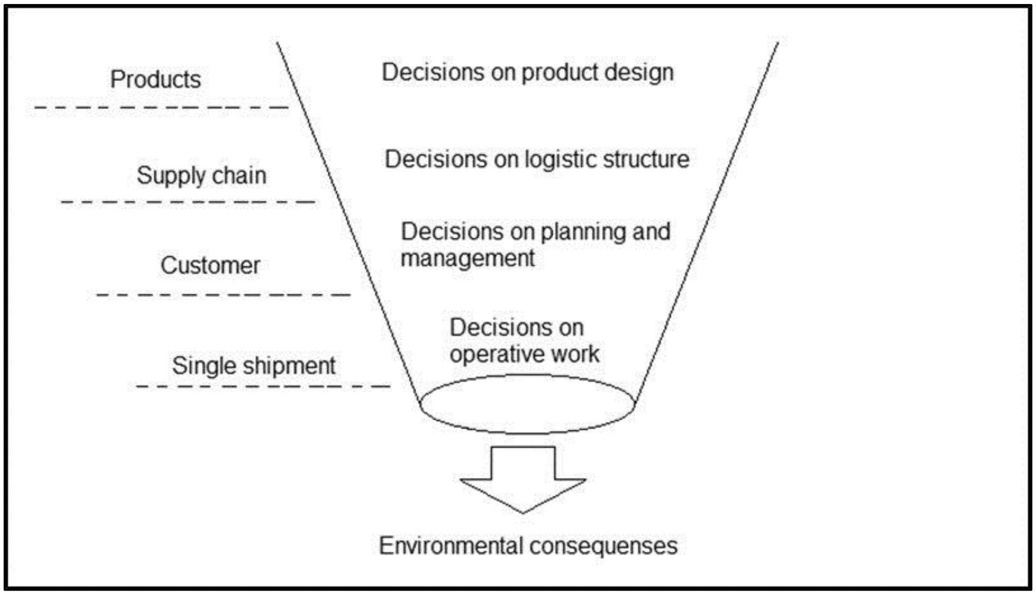


Figure 4.3.7: *The logistic organization funnel, where higher levels shape decision possibilities at lower levels. Adapted from Aronsson and Brodin (2006).*

The environmental concerns in terms of logistics are related to operations not to technology. All transport operations are connected to issues described in sections 4.3.1-4.3.6, and performing unnecessary operations lead to increased environmental load. As a consequence organizational logistic efficiency is of great importance as described by Hallordson (2010), who puts focus on energy efficiency as the greatest environmental challenge for logistics as human population increase and resource supply diminishes. Common indicators for logistic efficiency is tonnes of cargo per km, cargo capacity utilization (CCU), empty running and total distance driven by a vehicle fleet, so-called vehicle kilometres (McKinnon 2010). Regarding waste management transports they share some similarities with what is called reverse logistics, which is the process of returning material and goods from the point of consumption to the point of origin for reuse purposes. As described by McKinnon (2010) waste management and reverse logistics both deal with the opposite situation of standard delivery logistics, meaning that pick-up points are often greatly spread out and delivery points are consolidated. Decreasing environmental impact from operations can be done in numerous ways, examples are milk rounds, distribution using terminals where goods are collected for more efficient handling, fixed day deliveries in order to simplify logistic planning and "green departure" where the transporter decides delivery dates instead of the customer in order to reach high CCU (Jonsson et al. 2008).

4.4 Assessing sustainability

To be able to assess sustainability and move towards it, principles or prevailing conditions for what is seen as a sustainable society needs to be defined. Holmberg et al. (1996) formulated four socio-ecological principles for sustainability that covers the three dimensions of sustainability.

- Substances extracted from the lithosphere must not systematically accumulate in the ecosphere.
- Society-produced substances must not systematically accumulate in the ecosphere.
- The physical conditions for production and diversity within the ecosphere must not systematically deteriorate.
- The use of resources must be efficient and just with respect to meeting human needs.

The first three of the principles deal with the environmental dimension through the interaction between society and nature while the fourth covers the social and economic dimension.

These principles have been the base for the development of an operational model called "The Natural Step (TNS) Framework" made by The Natural Step, an international NGO helping organisations to strategically move towards sustainability (Behrends et al., 2008). The TNS Framework is centred around the concept of 'backcasting', where a company envisions a future business model that holds true to the four principles and sets up goals to reach it. It is used to help organisations to better understand and integrate environmental, economic, and social consideration in their operations (The Natural Step Foundation, 2010). As explained by Holmberg & Robèrt (2000) backcasting is a method where '*...future desired conditions are envisioned and steps are then defined to attain those conditions'*.

As mentioned the four principles set up the framework for what sustainability entails, to reach it there is a need of tools to assess if development is going the right way. There is great deal of tools that may be used to do this. According to Rober`t, K.-H. (2010), factor 10, ecological footprint and LCA are examples of such tools. Factor 10 is a concept describing that the current use of materials and energy is tenfold the capacity of the Earth, and as a consequence material and energy flows need to be reduced with a factor 10. Ecological footprint takes a systemic approach to assessment by calculating upstream resource use and converting it to how large of an area is needed to support a certain activity. The area is then related to estimations of the total area on the earth to conclude how taxing the activity is. LCA is a comprehensive strategy to compare products and services by doing calculations on resource use and environmental impact through their entire lifecycles, taking into account all relevant processes up and downstream connected to them such as raw material acquisition, production, use and disposal. By doing so the idea is to not miss relevant issues because of a too narrow outlook when performing the comparison. The need for a systemic approach is also supported by the fact that sustainability issues is increasingly moving away from local issues towards global issues as described in chapter 4.3. LCA is a frequently used tool for comparisons as it can give information on which product or service is the least taxing.

5 Market survey

The market survey is based on six questions in order to identify the state of the logistics and waste management markets. The survey examines what kind of sustainability aspects that are acknowledged by companies operating in these markets and how they quantify, calculate and report on these aspects. It also charts out the current supply of green transport services and in what way they are offered to customers. The six questions that have been used are listed below.

1. What does the concept of ‘sustainability’ or ‘sustainable transports’ mean to the company?
2. What kind of green services or green products are on offer from the company?
3. How are the green services or products offered to the customer?
4. How does the company quantify or estimate the environmental impact of their activities?
5. What sources of reference are used to support claims and calculations made by the company?
6. What is the level of transparency of results and statements from the company?

The answers to the survey questions together with a short company background profile have been documented for each company and can be reviewed in appendix A. A summary of each question is written below.

5.1 What does the concept of ‘sustainability’ or ‘sustainable transports’ mean to the company?

The companies included in the survey commonly refer to the issue of sustainability either directly according to the triple bottom line or to a self-defined variety of the triple bottom line. Self-defined varieties are more common for the bigger logistic companies like the Geodis Group, DHL, UPS and FedEx, which have diversified organisations and need sustainability policies that fit the entire company. Some of the companies, for example Ragns-Sells, do not have explicit sustainability policies but still expresses themselves in economic, social and environmental terms very similar to the concept of the triple bottom line. Two of the companies do not put environmental issues together with economic and social issues at all; DSV files their environmental commitments under the concept of Corporate Social Responsibility (CSR) and RenoNorden can be said to treat environmental work as an isolated topic.

Which environmental concerns that are treated in relation to sustainability and transports vary to a large extent between the companies, all of them acknowledge global warming and CO_2 emissions from vehicles as critical issues however. As a consequence of the focus on global warming a substantial part of information that is available from the companies deal with how to decrease fossil fuel use. Using bio fuels, new and efficient vehicle technologies, optimisations of transport routes and educating drivers in eco-driving are examples of measures that most companies have implemented in some form in order to do this. Generally the companies belonging to the waste management sector are focused on the environmental gains of recycling materials to a large extent. When their transport operations are discussed there is often a focus on technical measures such as vehicle technologies. The companies belonging to the logistics sector generally highlight logistic management to a greater degree than the waste management sector and also provide more extensive data on environmental vehicle performance.

Other than the focus on CO_2 few environmental issues are shared across all companies. Posten Norden, Green Cargo, DB Schenker and to some extent also DSV expands their reporting on air pollution to include more components than CO_2 such as CO, SO_X, NO_X, hydrocarbons and combustion particles. Vehicle noise is mentioned as an unwanted effect of transports by Posten, DSV, Ragn-Sells and SITA but none of them employ any methods to quantify it or avoid it. Constraints in the supply of materials and energy are noted by Posten, SITA, Ragn-Sells, Green Cargo, DHL and Dachser both in terms of electricity and fossil fuels or bio fuels. Some of these companies report on the amount of fuel that is used annually and set targets for reduction. Some of them also report on electricity in the same manner but not specifically for the transport activities but for the entire organisation.

Posten Norden, Green Cargo, Ragn-Sells and Geodis adopt a systems perspective on their activities and acknowledge the problem of environmental loads occurring upstream in the supply chain when using fuels and energy. On the fuel side, Posten Norden and Green Cargo adds WTT data on air pollution from NTM to their vehicle emissions. On the energy side, Green Cargo, Ragn-Sells and Geodis buy electricity from renewable source in various amounts in order to secure the capacity of their electricity consumption on the renewable market.

A number of other sustainability aspects are briefly and sporadically mentioned by many companies, generally they are not dealt with in detail or are vaguely described however. Two examples of this is the importance of not contributing to loss of biodiversity mentioned by UPS, and the commitment to reduce oils spills and water contamination mentioned by SITA. None of the companies go into details on how to work with these issues.

5.2 What kind of green services or green products are on offer from the company?

The green services offered by the studied companies differ in both in design and ambition. However, four different types of green services can be distinguished; carbon compensation, enhancing environmental performance through logistic solutions, providing customers with environmental statistics, or strengthening customers' environmental profile through certificates or labels. A summarized categorization of the companies according to the type of green service can be found in Table 5.2. The overall purpose of the green services found among the companies is offering services minimizing or offsetting emissions of CO_2. General approaches for minimizing emissions of CO_2, besides those of green services, used by a majority of the companies are logistic solutions such as route planning, increasing cargo utilization, multi-modal transportations, and technical solutions such as alternative fuels, new and efficient vehicle technologies, and eco-driving.

According to the survey, the logistic companies generally offer more distinct types of green services or products than the companies in the waste management industry. However, some of the logistic companies do not offer any green service while others, like DHL, Geodis, and UPS provide several alternatives.

DHL, UPS, and Posten Norden offer carbon neutral transport services by carbon compensating for the emissions incurred by the transport. By calculating the CO_2 emissions incurred the companies can offset their emissions by investing in climate protection projects. The DHL service 'GOGREEN' and the UPS service 'UPS carbon neutral' are standalone carbon neutral transport services while Posten Norden incorporates the carbon neutral transport in their service 'climate economic direct marketing', a service for companies wanting to send out marketing leaflets and other printed material. Posten Norden uses only ISO 14001 certified suppliers and paper quality certified with the Nordic Ecolable 'Svanen', and the delivery of the marketing material is climate compensated through the CDM-system. Posten Norden, DHL, and UPS label the packages and marketing material, and the service is further extended by DHL offering customers yearly certificates showing the total amount of CO_2 that has been compensated for on their behalf.

DSV and DHL offer green services that enhance the environmental performance of their activities through logistic solutions. DSV's green service 'DSV ECO Transport' is a green departure service that incorporates a five-day pick-up interval. When the pick-up is scheduled, the customer is notified. This increases utilization rate of the vehicles as well as lowering fuel consumption and cost. DHL's service 'PACKSTATION' consist of several self-service parcel stations spread around Germany where private customers can send and receive parcels at any time of the day. DHL claims that the service reduces traffic significantly and thereby reducing emissions of CO_2, PM, and other pollutants compared to employing home delivery.

DB Schenker and Geodis offer their customers statistical information of the environmental performance of the customers' shipments. These statistics are additional information to the general information and services available to customers through the companies' e-portals. Similar types of this kind of service is provided by Ragn-Sells and Stena Recycling, but focused at the environmental benefit of recycling. The companies offer customers statistics on amounts of transported waste and saved CO_2 emissions from recycling material instead of using virgin material.

None of the companies in the waste management industry offer their customers green services related to their transport activities. The focus is put on the environmental benefit of recycling material instead of using virgin material, and less focus is put on the environmental aspects related to the transport activities. Several of the companies offer their customers education in the fields of environment and recycling. Environmental impacts from transport activities are in some companies mentioned but seldom quantified. However, Ragn-Sells claims that they are working on implementing air pollution statistics from the transport activities as well.

Green Cargo and UPS offer customers' certification or labelling as a standalone green service, strengthening the environmental profile of the customer. Green Cargo evaluates the transport set-up of the customer, and grants the 'Green Cargo Climate Certificate' if the set-up generates less than 10 grams CO_2 per ton cargo and kilometre. UPS has a similar service in their 'Eco Responsible Packaging Program', a labelling system for customers choosing to work with UPS on reducing weight and dangerous chemicals of packaging. The packaging program involves an evaluation process of the process of the customer, if the customer scores enough points it is free to use the UPS certified labels on their packages.

Another DHL service comes from the DHL Freight Division that has developed a service called 'Green Tonnes'. Customers pay an extra charge for their transport making sure that corresponding transport volume is performed with renewable energy within DHL's transport system. This service is similar to the service 'Green Electricity' in Sweden where customers pay an extra charge for making sure that corresponding amount of electricity is produced by renewable energy. DHL presents a list the most "green" companies on their webpage, strengthening the environmental profile of the customer.

Online emission calculators are additional services provided by some of the companies. 'EcoTransIT' is a one type of emission calculator that is used by Green Cargo and DB Schenker, used in informational purpose for customers to make prior estimates of emissions and compare different modes of transport. Stena Recycling has developed 'The Climate Wheel', a type of calculator informing visitors of the environmental benefit of recycling material instead of using virgin materials.

Table 5.2: *Summarized categorization of the companies according to their green services.*

Service / Company	Carbon compensation	Logistics	Statistics	Customer env. profile
Waste management companies				
IL Recycling				
Ragn-Sells			X	
RenoNorden				
SITA				
Stena Recycling			X	
Logistic companies				
Dachser				
DB Schenker			X	
DHL	X	X		X
DSV		X		
FedEx				
Geodis Group			X	
Green Cargo				X
Posten Norden	X			X
UPS	X			X

5.3 How are the green services or products offered to the customers?

Depending on the type of green service the company is offering the way it is offered differs a lot. The service could be offered at a charge, for free, or as in the case of DSV's green departure service, at a cost less than the ordinary service. Generally, services marketed as the companies' green service comes with a fee. Customers can be more or less involved in the process, affecting the outcome of it.

By offering carbon neutral transports the corresponding CO_2 emissions incurred by transports are compensated for by investing in climate protection projects. DHL and UPS use an extra fee for the green service that is reinvested in the projects. The fee is based on a percentage of the transport cost or on a per package rate. Posten Norden however, offer their climate economic direct marketing free of charge and pay the cost of climate compensating for the emissions incurred by the associated transport themselves. Customers wanting to use the service 'climate economic marketing' need to contact Posten individually.

The green service of a five day pick-up interval provided by DSV is offered at a reduced price of up to 7 % than that of the normal delivery services and is according to DSV adding to the environmental profile of the customer. The DHL service 'PACKSTATION' is available to private customers in Germany and DHL attracts customers by applying a bonus point scheme where customers collect points for sent and received parcels. The points can be used as payment for future shipment, shopping vouchers, gifts, or donations.

The statistical services are offered in a variety of ways. DB Schenker's 'Emission Report' is available for free at their e-portal while Geodi's 'GreenService' comes at a fee that is collected into a fund dedicated to external research projects and internal improvement projects in the environmental field. Among the waste/recycling companies Ragn-Sells and Stena Recycling offer statistics on recycled waste and associated savings of CO_2 through their e-portals. Ragn-Sells offer the service at custom pricing while Stena Recycling offer the service for free.

Some of the green services are focused at the customer side of the activity. The Green Cargo service 'Green Cargo Climate Certificate' and the UPS service 'Eco Responsible Packaging Program' involve an evaluation of the customers transport set-up or packaging from an environmental point of view, and the companies grant certificates or labels if the customers fulfil the requirements. These approaches are different from other companies' since the customers are encouraged to make changes and to optimize their transport set-ups and packaging.

The 'Green Tonnes' service from DHL is offered at 0,40 SEK per ton/km and customers choose how much of the transport volume they want to pay for. Corresponding amount of transport volume is then performed through renewable energy in the DHL system.

To offer education to customers is another service provided by several of the studied companies. The logistic companies offer education in logistics while several of the waste/recycling companies offer environmental and waste management education. These educations can be designed to fit the specific organization and is often offered at custom pricing.

5.4 How do the companies quantify or estimate the environmental impact of their activities?

The methods and models used for environmental assessment currently used by the companies in the survey are diversified, both in terms of what they include and how they are designed. Some companies use a qualitative approach rather than measurements and quantifications. Statements and claims about environmental performance are common, but the extent to which they are backed up by references or data vary considerably. In general the companies often publish information on the entire organisation, and do not separate the environmental performance down to different subdivisions or specific transport operations and vehicle types. If specific information is supplied it often concerns air pollution in the form of CO_2.

Statistics on performance is supplied by all companies except IL Recycling, RenoNorden, SITA and Dachser. The type of statistics that is published vary between the companies and is related to how the environmental issue is perceived. The most common kind is annual fuel and energy consumption, the number of vehicles in a certain euro class and the number of drivers trained in eco-driving. DB Schenker, DSV and Ragn-Sells, provide more detailed information such as fuel consumption per vehicle type, average cargo capacity utilisation, or hazardous and waste materials used by a specific division of the company.

Nine of the companies go beyond statistics and have developed some form of calculation methods or models that provide more detailed information on their environmental performance. Because of the heavy focus on global warming by the industry, methods for calculating CO_2 emissions are most commonly employed. There are basically two ways in which this is done. The first is to consider only direct emissions from vehicles and thereby quantifying CO_2 emissions based on the carbon content of the fuel by using a conversion factor. The second is to take a systems approach and not only consider vehicle CO_2 emissions but also emissions produced during the production phase of the fuel by using WTT data. Green Cargo is the only company using the systems approach while DSV, Geodis, Posten Norden, UPS, Ragn-Sells, DB Schenker, DHL and FedEx all use conversion factors to go from fuel consumption to CO_2 emissions. Geodis and Posten Norden also calculate CO_2 emissions connected to their electricity consumption but do not relate them to any transport activities. Posten Norden, DB Schenker and Green Cargo do their more extensive calculations on air pollution components by using the NTM method, with assumptions done regarding average vehicle utilisation rates. DSV do calculations on NO_X and hydrocarbons according to their own proprietary model which is not disclosed to the public.

As noted under section 5.1 several companies mention a number sustainability aspect other than CO_2 emission and limitations on fuel and energy, none of them are measured or treated in a systematic way however.

5.5 What sources of reference are used to support claims and calculations made by the company?

The statistical data supplied by the companies are presented in their sustainability reports in most cases, some of them are reviewed by third parties as a way of increasing their credibility. Data such as fuel and energy consumption is measured directly by the companies themselves and specified clearly in most cases. What sources that are used for CO_2 calculations differ somewhat more as there is no standard on the market on how this should be performed. Posten Norden, DB Schenker and Green Cargo all use NTM for the emissions calculations. Green Cargo also uses NTM for their calculations of emissions from fuel production. Ragn-Sells uses emission factors provided by SPI which is based on the carbon content of different fuels.

DSV, Geodis, UPS, and DHL use their own proprietary emission models. UPS and DHL do not provide their calculation methods to the general public, instead they refer to third party certifiers to ensure that the results can be trusted. DHL refers to their certification by the ISO 14064 standard and UPS is certified by the Société Générale de Surveillance (SGS). DSV uses an average CO_2 emissions value of 2,65 Kg per litre fuel, which is similar EU Mk3 diesel according to SPI (2010). The Geodis Group uses a slightly higher value of 2,68.

5.6 What is the level of transparency of results and statements from the company?

The level of transparency varies to a great degree. Environmental reporting and proper specifications on calculation methods is of great importance for credibility. In this respect the companies in the waste management sector generally have a lower level of transparency than the companies in the logistics sector. IL Recycling and Ragn-Sells provide environmental reports, Stena Recycling, RenoNorden and SITA does not however, which can be seen as lacking in comparison to other companies in the survey. Among the companies in the logistics sector, Dachser is the only one not providing any reporting.

Regarding the logistics sector specifically, the two large package carriers, FedEx and UPS, and to some extent also DHL, do not disclose their working methods to the general public and rely on certification to validate them. Doing so makes these methods difficult to evaluate and compare to other companies, and exemplifies the need for transparency. Six of the companies in this sector employ the GRI reporting standard which generally means that there is a relevant information base provided. Geodis and DSV use their own reporting structures which work well in both cases since the information is clearly presented, although it is not as comprehensive compared to that of GRI reports.

Regarding the waste disposal sector, Ragn-Sells is the only company providing clear and traceable information on how CO_2 calculations are made and what activities are included in those calculations. IL Recycling is the only other company providing a sustainability report, even though it was issued in 2009 for the first time and the company has not yet developed their reporting to a level that is comparable to others in this survey. The lack of reporting from the other companies in the sector is notable and make claims on environmental commitments to transport activities hard to evaluate.

6 Application of theory

This chapter analyses and develops the empirical findings of the literature review.

6.1 Defining an environmental sustainability framework for transports

By combining the bodies of information studied in the literature review, a set of issues of what sustainability means for transports can be established. As mentioned in section 4.3 the different bodies emphasise different kinds of issues, but by including the ones that are agreed on by all parties as well as taking an inclusive approach to ones that are mentioned only by a few, the complete set will be comprehensive but with the advantage of not overlooking issues that at first may seem unimportant. The inclusive approach is also supported by the fact that sustainability in itself is a broad subject which cannot be treated with a narrow field of view. With the TNS principles for sustainability as a stepping-stone the issues found in literature can be categorized into a new framework for sustainability suited for transport operations. The categorization can be seen as having five areas of concern; air pollution, noise, energy constraints, material constraints and ecosystem vitality. Within every category are factors from the literature that have negative contribution to environmentally sustainable transports, see table 6.1 below.

As a comparison the framework can be related to the natural step principles by Holmberg et al. (1996), see figure 6.1. The principles are strongly connected to material use and the noise category therefore falls somewhat outside the comparison, which has been symbolised with a dashed line. Other than that the framework correlates well with the principles of sustainability. It can be noted that the energy and material constraints categories are connected to two principles each. They are hence not only connected to negative effects on sustainability because of the potential to increase harmful substances in the environment, but also because energy and material goods are limited resources and should be used efficiently.

The air pollution category is mainly affected by CO_2, CO, NO_X, SO_X, N_2O, NMVOC, CH_4 and PMs, the noise category by vehicle noise in urban areas, the energy and material constraints categories by the overall use of energy and materials, and the ecosystem vitality category by amount and placement of traffic, see section 4.3 for details on how the components of each category affects sustainability.

Table 6.1: *The EST framework. The categories and their respective factors having negative impact on the environmental sustainability of transports.*

Air pollution	**Noise**	**Energy constraints**	**Material constraints**	**Ecosystem vitality**
Emissions from vehicle combustion	Vehicle noise	Fossil fuel use	Use of vehicle maintenance products	Soil and water contamination
Emissions of vehicle tyre particles		Bio fuel use	Use of scarce vehicle construction materials	Environmental intrusion
Emissions from fuel production		Electricity use	Land use for bio fuel production	Barrier effect
Emissions from electricity production		Energy use during fuel production		

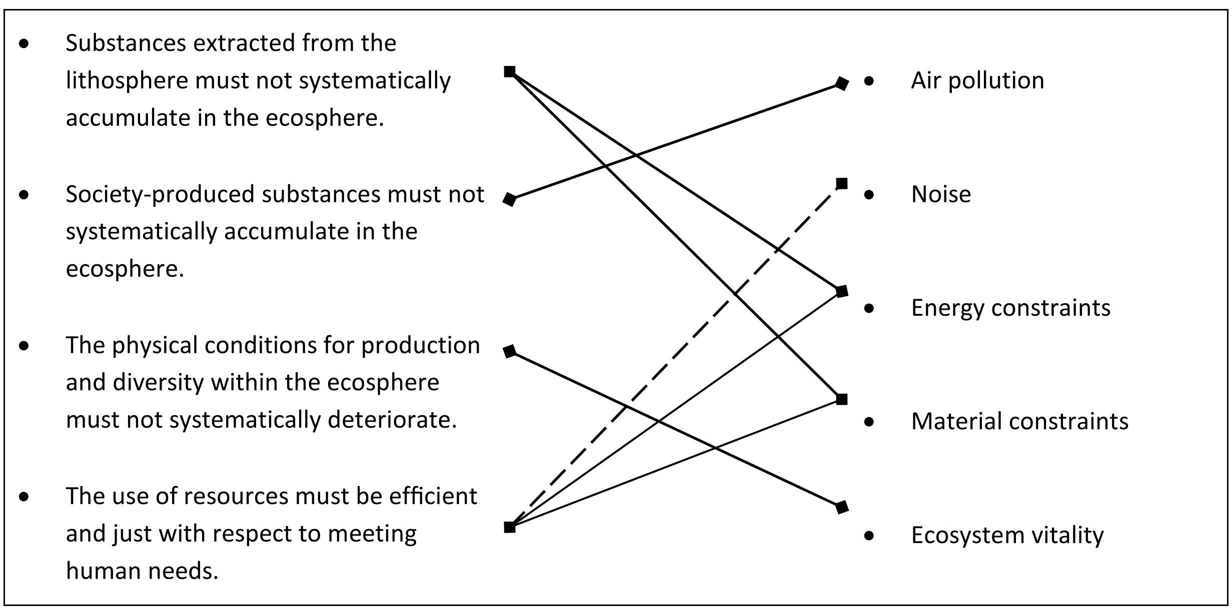


Figure 6.1: *The correlation between the four principles of sustainability and the EST framework. The dashed line symbolises a weak correlation.*

6.2 Analysis of market survey

Based on the findings from the market survey a number of observations can be made, many which seem to relate to the different views of what sustainability is. As a first note, when comparing findings from the literature study to ones in the market survey, there are notable discrepancies in the number of aspects that are considered as important with regards to EST. In general the literature body includes more aspect than the companies from the market survey do. A large part of the information available from companies are focused on CO_2 emissions and vehicle fuel use. Comparing this to table 6.1 it can be noted that the man focus of the industry hence lie in two of the sustainability factors, the other factors are not treated in detail by many companies, creating a great deal on unattended factors, see table 6.2. As sustainability emphasises the need to conserve valuable resource over time on a global scale, an interpretation of the missing factors is that the current market has a local rather than a global standpoint on the environmental impacts of its actions, as well as having a momentary rather than a long-term horizon on environmental issues.

Table 6.2*: Market focus (grey) compared to literature focus on EST*

Air pollution	**Noise**	**Energy constraints**	**Material constraints**	**Ecosystem vitality**
Emissions from vehicle combustion	Vehicle noise	Fossil fuel use	Use of vehicle maintenance products	Soil and water contamination
Emissions of vehicle tyre particles		Bio fuel use	Use of scarce vehicle construction materials	Environmental intrusion
Emissions from fuel production		Electricity use	Land use for bio fuel production	Barrier effect
Emissions from electricity production		Energy use during fuel production		

Beyond comparing sustainability aspects of the entire market to literature, it is also relevant to compare the two sectors within the market to each other. The first question in the survey deals with how the market perceives environmental sustainability and EST, which gives a good base for such a comparison. The results show that companies in the logistics sector generally have put more effort into developing methods to measure and manage the environmental impacts connected to transport operations compared to companies in the waste management sector. This is not surprising since the waste management sector has a wide array of business operations where transports of waste is only one part, while the logistics sector deals specifically with transports as the core business. However, this also means that when comparing how companies in the two sectors present themselves and what services they provide, waste management companies do not seem to recognize transports as a business opportunity to the same extent as logistic companies. As a consequence, the transport sector seems to be ahead both in terms of dealing with EST as well as profiting from them.

Since global warming and climate change is the most common environmental issue dealt with much focus is put on how to reduce fuel consumption and the emissions of CO_2. The measures discussed by companies range from technical solutions such as engine optimization and changing fuels, to logistic solutions such as increasing cargo utilization and route planning. However, by only focusing on the reductions of CO_2 several issues from the EST framework are overlooked and the transport system might get sub optimized. An engine optimized for fuel consumption might not be the optimal choice considering noise levels etc. Since the focus is put on CO_2 the green services offered to customers also revolve around CO_2. Few of the companies deal with other environmental issues, and only one is taking a systems approach for the calculations. Posten Norden, Green Cargo, and DB Schenker use the NTM model for calculating their emissions and can therefore quantify emissions of several other pollutants beside CO_2. Of the studied companies Green Cargo is the only company taking a systems approach by including the emissions from the production of the fuels.

By limiting the focus only to CO_2 and not having a systems perspective, a true picture of the environmental performance of a transport from a sustainability perspective is impossible to obtain. If the companies were to expand their view on environmental sustainability and take a systems perspective the possibility to offer more, and more diversified green services arise. By applying these approaches to the calculation model for Renova, the company will have a potential to be the market leader in green services.

7 Creating an evaluation model

By combining the EST framework described in section 6.1 together with the literature review section 4.4 'Assessing sustainability', as well as the results from the market survey in section 6.2 a relevant model for evaluation of EST can be developed. The model has three preconditions; it should be based on the literature study, it should be able to compare environmental efficiency of different vehicles and fuels, and it should be able to be used on the market if possible.

As described in section 6.1 the EST framework is affected by both technical and logistic efficiency. An interpretation of this is a three layered structure with the EST framework at the bottom being affected by a technical and a logistic layer lying above it. The representation symbolises that logistic organisation affects both choice and use of technology, and that technology affects environmental sustainability, see figure 7.1

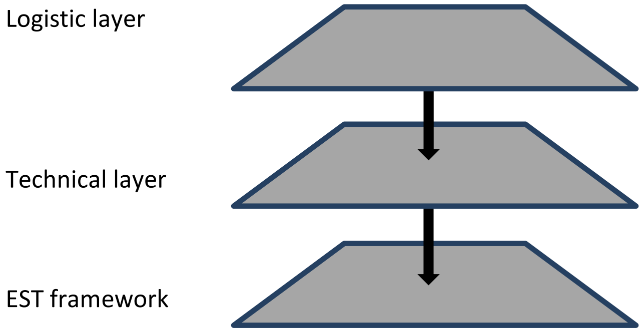


Figure 7.1*: A visual representation of the EST model, the arrows represent influence.*

A natural progression is to define each of the top layers and to measure how they contribute to the EST framework. Based on the literature in chapter 4.3.5 and 4.3.6 on fuel and energy production, a relevant approach is applying a systems perspective to the technical layer as the Renova fleet uses both electricity and several fuel types. Each configuration of vehicle, fuel and electricity makes up its own system. To be able to compare them it is reasonable to use the LCA approach described in section 4.4 'Assessing sustainability' where environmental impact is measured for each part of the system. This is also in line with the EST framework that includes factors from all parts of the system. The technical layers should therefore represent the current technical system of Renova that is the source of the EST factors, including the different vehicles, fuels and fuel production facilities, see figure 7.2 below.

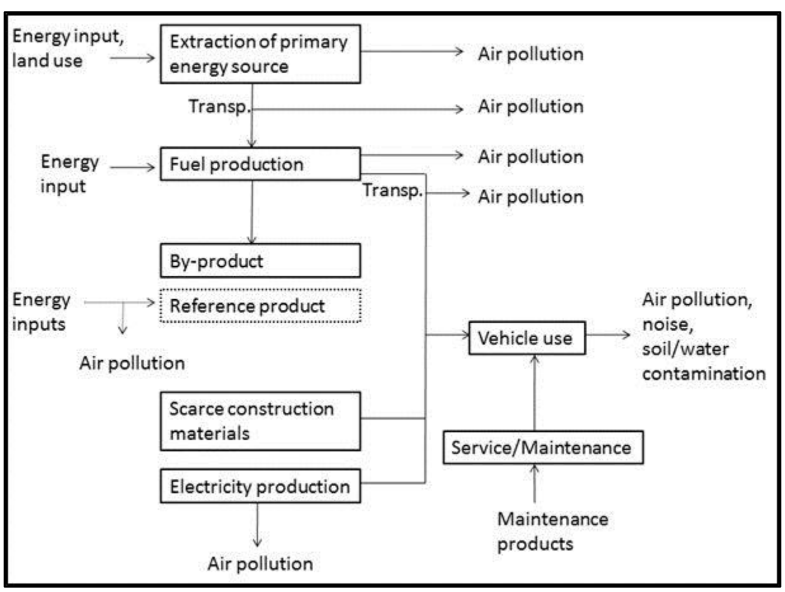


Figure 7.2: *The technical layer of Renova.*

As was noted in section 4.3.5 ‘Fuel production’ three operational stages in the fuel production chain are relevant contributors to air pollution and energy use and therefore included. The rest of the EST factors are represented by their separate box in the system. All the boxes in the system links up the vehicle use box, where the data on fuel use, driving distance, number of assignments and euro class type is collected for each vehicle. By translating this data upstream throughout the system, the impacts from all boxes can be calculated. To exemplify, by measuring the fuel consumption of a vehicle and by relating all environmentally taxing resource uses from the other parts of the system to that consumption, the total resource use of the system can be calculated. As the environmental impact of the system depends on which vehicle and fuel is used, separate calculations are needed for each vehicle type. Each calculation is described in section 7.1 below.

The logistic layer is comprised of the organization of logistic operations at Renova. Each vehicle is built to perform a specific task and to carry a specific cargo, because of that each vehicle is linked to its own logistic operations scheme. However since some logistic operations include the use of more than one vehicle type these operation schemes are interdependent and cannot be evaluated separately. As was described in 4.3.7 ‘Logistic management’, environmental load increase if logistics are not efficient. To evaluate logistic efficiency detailed information on how a vehicle is used is needed. Key information includes driving distances with and without cargo, as well as the amount of cargo. This information is not available in this project and the logistic layer will therefore be examined in a general manner by charting out the characteristics of each vehicle’s logistic patterns, which may give rise to inefficiencies. A discussion of these kinds of vehicle efficiencies and the impact will be discussed in chapter 7.3.

By calculating the EST factors from the technical system and conducting an analysis of logistic influence the first precondition of the model is met. Doing this for all the different vehicles types at Renova enables comparison, which is the second precondition. As section 6.2 showed, the current market focus is on CO_2 emissions and fuel efficiency. As the model enables calculation of CO_2 emissions and fuel consumption as well as giving the possibilities to communicate the importance of the other EST factors the model has potential to be used on the market, which was the third precondition.

7.1 Methods of evaluation

Data has been provided by Renova on vehicle specifications such as type of vehicle, type of motor, year of construction, weights, hydraulic systems, and Euro V classification, as well as quarterly data on travelled distances, number of pick-ups, and refuelling of fuels and AdBlue. The vehicles have been categorized according to vehicle group, weight class, and fuel type as the example in Figure 7.1.1 displays.

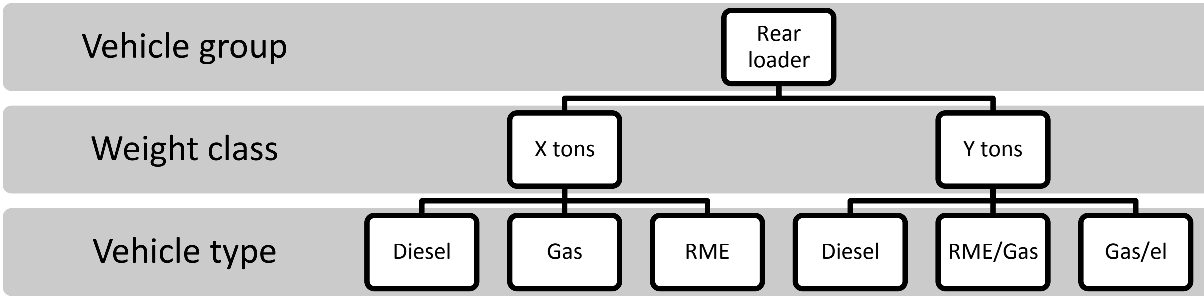


Figure 7.1.1: Categorization of vehicles. A general illustration of how the vehicles have been categorized. Note that this specific case does not correlate to the current conditions at Renova.

Average fuel consumption per kilometre has been calculated for each vehicle type based on distances and refuelling over a year for each vehicle. In cases where quarterly data is missing or corrupt, data for existing quarters have been used and modelled to represent a year, e.g. if only data for two quarters have been available, the sum has been multiplied by 2 to represent a year. The intention of categorizing the vehicles in terms of weight and fuel type is to be able to make fair comparisons between use of different fuels and technologies for vehicles operating in the same weight class.

Since the results of the evaluation model is intended to be used as a comparison between different vehicle types within the same group and weight class, the assumption that each vehicle of a certain weight class within a vehicle group performs roughly the same work over a year has been made. The result of this assumption is that it makes factors like speed, temperature, driving style, etc., that heavily effect some emissions as described in section 4.3.1, being equal for vehicles operating in the same weight class.

To be able to specify the vehicle type for vehicles using more than one fuel, apart from RME/Gas vehicles that is a bi-fuel type, categorization has been made according to the fuel that has been refuelled the most, e.g. a vehicle running on 90 % diesel and 10 % RME is categorized as a diesel vehicle. However, the use of RME will still be included in the average fuel consumption for that vehicle type.

As mentioned in chapter 3, a majority of the gas used by the vehicles at Renova is biogas through the Green Gas principle. The company has a quota of Green Gas per year that when exceeded is replaced by CNG, that in Sweden is a mixture of natural gas and biogas. This is acknowledged by calculating the total amount of gas being used over a year and the amount exceeding the quota is added as CNG in a percentage of the total amount of used gas. Therefore, over a year a gas vehicle is to a large extent running on biogas and to a smaller extent on CNG.

To be able to calculate the emissions and energy use associated with the different vehicles and fuels the energy content in the fuels has been the used as the basis for calculation. The data on energy content is taken from Naturvårdsverket (2011b) and can be seen in Table 7.1.1.

Table 7.1.1: *Energy content in fuel, expressed in MJ/l or MJ/m³ (Naturvårdsverket, 2011b)*

Diesel (MJ/l)	**Natural gas (MJ/m^3)**	**Biogas (MJ/m^3)**	**RME (MJ/l)**
35,28	39,5	35,3	33

In order to get a feeling of each vehicle type's environmental performance a vehicle representing a "typical vehicle" in each vehicle group is added to each group. This vehicle has been calculated by multiplying emissions for each vehicle type with the number of vehicles of that type. The emissions are summed for all vehicles in the group and divided with the number of vehicles operating in that group.

Also added are resulting emissions for Euro V diesel vehicles and Euro I-IV diesel vehicles in order to be able to compare differences between a new fleet of vehicles to a typical fleet of vehicles that varies in construction years.

7.1.1 Emissions from fuel combustion

Based on the energy content in the different fuels emission factor values can be used to estimate the emissions caused by a specific vehicle and fuel. The emissions will then be directly connected to the fuel consumption which can be seen as rough estimate for some of the emissions that depend on factors like speed, temperature, driving style, etc. One widely used method that considers these factors is used by NTM where speed variations depending on type of traffic (highway, rural, urban) are incorporated into the model generating more reliable results of absolute values of emissions. As NTM is proprietary it has not been able to be used here. Therefore the absolute values of the emissions will be a rough indication of a vehicle's environmental performance, while the comparison between the vehicles will be satisfactory.

Based on the recommendations from IVL (Uppenberg et al., 2001) emission factors, except for SO_X, for the different fuels have been chosen according to Blinge (1997), see table 7.1.1.1. The data behind these factors have been developed by MTC on behalf of 'Alternativbränsleutredningen' in order to obtain a fair comparison between different types of fuels and are therefore appropriate factors for the purpose of this assessment. As can be seen in the table some emission factors have not been available. The emission factor for SO_X has been calculated through sulphur content in present diesel Mk1 and can be seen in Appendix B. In table 7.1.1.1 the emission factors for diesel and natural gas represent vehicles having best available technology in 1997 while for biogas and RME factors represent vehicles constructed 1990-1996.

Table 7.1.1.1*: Emission factors from fuel combustion for heavy vehicles (Blinge, 1997). Lines represents non available data.*

Emissions to air (g/Mj)	**Diesel (BAT 1997)**	**Natural gas (BAT 1997)**	**Biogas (1990-1996)**	**RME (1990-1996)**
CO_2	73	52	0	0
SO_x *	0,00046	-	-	-
NO_x	0,72	0,17	0,0017	0,83
N_2O	0,003	-	-	-
CO	0,011	0,0017	0,0017	0,011
NMVOC	0,011	0,0042	0,0042	0,011
CH_4	0,006	0,038	0,14	-
PM	0,011	0,0017	0,0017	0,011

*Calculated emission factor, see Appendix B for calculation procedure.

Alongside the type of fuel also the type of engine affect the emissions. Emissions of CO, HC, NO_x, and PM are regulated through the Euro classification that engines need to fulfil before being sold. Since the introduction of the first Euro classification limits, the limits for regulated emissions have become more and more stringent with each new Euro class (DieselNet, 2009). As mentioned in section 3 the Euro class denomination vary among the fleet of vehicles employed at Renova and in order to get appropriate emission factors for the regulated emissions for each type of Euro class the emission factors need to be designed to fit each Euro class. By using the percentage differences between the emission limits set by the Euro standards potential differences in exhaust emissions are estimated for vehicles in different Euro classes. By knowing the construction year for the vehicles representing the emission factors in table7.1.1.1 it is possible to match them to corresponding implementation year of Euro class. The emission standards and year of implementation for heavy diesel and gas engines can be seen in Table 7.1.1.2 and Table 7.1.1.3 respectively. Figures in brackets represent the percentage change in emission limits compared to the limits for Euro I and are used later when calculating emission factors for each Euro class.

Table 7.1.1.2: *Emission standards for Euro I-VI for heavy diesel vehicles (DieselNet, 2009). Figures in brackets represent the percentage change in emission limits compared to the limits for Euro I.*

		Regulated emission (g/kWh)			
Euro class	**Year of implementation**	**CO**	**HC**	**NO_x**	**PM**
I	1992	4,5	1,1	8	0,36
II	1998	4 (-11,1%)	1,1 (0)	7 (-12,5%)	0,15 (-58,3%)
III	2000	2,1 (-53,3%)	0,66 (-40,0%)	5 (-37,5%)	0,1 (-72,2%)
IV	2005	1,5 (-66,7%)	0,46 (-58,2%)	3,5 (-56,3%)	0,02 (-94,4%)
V	2008	1,5 (-66,7%)	0,46 (-58,2%)	2 (-75,0%)	0,02 (-94,4%)
VI	2013	1,5 (-66,7%)	0,13 (-88,2%)	0,4 (-95,0%)	0,01 (-97,2%)

Table 7.1.1.3: *Emission standards for Euro III-VI for heavy gas vehicles (DieselNet, 2009). Figures in brackets represent the percentage change in emission limits compared to the limits for Euro I (Euro V for PM). Lines represents not available.*

		Regulated emissions (g/kWh)				
Euro class	**Year of implemetaion**	**CO**	**NMVOC**	**CH_4**	**NO_x**	**PM**
III	2000	5,45	0,78	1,6	5	-
IV	2005	4 (-26,6%)	0,55 (-29,5%)	1,1 (-31,3%)	3,5 (-30,0%)	-
V	2008	4 (-26,6%)	0,55 (-29,5%)	1,1 (-31,3%)	3,5 (-30,0%)	0,03
VI	2013	4 (-26,6%)	0,16 (-79,5%)	0,5 (-68,8%)	0,4 (-92,2%)	0,01 (-66,7%)

For gas vehicles the Euro classification was introduced in year 2000 (DieselNet, 2009). The first Euro class is therefore Euro III and vehicles constructed before that are not classified according to any Euro standards. Emissions of PM are not specified for Euro III-IV and therefore Euro V has been used as a basis for normalization.

The emission factors from Table 7.1.1.1 are translated into corresponding Euro classes by using the construction year of the vehicles and matching it to year of implementation of the Euro standards from Table 7.1.1.2 and Table 7.1.1.3. (e.g. if a diesel vehicle is constructed in 2001 it would be classified as a Euro III vehicle). For diesel, best available technology in year 1997 has been translated into Euro II, and for RME vehicles constructed 1990-1996 has been translated into Euro I. For natural gas and biogas vehicles the translation is less straightforward since the Euro III standard is the first standard introduced for gas engines in year 2000 (compared to BAT 1997 and vehicles constructed 1990-1996). Since there are no prior Euro classes to Euro III this has been used for both the natural gas and biogas vehicles.

In Table 7.1.1.4 the calculated emission factors for each Euro class and fuel can be seen. Emission factors for CO_2 and SO_X remain constant through the all the Euro classes since they are proportional to carbon and sulphur contents in the fuels. For diesel and RME the percentage change for HC has been used to calculate emission factors for CH_4 and NMVOC of each Euro class. The reason for this is that these emissions belong to the general term HC and that no limits are specified separately for these emissions.

Table 7.1.1.4: *Calculated emission factors per Euro class and fuel type. Lines represents not available.*

Euro I				
(g/MJ)	Diesel	NG	Biogas	RME
CO_2	73	-	-	0
SO_x	0,00046	-	-	-
NO_x	0,82286	-	-	0,83
N_2O	0,003	-	-	-
CO	0,01238	-	-	0,011
NMVOC	0,011	-	-	0,011
CH_4	0,006	-	-	-
PM	0,0264	-	-	0,011

Euro II				
(g/MJ)	Diesel	NG	Biogas	RME
CO_2	73	-	-	0
SO_x	0,00046	-	-	-
NO_x	0,72	-	-	0,72625
N_2O	0,003	-	-	-
CO	0,011	-	-	0,00978
NMVOC	0,011	-	-	0,011
CH_4	0,006	-	-	-
PM	0,011	-	-	0,004583

Euro III				
(g/MJ)	Diesel	NG	Biogas	RME
CO_2	73	52	0	0
SO_x	0,00046	-	-	-
NO_x	0,514286	0,17	0,167	0,51875
N_2O	0,003	-	-	-
CO	0,005775	0,0017	0,0017	0,005133
NMVOC	0,0066	0,0042	0,0042	0,0066
CH_4	0,0036	0,038	0,14	-
PM	0,0044	0,0017	0,0017	0,003056

Euro IV				
(g/MJ)	Diesel	NG	Biogas	RME
CO_2	73	52	0	0
SO_x	0,00046	-	-	-
NO_x	0,36	0,119	0,1169	0,363125
N_2O	0,003	-	-	-
CO	0,004125	0,001248	0,001248	0,003667
NMVOC	0,0046	0,002962	0,002962	0,0046
CH_4	0,002509	0,026125	0,09625	-
PM	0,00088	0,0017	0,0017	0,000611

Euro V				
(g/MJ)	Diesel	NG	Biogas	RME
CO_2	73	52	0	0
SO_x	0,00046	-	-	-
NO_x	0,205714	0,119	0,1169	0,2075
N_2O	0,003	-	-	-
CO	0,004125	0,00125	0,00125	0,003667
NMVOC	0,0046	0,00296	0,00296	0,0046
CH_4	0,002509	0,2613	0,09625	-
PM	0,00088	0,0017	0,0017	0,000611

Euro VI				
(g/MJ)	Diesel	NG	Biogas	RME
CO_2	73	52	0	0
SO_x	0,00046	-	-	-
NO_x	0,041143	0,0136	0,01336	0,0415
N_2O	0,003	-	-	-
CO	0,004125	0,00125	0,00125	0,003667
NMVOC	0,0013	0,0086	0,0086	0,0013
CH_4	0,000709	0,01188	0,04375	-
PM	0,00044	0,0057	0,0057	0,000306

7.1.2 Emissions of PM from road surface, tire, and breaking system wear

Emission factors for PM from wear of road surfaces, tires and breaking systems and are highly dependent on type of road surface, speed, tires, and type of breaking system. No attributes reducing the risk of these PM emissions have been found among the vehicles employed at Renova. Vehicles operating in the same class are therefore assumed to have the same levels of PM emissions since they have the same type of tires and operate on similar road surface conditions in a similar way.

7.1.3 Emissions from fuel production and distribution

Since the environmental impact from the vehicles is studied in a system perspective the emissions generated from the production of fuels are included in the assessment and added to each vehicle. The emission factors used here are recommendations from IVL (Uppenberg et al., 2001) and derived from several different sources. Factors for diesel and RME are from Blinge (1997), for natural gas from Sydkraft (2000), and for biogas from Nilsson (2000). The reason for using these factors are that the studies are of high quality from an LCA point of view and represent actual working systems or best available technology for the fuels included in this study. The factors are seen in Table 7.1.3.1 and represent grams of emitted pollutant per MJ produced fuel.

Table 7.1.3.1*: Emission factors for fuel production and distribution for heavy duty vehicles (Uppenberg et al., 2001). Lines represents not available.*

Emissions to air (g/MJ)	**Diesel**	**Natural gas**	**Biogas**	**RME**
CO_2	3,5	4,3	3,48	9
SO_x	0,019	0,0033	0,0042	0,018
NO_x	0,031	0,02	0,018	0,081
N_2O	0	0,000098	-	0,067
CO	0,002	-	0,0012	0,02
NMVOC	0,033	0,0026	0,64	0,031
CH_4	0,002	0,012	0,64	0,031
PM	0,001	0,00033	0,0016	0,002

7.1.4 Emissions from electricity production

For vehicles using electricity for propulsion and/or loading and compression emissions from electricity use come from the production and distribution of electricity. Emission factors for electricity production and distribution have been calculated from the data provided by IEA (2000) and represent the Swedish average energy mix as recommended by IVL (2009) as mentioned in section 4.3.5. The factors are seen in Table 7.1.4.1 and expressed as gram of pollutant per produced MJ of electricity. For further information on the calculation procedure of the emission factors see Appendix C.

Table 7.1.4.1*: Emission factors for electricity production and distribution, Swedish average energy mix (IEA, 2000)*

Emissions to air (g/MJ)	**Total**
CO_2	13,3777
SO_x (SO_2)	0,0852
NO_x	0,0316
N_2O	0,0008
CO	0,0122
NMVOC	0,0161
CH_4	0,0335
PM	0,0134

Energy use for electricity production is assumed to be low in comparison to the other fuels since over 90 % of the electricity in Sweden is generated through hydro- and nuclear power with low energy inputs and are therefore left out.

7.1.5 Vehicle noise

As mentioned in section 4.3.2 noise levels cannot be attributed to specific types of vehicles since they are heavily affected by local conditions such as road conditions and driving styles. Therefore vehicle noise will be treated in a qualitative manner and not quantified in absolute values. Furthermore, vehicles in the same class are assumed to have similar noise levels and are only distinguished through noise reducing attributes such as electric loading and compression, electric propulsion, and gas propulsion. Vehicles employing these techniques are marked as having less impact in this category.

7.1.6 Fossil fuel use

As mentioned in section 4.3.3 energy consumption is closely connected to the principles of sustainability and energy efficiency is an important aspect that needs to be considered. For vehicles using fossil fuels, such as diesel and the natural gas part of the fuel for gas vehicles, the fossil fuel use is expressed as MJ per kilometre.

7.1.7 Bio fuel use

Connected to use of biofuels are the aspects of energy constraints put on the production side of the fuel and is an important aspect in a sustainability perspective as described in section 4.3.3. Therefore as a measure of energy efficiency for vehicles using biofuels, such as RME and the biogas part of the fuel for gas vehicles, the biofuel use is expressed as MJ per kilometre.

7.1.8 Electricity use

The electricity used by vehicles using electric hybrid technique for lifting and compressing waste has been based on the data provided in Jensen (2004). The author has evaluated differences in energy use and fuel consumption between gas vehicles employing electrical hybrid techniques to gas vehicles that do not. Measurements of the electricity energy use for four vehicles was carried out by Jensen (2004) with the use of electrical meters installed at the parking area that was read each day and related to the amount of collected waste of that day. Since the electrical energy use is directly proportional to the amount of collected waste an average energy use (kWh/ton) was calculated from the four vehicles. This value has been translated into electricity use per pick-up since no data for collected amounts of waste has been available. The factor is based on electricity use for gas vehicles but has been used for other electric hybrid vehicles running on other fuels.

To be able to quantify the electricity use for the “Super-electric-hybrid” vehicle that uses electricity for both the operations and for propulsion at low speeds, the following calculation has been made: The difference in energy use between the “Super-electric-hybrid” vehicle and vehicles operating in the same weight class using the same fuel has been calculated. This difference is assumed to consist of the energy from electricity for operations and propulsion. The electric energy use for the operations are calculated in the same way as described above, while the remaining is assumed to be the electric energy use for propulsion.

7.1.9 Energy input during fuel production

The factors used here are recommendations from IVL (Uppenberg et al., 2001) and derived from the same sources as for emissions from fuel production as described earlier, i.e. factors for diesel and RME from Blinge (1997), for natural gas from Sydkraft (2000), and for biogas from Nilsson (2000). The factors are seen in Table 7.1.9.1.

Table 7.1.9.1: *Energy input factors for fuel production.*

Energy (MJ/MJ_f)	**Diesel**	**Natural gas**	**Biogas**	**RME**
Fossil energy	-	0,067	-	-
Renewable energy	-	0,000169	-	-
Total energy (fossil and renewable)	0,06	0,0687	0,52	0,3

7.1.10 Use of vehicle maintenance products

This category consists of vehicle maintenance products such as motor oil, hydraulic oil, spare parts, and washing products Data has not been provided for these products and can therefore not be quantified. They are assumed to be at same levels for all vehicles.

7.1.11 Use of scarce vehicle construction materials

As mentioned in section 4.3.6 the use of scarce construction materials is an issue needed to be considered. Vehicles within the same class are assumed to have the same amount of construction material except for the materials used in the batteries for vehicles using electric hybrid techniques for lifting and compression of waste and/or propulsion. The category is treated in a qualitative manner by pointing out vehicle types using electricity, thereby being potential carriers of scarce construction materials in the batteries.

7.1.12 Land use for bio-fuel production

For the production of RME growing and harvesting of rapeseed is needed. For vehicle types using RME the corresponding land needed for growing the rapeseed will be expressed as hectare per year. Additionally, the share of land that this corresponds to in relation to available land for growing rapeseed will also be expressed. Data for available land for rapeseed growing and land efficiency are derived from Börjesson (2007a) and seen in Table 7.1.12.1

Table 7.1.12.1*: Land efficiency for growing rapeseed in the south of Gothia, and Swedish land availability for growing rapeseed for RME production (Börjesson, 2007a).*

Land efficiency (MJ/ha,year)	**Land availability (ha)**
35 000	80 000

7.1.13 Soil and water contamination

As mentioned in section 4.3.6 soil and water contamination are caused by runoff of various contaminating substances. The impacts are assessed in a qualitative manner by addressing vehicles having attributes that reduce the risk for spills and leakages of hazardous substances as having less impact in this category. Use of RME and/or gas is preferable in this sense since RME is biodegradable and leakage of gas gets airborne. Vehicles equipped with hydraulic systems using water instead of oil are also seen as preferable since it reduces the risk for oil spills.

7.1.14 Environmental intrusion and barrier effect

These issues are, as mentioned in section 4.3.6, related to increasing traffic volumes causing less accessibility between areas and intrusion of natural habitats. One rough way of expressing the amount of traffic generated by a fleet of vehicles is to calculate the vehicle-kilometer incurred by the fleet over a year. The less vehicle-kilometer a vehicle type has the less impact the type has in this category. The actual impact will thereby not be determined, instead vehicle-kilometers is used as an indicator of a vehicle type's impact in this category.

7.2 Developing software tool

As requested by Renova, results from the model should be updateable if vehicles and fuels are changed in the future, it should also be easy to compare vehicle types and possibly relate the environmental efficiency to rest of the market. To do this, the technical layer of the model was coded into Excel. The influence of the logistic layer is not included in the Excel tool as Renova is mainly interested in technical comparisons. The use of Excel is appropriate since Excel is widely used and because new data from Renova's internal database is easily extracted into it. The tool consists of several Excel sheets. First there is one master back-end sheet where all calculations for the quantitative EST factors are made. The master sheet bases its calculations on the calculation factors describes in section 7.1 above, which are coded into a separate sheet. The calculations rely on nine inputs from the user on each vehicle type; number of vehicles, fuel and electricity consumption, AdBlue consumption, distance travelled, number of assignments and finally the number of vehicles in each Euro class, see figure 7.2.1. Consumption, distance and assignments are entered as averages per quarter. Average values are automatically calculated from user inputs to represent an average weight class, which is later used for comparison purposes. The inputs representing the current situation at Renova have been extracted from the company's internal database as describe in section 7.1, and have been entered as initial values. The input and the calculation factors can later be changed in order to supply Renova with new results if the situation changes.

The results for each vehicle group are presented on separate sheets, which represent the EST framework table 6.1. The result sheets give the user the option of choosing what weight class and air emissions to be displayed and then displays the quantitative factors in numbers as well as bar charts for each part of the system. If the weight class ‘All’ is selected, the automatically calculated average weight class is used. Results are displayed per km and per assignment, in grams for air pollution and in mega joules for energy. The information on the result sheets are linked to master calculation sheet, if the user changes any input data the information is updated accordingly. The qualitative factors are evaluated in text and tables and displayed to the right of the quantitative results, see figure 7.2.2. The qualitative evaluation picks up on differences between the vehicle types as described in section 7.1.

The air pollution part of the results sheets also include separate values for diesel Euro I-IV and Euro V where applicable, this by request from Renova. As Euro I-IV diesel vehicles are commonly used by other companies on the waste management market, and because Renova employs a large amount of Euro V vehicles, the separate values can be seen as references to position Renova in relation to other companies. The results also include separate “typical vehicle” results, which are calculations on the combined emissions and fuel use by all vehicles within a vehicle group, averaged on the number vehicles in the group. The resulting values reflect the environmental efficiency of a typical vehicle within the vehicle group, irrespective of weight class or fuel.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Fordonstyp		Antal fordon	Tankad mängd					Körda km	Utförda uppdrag	Euroklasser					
2				Diesel	Gas	RME	El	AdBlue			Euro I	Euro II	Euro III	Euro IV	Euro V	Euro VI
3			st	l/kvartal	m3/kvartal	l/kvartal	kWh/kvartal	l/kvartal	km/kvartal	st/kvartal	st	st	st	st	st	st
115																
116	Baklastare															
117	X ton	Diesel	7	1000				1000	5000	2000	1	2	3	4	5	6
118		Gas	6		1000				5000	2000	1	2	3	4	5	6
119		Gas/el	5		1000		1000		5000	2000	1	2	3	4	5	6
120		RME/Gas	4			1000			5000	2000	1	2	3	4	5	6
121		RME/Gas/El	3		1000	1000	1000		5000	2000	1	2	3	4	5	6
122		RME	2			1000		1000	5000	2000	1	2	3	4	5	6
123		Superelhybrid	1	1000			1000		5000	2000	1	2	3	4	5	6
124																
125	Y ton	Diesel	7	1000				1000	5000	2000	1	2	3	4	5	6
126		Gas	6		1000				5000	2000	1	2	3	4	5	6
127		Gas/el	5		1000		1000		5000	2000	1	2	3	4	5	6
128		RME/Gas	4			1000			5000	2000	1	2	3	4	5	6
129		RME/Gas/El	3		1000	1000	1000		5000	2000	1	2	3	4	5	6
130		RME	2			1000		1000	5000	2000	1	2	3	4	5	6
131		Superelhybrid	1	1000			1000		5000	2000	1	2	3	4	5	6
132																
133	Z ton	Diesel	7	1000				1000	5000	2000	1	2	3	4	5	6
134		Gas	6		1000				5000	2000	1	2	3	4	5	6
135		Gas/el	5		1000		1000		5000	2000	1	2	3	4	5	6
136		RME/Gas	4			1000			5000	2000	1	2	3	4	5	6
137		RME/Gas/El	3		1000	1000	1000		5000	2000	1	2	3	4	5	6
138		RME	2			1000		1000	5000	2000	1	2	3	4	5	6
139		Superelhybrid	1	1000			1000		5000	2000	1	2	3	4	5	6
140																
141	Medel	Diesel	7	1000				1000	5000	2000	1	2	3	4	5	6
142		Gas	6		1000				5000	2000	1	2	3	4	5	6
143		Gas/el	5		1000		1000		5000	2000	1	2	3	4	5	6
144		RME/Gas	4			1000			5000	2000	1	2	3	4	5	6
145		RME/Gas/El	3		1000	1000	1000		5000	2000	1	2	3	4	5	6
146		RME	2			1000		1000	5000	2000	1	2	3	4	5	6
147		Superelhybrid	1	1000			1000		5000	2000	1	2	3	4	5	6

Figure 7.2.1: *The inputs needed from the user in order to perform calculations. Note that this specific case does not correlate to the current conditions at Renova.*

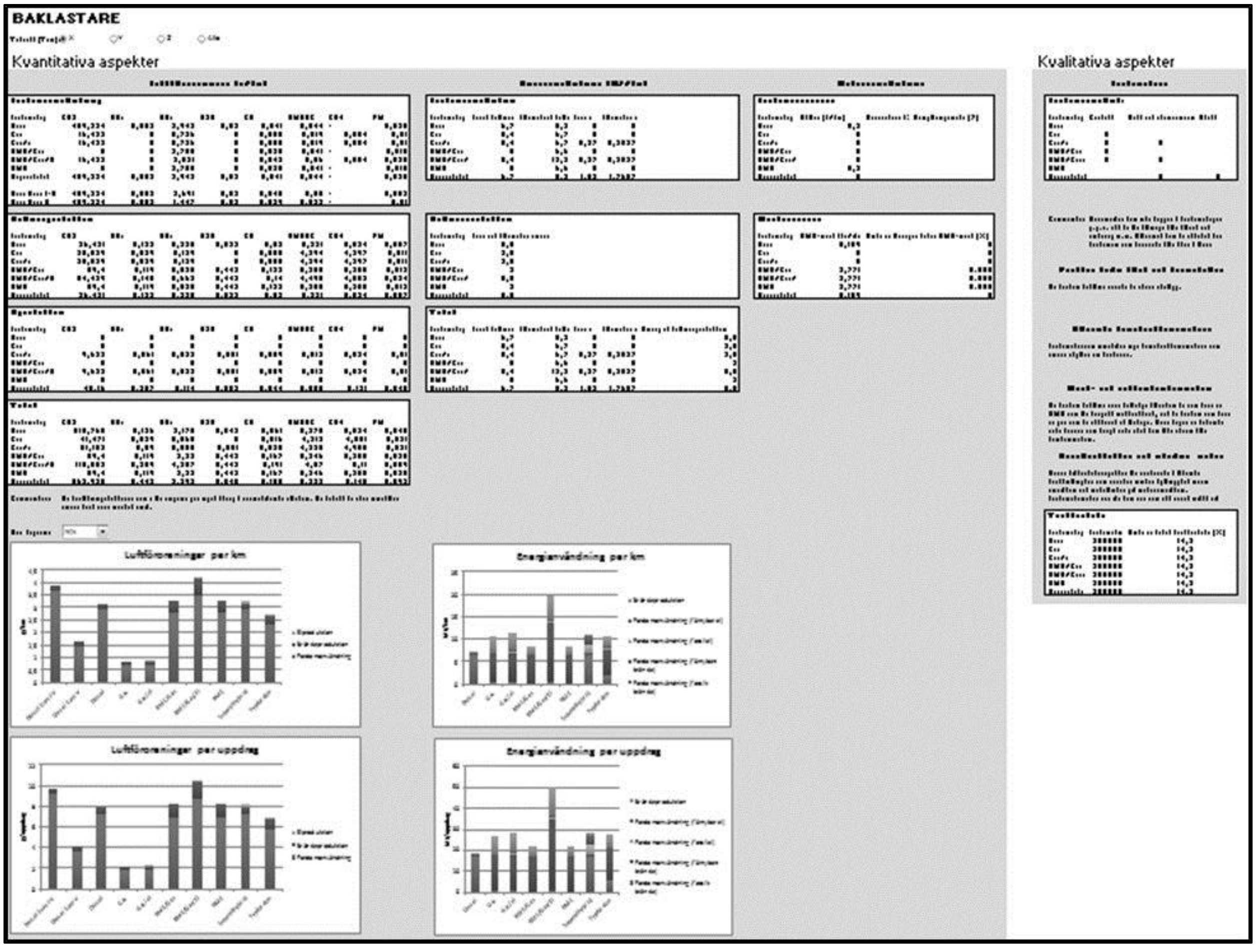


Figure 7.2.2: *View of a results sheet. The left hand side displays quantitative results and the right hand side the qualitative results. Note that this specific case does not correlate to the current conditions at Renova.*

7.3 Influence of logistic efficiency

Since the input to the model is mainly fuel consumption and driving distance, it is relevant to study how logistic operations affect the input, and ultimately the output values. As described in chapter 3, there are basically three types of operations at Renova; Pick-up/Drop-off, 'Milk round pick-up'/Drop-off and Pick-up/'Milk round drop-off'. Each of them can be performed several times a day or only once depending on vehicle type. The transport types can schematically be represented by CCU/distance plots, see figure 7.3. As can be seen the general operation of all vehicles can be divided into five steps; an initial empty positioning trip, an instant or a milk round pick-up, a fixed CCU transport trip, an instant or a milk round drop-off and finally another empty positioning trip. The theoretical ideal for a transport operation is that the CCU is 100% along the entire trip in order not to use a vehicle more than necessary, which would correspond to entirely filled charts in figure 7.3. With the same reasoning, empty space can be seen as inefficiencies and non-value adding contribution to the EST factors, which should be avoided.

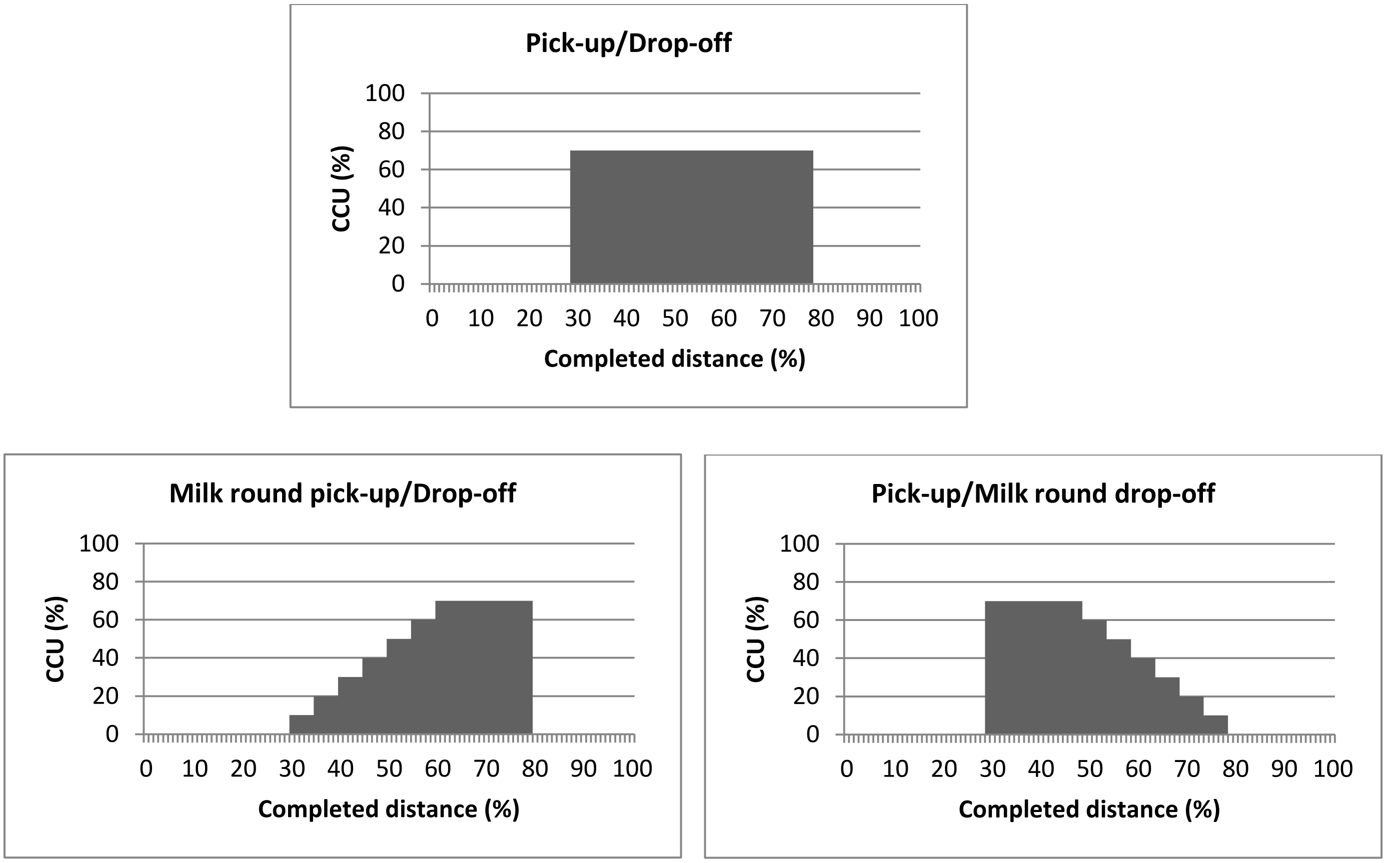


Figure 7.3: *Schematic view of the transport types at Renova. The x-axis shows share of distance completed on route, the y-axis shows CCU. Note that this specific case does not correlate to the current conditions at Renova.*

When studying each vehicle operation it can be noted they are subjected to individual logistic constraints that make it more or less difficult to reach a high level of efficiency. Two major groups can be distinguished; the vehicles performing milk round pick-ups and the ones performing pick-ups/drop-offs. Vehicles performing milk round pick-ups have a fixed but often high number of stops independent of the amount of waste to be collected at the stop, which makes it difficult to reach a high CCU. Each stop involves braking until standstill, idling while performing operations, and acceleration from standstill. Compared to free flowing traffic, this stop-and-go pattern uses more energy and is likely to generate increased noise impact if operating in residential areas. The advantage of the milk round is that the route may be well planned so that the total driving distances as well as positioning trips are minimised. Instant pick-ups have the opposite problem to milk rounds, as vehicles performing such operations are on-call to pick up waste containers when full, meaning high CCU and generally fewer stops but instead longer empty positioning trips. The conclusion is that high CCU should be the focus of milk round pick-ups and that route planning should be the focus of instant pick-ups/drop-offs.

Furthermore there are two type of constraints related to cargo and cargo containers. The first is related to the fact that each vehicle is designed for a specific cargo type. Vehicles carrying bulky or hard to collect cargo is likely to be restricted by the volume capacity of the vehicle and not weight. In such cases the cargo could be transported with a smaller vehicle or container if the cargo was compressed or stored more efficiently. The other aspect related to cargo containers is that heavy containers are limited to vehicles performing pick-up/drop-off operations. Lighter containers can be handled by either front loaders or heavy rear loaders if the cargo is suitable, enabling several containers to be emptied without going to an emptying station in-between. In both cases managing how the cargo is stored should be in focus so that the right vehicle is able to pick it up and transport it in an efficient way.

8. Evaluation of model

This section describes the evaluation of the model with the purpose of defining its robustness.

8.1 Sensitivity of model

Because the model inputs are partly based on assumptions there are uncertainties in the quantitative model results. It is therefore relevant to examine how sensitive the results are to the assumptions. The final quantitative model results can be seen as multiples of the user inputs, where emissions factors for each Euro class work as the multipliers. As a result, quality of input data and assignment of vehicle Euro classes is of great importance for the output.

Regarding the first issue of data quality one aspect is input variation. It originates from the assumption that each vehicle of a certain weight class within a vehicle group performs roughly the same work over a year. As a consequence the fuel efficiency within each vehicle type should theoretically be the same. Slight variations in work may exist however as well as differences in driving styles and other specific conditions that cause variation in fuel efficiency. The model uses average values for fuel efficiency based on calculations described in section 7.1. Since all quantitative results follow from these averages it is of interest to know their variation. By calculating the standard deviation on fuel efficiency for each vehicle type that includes several vehicles, the precisions of the pre-entered user input data can be estimated.

The average value of deviation for all vehicle types in a vehicle group is presented in figure 8.1 below. The values are given in percentage, in the form of standard deviation over average fuel consumption, meaning that all subsequent calculations will have the same standard deviation. As can be noted eight out of eleven vehicle groups are represented. The average value of 10% can be seen as a rough estimate for all vehicle groups as the missing groups have similarities to ones that are represented, for example the Pick-up is very similar to the Van in operation and characteristics and should therefore have similar standard deviation of input data. The deviations do not compromise the comparability of results but should be noted.

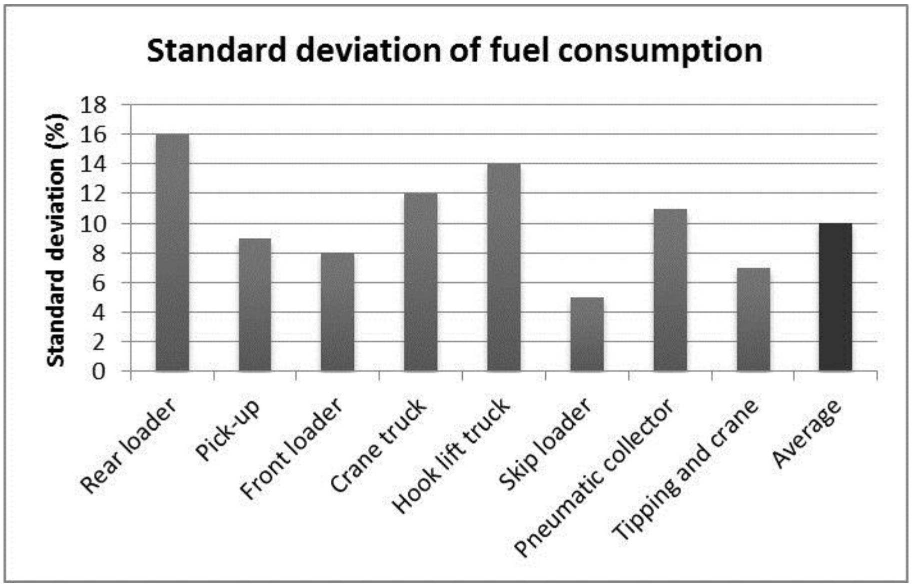


Figure 8.1: *Standard deviation in fuel consumption between different vehicle types, averaged together for each vehicle group.*

Beyond fuel efficiency variation, assumptions have been made regarding vehicle electricity use described in section 7.1. Electricity have strong influence on air pollution in the form of PM, CO, and SO_X from electricity production facilities, giving vehicles using electricity a disadvantage in comparison. As there are no means to evaluate how close the approximation of electricity consumption is, it is strongly recommended that measurements are performed on all relevant vehicles.

Regarding the second issue, the Euro class designation of vehicles below Euro V is unknown and assumed to match the construction year of each vehicle as described in section 7.1. This creates a problem since vehicles constructed the year before a new Euro standard is implemented might be fitted with engines already compliant with a new upcoming Euro class. In Renova’s case it can be attributed to nine vehicles constructed in 1999 and 2004. By assigning the vehicles with a level higher than the original assumption, and by doing so creating a best-case scenario, the differences in emissions levels can be studied. Results show that emission levels were lowered roughly 5-15% on average for regulated emissions for the vehicle types affected. The change is small enough not to alter the comparison between vehicles but shows that Euro class designation is indeed important. It is therefore recommended that information on actual Euro classification is collected.

8.2 Reliability of model

The quality of the provided data, the factors used and assumptions made along the development of the evaluation model will affect the results and will be further investigated in this section. Most focus will be put upon the factors affecting the reliability of the quantitative categories since these are more sensitive to data quality, calculation factors, and assumptions. However, factors affecting the reliability of the qualitative categories will be considered as well.

Concerning the input data is the is the fact that the operations of lifting, compressing, tipping, etc and idling driving are incorporated into the provided data of the fuel consumption for each vehicle. By incorporating them into the data the calculation of fuel consumption per kilometre for vehicles doing many operations and running at idle at long periods will be slightly misleading. Since the emissions are directly connected to the fuel consumption also the absolute values of the emissions will be affected. To be able to make an evaluation where the result for those vehicles are more reliable, energy consumption for the operations and at idle need to be quantified and emission factors need to be established for those operations. This has not been able to be done here since data have not been available neither for the operations nor at idle. However, this is assumed to have little influence on the comparison between vehicles operating in the same class since they are operating in the same way. For vehicles operating more like a normal truck, having few operations and less idle-time, the calculations and emission factors still hold making absolute values of the results more reliable.

Construction year of each vehicle has been used and translated into a Euro class depending on the year of implementation of the standard as explained in section 7.1 and analysed in section 8.1. In order to be sure that right Euro class is chosen for each vehicle, this should be further investigated since the results of regulated emissions then will be more accurate and reliable.

In the development process of the evaluation model the assumption was made that the output of emission from different Euro classes differ corresponding to the differences in emission limits set by the Euro standards. By investigating the differences in result between vehicles in different Euro classes from the online emission calculator EcoTransIT this assumption will be tested. The emission calculator calculates different emission factors depending on road categories and topography differences making the result more authentic than using set factors. Therefore a comparison will show the reliability of making the assumption described above. In EcoTransIT five calculations have been made, one for each Euro class, keeping all other data inputs constant. Percentage changes of the regulated emissions of NO_X, NMVOC, and PM for each Euro class compared to Euro I have been calculated in the same way as in section 7.1. Emissions of CO and CH_4 are not included in the EcoTransIT calculation and can therefore not be compared. The results seen in table 8.2 are the percentage changes calculated from both the EcoTransIT results and the calculations made for the evaluation model in section 7.1.

Table 8.2: *Comparison of Euro class percentage changes from Euro I for EcoTransIT and evaluation model.*

Euro class	**NO_X**		**NMVOC**		**PM**	
	EcoTransIT	Model	EcoTransIT	Model (HC)	EcoTransIT	Model
I	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
II	+5%	-12,5%	-50,0%	0	-40,0%	-58,3%
III	-22,0%	-37,5%	-50,0%	-40,0%	-50,0%	-72,2%
IV	-59,0%	-56,3%	-95,0%	-58,2%	-90,0%	-94,4%
V	-75%	-75,0%	-95,0%	-58,2%	-90,0%	-94,4%

As can be seen, the values in table 8.2 are fairly good for NO_X and PM while for NMVOC there are quite large differences. The results show that for NO_X and PM the assumption made to be able to distinguish emission factors for each Euro class can be seen as satisfactory while for NMVOC it did not meet the requirements. This indicates that the percentage changes for HC do not translate to the changes for NMVOC which was assumed. The impact that the incorrect assumption has on the results for absolute emissions of NMVOC is that they might be higher than they actually are, which is more preferable than underestimating the emissions. If this also is the case for exhaust emissions of CH_4 which was calculated in the same way cannot be answered since no data for comparison has been available. How well the assumption holds for CO cannot be answered either since the emission was not included in the EcoTransIT calculation. As a result, the resulting absolute values for emissions of NO_X and PM can be seen as reliable, while for NMVOC, CH_4, and CO they should be treated with caution. However, in relative terms the resulting values for all the regulated emissions can still be used as a basis for the comparison between vehicle types. In absence of incorporated simulation models for topography, traffic flows, etc. the assumption that the differences in exhaust emissions for different Euro classes correspond to the differences in emission limits set by the Euro standards can therefore be seen as a fairly good assumptions.

Another aspect that needs consideration is the assumption made in the electric energy use calculations for the Super-electric-hybrid vehicle. The assumption that the vehicle uses the same amount of energy as vehicles in the same weight class is a rough generalization since the aspect differences in energy efficiencies due to different engines are neglected. Data for travelled distances and efficiencies of the engines would be needed in order to get more reliable results. Since electric engines in general are assumed to be more energy efficient than diesel or gas engines the model assumption disfavours the Super-electric-hybrid in terms of energy consumption.

As mentioned before some of the emissions depend on aspects like speed, temperature, driving style, etc, and by using emission factors these aspects are disregarded. This reduces the reliability of the absolute values of the emissions while the comparison between vehicles operating in the same weight class still holds since they are assumed to perform in the same way. In absence of simulation models for differences in topography, traffic flows, etc. the use of set emission factors is a common way of expressing emissions for vehicles. The reliability of the sources for emission factors are therefore more interesting to evaluate. As described in section 7.1 the emission factors are chosen in line with the recommendations of IVL (Uppenberg et al., 2001), which can be seen as a reliable source of information. Furthermore, the factors are developed in order to obtain a fair comparison between different types of fuels for a vehicle and are therefore appropriate factors for the purpose of this assessment.

Emission and energy factors for fuel production are also based on the recommendations from IVL (Uppenberg et al., 2001) and collected from different sources. The reason for using these sources is that they have based their factors on data representing real production conditions for the fuels included in this study. A commonly used source of information for emissions and energy factors for production of vehicle fuels are the JEC reports as explained in section 4.3.5. The reason for not choosing factors from these sources is that they are not representing the actual conditions of the fuels that are included in this study. Furthermore, factors are only provided for the green house gases (CO_2, CH_4 and N_2O) and energy while the scope of this study includes aspects for additional environmental aspects beside global warming and energy consumption.

Some of the factors influencing the categories in the EST model have been dealt with in a qualitative manner. Instead of trying to evaluate these factors in a quantitative way by making assumptions, they are treated in a qualitative way by pointing out attributes that could either reduce or enhance the environmental impacts. The chosen attributes that the evaluation model considers are straightforward aspects such as hydraulic systems using water instead of oil reduces the risk of oil spills, or that electric motors/engines reduces noise compared to diesel engines. The chosen attributes are based on logical and scientifically basis and are therefore seen as reliable.

To conclude this section, the results are recommended to be used more as a comparison of the efficiencies between the vehicles within the company than as a base for comparison of absolute values to other companies. The more operations and idle time a vehicle has the less reliable and comparable the absolute values of the results are. For some vehicles, those operating more like a conventional truck, also the absolute values are considered as reliable and comparable to other companies.

To further increase the reliability and comparability of the results energy use during the operations and at idle need to be measured and quantified. To get more accurate results, especially for the regulated emissions, the NTM method is recommended since it is a proven and accepted method that incorporates simulation models that consider speed variations depending on type of traffic (highway, rural, urban) generating more reliable results of absolute values of emissions. For the Super-electric-hybrid vehicle data for travelled distances and efficiencies of the engines would be needed in order to get more reliable results of the electric energy consumption.

8.3 Model usefulness on market

As the market survey shows, information on CO_2 emissions from fuel combustion and fuel consumption is relevant to communicate to the market. Based on the reliability analysis in section 8.2 the model can successfully be used to communicate this information in relative terms between the different vehicle types of Renova. Absolute values should not be used mainly because vehicle operations are built into the fuel consumption data, which gives higher values than the actual case. Vehicle combustion emissions of CO_2, SO_X and NO_X are deemed most reliable, especially for those vehicles closely resembling ordinary trucks such as the Pick-up and Van. The implementation of displaying separate emission values for Euro I-IV enables theoretical comparison of Renova's efficiency to other companies. The comparison is heavily reliant on that the market indeed operate within those Euro classes, and that the vehicles of Renova that constitute Euro I-IV perform the same work with the same efficiency as other companies. As the market survey to shows that the market only identifies a portion of the EST factors, the model can also be thought of as a mean to communicate a wider context of sustainability and expand the possibilities for marketing. Even though the qualitative evaluation cannot provide measurements it identifies vehicle properties that decrease contribution to the EST framework. As such it can be used to strengthen Renova's position.

In relation to connecting the model results to services, the model lends itself to providing statistics on CO_2 and energy use over periods of time, as well as to be a base for carbon compensation services. Because the model provides relative results other services should be based on comparisons within Renova, such as providing customers with option of buying into waste transport capacity of a certain vehicle type. This holds true for both qualitative and quantitative EST factors. Furthermore, by expanding the view on sustainability the potential for these kinds of services increase as the characteristics of the different vehicles at Renova affects the EST factors differently. With the same reasoning the model could be the basis for a number of environmental profiling services such as certificates and environmental labelling of containers at pick up sites that strengthen both the profile of Renova and customers.

The fact that vehicle operations and CCUs are incorporated into the data of the fuel consumption limits the comparability to other companies and the usefulness of the model as a market tool. A common way of communicating a vehicle's environmental performance is to express it per kilometre or per tonne and kilometre of a running vehicle. Expressing results per tonne and kilometre also gives information on logistic efficiency which is important for credibility. CCU information would also mean the possibility of communicating environmental load per tonne of waste, putting focus on the fact that reducing waste itself is valuable for sustainability and also promoting waste management at customers, such as choosing appropriate sized containers etc.

9 Conclusions

The purpose of this thesis was to investigate the concept of environmental sustainability in relation to transports, to investigate how the concept is used on the current market, and to develop an evaluation model for the concept that will aid Renova in their efforts to further their environmental work. The model should guide Renova in knowing which environmental issues of sustainability that are of importance, and enable them to compare their vehicles in respect to those issues. The model was to be designed as a software tool that enables Renova to perform updates of the comparisons in case the conditions surrounding their transport activities change in the future. The tool was also to be designed in such a way that results can be communicated on the waste management market. To fulfil the purpose, a series of objectives were completed to answer the following research questions:

- What defines environmental sustainable transports and which factors causing environmental impacts are of most importance?
- What is the market view on environmental sustainability and are the methods of assessment used in industry today in line with the research of the field?
- How can literature on environmental sustainable transports be translated and applied in order to develop the environmental performance of a specific company like Renova?

The following paragraphs describe how the questions have been answered and what conclusions can be made. They also conclude how the thesis has contributed to current knowledge and possibilities for future developments of results.

The first question has been answered through an extensive literature review in the field of EST and by pinpointing the most important environmental aspects connected to it. Through acknowledging the principles of sustainability the work resulted in a new framework for EST seen in table 9.1. The framework can be seen as a definition of what aspects are needed in order to assess transport activities from an EST point of view.

Table 9.1: *The EST framework. The categories and their respective factors having negative impact on the environmental sustainability of transports.*

Air pollution	**Noise**	**Energy constraints**	**Material constraints**	**Ecosystem vitality**
Emissions from vehicle combustion	Vehicle noise	Fossil fuel use	Use of vehicle maintenance products	Soil and water contamination
Emissions of vehicle tyre particles		Bio fuel use	Use of scarce vehicle construction materials	Environmental intrusion
Emissions from fuel production		Electricity use	Land use for bio fuel production	Barrier effect
Emissions from electricity production		Energy use during fuel production		

The second question was answered by analysing the current situation of the logistic and waste management markets in terms of their view on sustainability and how they assess the environmental impacts of their transport activities. The first conclusion is that the current market view of sustainability is limited to mostly CO_2 emissions and vehicle fuel use. Consequently, industry methods of assessing environmental impact from transport activities are limited to these aspects. The second conclusion is therefore that current methods of environmental assessment used in industry today are not in line with research of the field.

The third question has been answered through the work made in chapter 6 and 7. It can be concluded that by using the framework of EST as a base and applying an LCA like approach for the environmental assessment, a model for evaluating EST can be developed. As described in chapter 7 the EST framework is affected by both technical and logistic efficiency, which can be symbolised as a three layered structure with the EST framework at the bottom being affected by a technical and a logistic layer lying above it. The technical layer was defined for Renova and methods for evaluation of aspects contributing to the EST framework were established in section 7.1. As a result an operational Excel tool for the technical layer has been developed evaluating the EST factors. In addition aspects on how the logistic layer affects results were discussed in section 7.3.

The results of the thesis have contributed to the concretisation of EST aspects raised by different bodies of information by converting the aspects into an operational model for EST evaluation. The current market view of EST has through the work of this thesis been expanded by acknowledging the principles of sustainability and taking a system approach. The results have also updated the view of the current situation on the waste management and transport industry markets.

Regarding future potentials to develop the results, the thesis has made a comprehensive investigation of the technical layer of transports for a waste management company like Renova, however the logistic layer has been examined in a more general manner. To improve the EST evaluation model it is relevant is to investigate the logistic layer more thoroughly, which is a prospect of future research. By defining factors like freight cargo weight and cargo capacity utilization it would be possible to express environmental impacts per tonne kilometre which is relevant for more details on logistic efficiency.

Through the work of this thesis answers to the research questions have been answered and the aim of the thesis is seen as fulfilled. The evaluation model has been developed into an operational Excel tool assessing all the heavy vehicles employed by Renova, from an EST perspective. By using the model as recommended there are possibilities for Renova to offer alternate environmentally preferable services to customers.

10 Recommendations to Renova

In order to get the right emission factors for the exhaust emissions, the Euro class designation is important. It is therefore recommended that information on actual Euro classification is collected, as they are now partly based on assumptions.

In order to further improve the output of the evaluation model there are some important aspects that may be considered. Firstly, energy use during operations and at idle need to be measured and quantified in order to separate the emissions related to operations from the ones generated from propulsion. Secondly, as there are no means to evaluate how good the approximation of electricity consumption is, it is strongly recommended that measurements be performed on all relevant vehicles. In order to increase the accuracy of the results in emissions and energy use for the Super-electric-hybrid, it is recommended to measure the distance, time, and electricity consumption of the vehicle when using the electric engine.

To increase the reliability and usefulness as well as comparability of the evaluation model, it is recommended to measure cargo capacity utilization to be able to express the emissions and energy consumption per ton or ton kilometre. This would enable a more thorough understanding of logistic efficiency and may open up new ways of communicating the environmental performance of operations.

It is necessary to point out once again that results are recommended to be used as comparisons of environmental efficiency between vehicles of Renova, and that absolute values are to be used with caution. If more accurate results are needed, especially for the regulated emissions, the NTM method is recommended since it is a proven and accepted method that incorporates simulation models to generate reliable emission factors. Furthermore if comparisons are made through the use of the separate emission values for Euro I-V vehicles, as a representation of the market, it is heavily reliant on that the market indeed operates within those Euro classes and performs the same work at the same efficiency as Renova.

To further improve the business potential of company transports, the logistic industry may be seen as a guide since it is profiled solely on those issues. By involving customers in the planning of the transport set-up, as is being done with the waste management side of the business, customers can affect the outcome of transport activities. Doing so enables Renova to incorporate transports as a more profiled business alongside the business of waste management. Selling cargo capacity of certain vehicles much like the principles of “Green electricity” or “Green gas” may be appropriate, and is supported by the model.

Lastly, since logistic management can be a powerful measure to influence the environmental performance of transport operations it is strongly recommended to keep work between divisions of environment and logistics closely integrated. Doing so improves the potential to gain further insight into the environmental benefits of intelligent and efficient logistics.

11 References

Althaus, H.-J., de Haan, P. & Scholz, R.W., 2009. Traffic noise in LCA Part 2: Analysis of existing methods and proposition of a new framework for consistent, context-sensitive LCI modeling of road transport noise emission. *International Journal of Lice Cycle Assessment*, 14(7), pp.676-86.

Alvfors, P. et al., 2010. *Research and development challenges for Swedish biofuels actors - three illustrative examples*. Gothenburg: Svenskt kunskapscentrum för förnybara drivmedel f3.

Aronsson, H. & Huge Brodin, M., 2006. The environmental impact of changing logistics structures. *The International Journal of Logistics Management*, 17(3), pp.394-415.

Beatley, T., 1995. The Many Meanings of Sustainability. *Journal of Planning Literature*, 9(4), pp.339-42.

Behrends, S., Lindholm, M. & Woxenius, J., 2008. The Impact of Urban Freight Transport: A Definition of Sustainability from an Actor's Perspective. *Transportation Planning and Technology*, 31(6), pp.693-713.

Belhaj, M. & Fridell, E., 2008. *External costs in the transport sector: A literature review*. Report. Gothenburg: IVL Swedish Environmental Research Institute.

Black, W.R., 1996. Sustainable transportation: a US perspective. *Journal of Transport Gegraphy*, 4(3), pp.151-59.

Blinge, M. et al., 1997. *Livscykelanalys (LCA) av drivmedel*. KFB-report 1997:5. Stockholm: Svenska Kommunikationsforskningsberedningen.

Börjesson, P., 2007a. *Förädling och avsättning av jordbruksbaserade biobränslen*. Report. Lund: University of Lund Environmental and Energy Systems Studies.

Börjesson, P., 2007b. *Produktionsförutsättningar för biobränslen inom svenskt jordbruk*. Report. Lund: University of Lund Environmental and Energy Systems Studies.

Börjesson, P. et al., 2008. *Hållbara drivmedel - finns de?* Report. Lund: Lund University Environmental and Energy Systems Studies.

Börjesson, P., Tufvesson, L. & Lantz, M., 2010. *Livscykelanalys av svenska biodrivmedel*. Lund: Lunds Tekniska Högskola Institutionen för teknik och samhälle.

Brambilla, G., 2001. Measurement techniques for transport noise. *Radiation protection dosimetry*, 97(4), pp.433-36.

Chapman, L., 2006. Transport and climate change: a review. *Journal of Transport Geography*, 15(5), pp.354 - 367.

Chapman, L., 2007. Transport and climate change. *Journal of Transport Geography*, (15), pp.354-67.

Dachser, 2011b. *Sustainability*. [Online] Available at: http://www.dachser.com/de/en/sustainability.htm [Accessed 07 April 2011].

Dachser, 2011c. *Dachser becomes DIN environmental expert*. [Online] Available at: http://www.dachser.com/de/en/environment_expert.htm [Accessed 08 April 2011].

Dachser, 2011d. *Miljöpolicy*. [Online] Available at: http://www.dachser.se/C12572DF00276493/CurrentBaseLink/W285SEU2137LNTTSV [Accessed 06 April 2011].

Dachser, 2011. *Facts*. [Online] Available at: http://www.dachser.com/de/en/facts.htm [Accessed 07 April 2011].

DB Schenker, 2010. *DB Schenkers Emission Report*. [Online] Available at: http://www.schenker.se/upload/attachments/1113/111325/manual_EmissionReport_ver1.pdf [Accessed 30 March 2011].

DB Schenker, 2011. *Miljö/Emissioner*. [Online] Available at: http://www.schenker.se/servlet/se.ementor.econgero.servlet.presentation.Main?data.node.id=23428&data.language.id=1 [Accessed 30 March 2011].

den Boer, E., Brouwer, F., Schroten, A. & van Essen, H., 2009. *Are trucks taking their toll?* Report. Delft: CE Delft.

Deutsche Bahn AG, 2009 b. *On track for tomorrow. DB's Mission Statement.* [Online] Available at: http://www.dbschenker.com/site/shared/en/file__attachements/information__material/konzernleitbild.pdf [Accessed 30 March 2011].

Deutsche Bahn AG, 2009 c. *Environmental Goals*. [Online] Available at: http://www.dbschenker.com/site/logistics/dbschenker/com/en/environmental/guidelines/environmental__goals/environmental__goals.html [Accessed 30 March 2011].

Deutsche Bahn AG, 2009. *Principles of Sustainability*. [Online] Available at: http://www.dbschenker.com/site/logistics/dbschenker/com/en/environmental/guidelines/principles/principles.html [Accessed 30 March 2011].

Deutsche Bahn AG, 2010. *Profile*. [Online] Available at: http://www.dbschenker.com/site/logistics/dbschenker/com/en/about__dbschenker/profile/profile.html [Accessed 30 March 2011].

Deutsche Post DHL, 2011. *GoGreen*. [Online] Available at: http://www.dpdhl-gogreen.com/go/ [Accessed 29 March 2011].

DHL DP, 2010. *Sustainability Report 2009*. DHL DP.

DHL Express, 2010b. *DHL Express Serviceguide*. [Online] Available at: http://www.dhl.se/content/dam/downloads/se/express/se/downloadcenter/dhl_express_serviceguide_513050_100901.pdf [Accessed 29 March 2011].

DHL Express, 2011. *Gröna Ton*. [Online] Available at: http://www.dhl.se/content/dam/downloads/se/logistics/se/grona_ton_se.pdf [Accessed 29 March 2011].

DHL, 2011b. *DHL Packstation*. [Online] Available at: http://www.dhl.de/en/paket/privatkunden/packstation.html [Accessed 29 March 2011].

DHL, 2011. *Corporate Responsibility at DHL*. [Online] Available at: http://www.dhl.com/en/about_us/sustainability.html [Accessed 29 March 2011].

DieselNet, 2009. *Emission standards, European Union, Heavy-Duty Diesel Truck and Bus Engines*. [Online] Available at: http://www.dieselnet.com/standards/eu/hd.php [Accessed 25 May 2011].

DSV, 2009b. *Aktuella rabatter DSV ECO*. [Online] Available at: http://www.dsv.com/irj/go/km/docs/documents/DSV_DFDS%20Transport/Integrated%20Internet/External%20Web%20Site%20Repository/SE/SE/Produkter%20&%20Tjänster/Vägtransporter/DSV%20ECO/DSVECO%20-%20Aktuella%20rabatter.pdf [Accessed 28 April 2011].

DSV, 2009. *Sustainability Review 2009*. DSV.

DSV, 2011b. *Road Division*. [Online] Available at: http://www.dsv.com/irj/servlet/prt/portal/prtroot/ExternalWebGui.IntegratedInternet?content=/documents/DSV_DFDS%20Transport/Integrated%20Internet/External%20Web%20Site%20Repository/COM/ENG# [Accessed 29 March 2011].

DSV, 2011c. *DSV ECO transport*. [Online] Available at: http://www.dsv.com/irj/servlet/prt/portal/prtroot/ExternalWebGui.IntegratedInternet?content=/documents/DSV_DFDS%20Transport/Integrated%20Internet/External%20Web%20Site%20Repository/COM/ENG# [Accessed 29 March 2011].

DSV, 2011. *Corporate Social Responsibility*. [Online] Available at: http://www.dsv.com/irj/servlet/prt/portal/prtroot/ExternalWebGui.IntegratedInternet?content=/documents/DSV_DFDS%20Transport/Integrated%20Internet/External%20Web%20Site%20Repository/COM/ENG# [Accessed 29 March 2011].

Ecotraffic, 2010. *Well to wheel efficiency for heavy duty vehicles*. Stockholm: Ecotraffic ERD.

Ericsson, E. & Ahlström, P., 2008. Miljö. In C. Hydén, ed. *Trafiken i den hållbara staden*. Malmö: Författarna och Studentlitteratur. pp.153-214.

European Commision, 2001. A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development. Brussels, 2001. Commission of the European Communities.

European Commission, 2004. Towards a Thematic Strategy on the Urban Environment. Brussels, 2004. Commission of the European Communities.

European Environment Agency, 2010a. *Towards a resource-efficient transport system*. Report. European Environment Agency.

European Environment Agency, 2010b. *State and Outlook Report 2010*. Report. European Environment Agency.

European Environment Agency, 2010c. *Good practice guide on noise exposure and potential health effects*. Technical Report. Copenhagen: European Environment Agency.

European Environmental Agency, 2007. *Air pollution in Europe*. Report. Copenhagen: European Environmental Agency.

European Environmental Agency, 2009. *Transport at a crossroads*. Report. Copenhagen: European Environmental Agency.

Eurostat, 2009. *Panorama of Transport*. Report. Eurostat.

Express, D., 2010. *DHL inrikes tillval och tillägg*. [Online] Available at: http://www.dhl.se/content/dam/downloads/se/logistics/se/dhl_inrikes_tillval_och_tillagg_011110.pdf [Accessed 29 March 2011].

FedEx, 2010. *Everything is connected - A Global Citizenship Update for 2009*. [Online] Available at: http://about.fedex.designcdt.com/files/FedEx_09_GCR_final_boomrk_0415.pdf [Accessed 07 April 2011].

FedEx, 2011 b. *Earth Smart Vision*. [Online] Available at: http://earthsmart.van.fedex.com/#2 [Accessed 07 April 2011].

FedEx, 2011. *FedEx Corporation*. [Online] Available at: http://about.fedex.designcdt.com/our_company/company_information/fedex_corporation [Accessed 07 April 2011].

Ferrand, E.F., 2006. Air pollutant effects. In J.R. Pfafflin & E.N. Ziegler, eds. *Encyclopedia of Environmental Science and Engineering*. Fifth edition ed. CRC Press. pp.29-43.

FordonsGas, 2011. *GrönGas*. [Online] Available at: http://www.fordonsgas.se/Svenska/Om_gas/GronGas.aspx [Accessed 30 May 2011].

Geodis Wilson, 2011. *Green Service - en del av arbetet*. [Online] Available at: http://www.geodiswilson.com/upload/Nordic/SE/Product_sheets/GW_SE_GreenService_Low_res.pdf [Accessed 29 March 2011].

Geodis, 2008. *Sustainable development report*. Geodis.

Geodis, 2011. *A global organisation for an end-to-end service*. [Online] Available at: http://www.geodis.com/geodis-group-organisation-@/article.jspz?id=310&categ=227 [Accessed 29 March 2011].

Geodis, 2011b. *A responsible approach*. [Online] Available at: http://www.geodis.com/geodis-sustainable-development-commitments-@/article.jspz?id=272&categ=179 [Accessed 29 March 2011].

Geodis, 2011c. *Taking care of the environment*. [Online] Available at: http://www.geodis.com/geodis-sustainable-development-environment-@/article.jspz?id=274&categ=185 [Accessed 29 March 2011].

Giddens, A., 2009. *Politics of Climate Change*. Cambridge: Polity Press.

Green Cargo, 2009b. *Affärsidé & vision*. [Online] Available at: http://www.greencargo.com/sv/Om-oss/Foretagsfakta/Affarside--vision/ [Accessed 26 March 2011].

Green Cargo, 2010b. *Ny miljökalkylator som täcker hela världen*. [Online] Available at: http://www.greencargo.com/sv/Hallbar-utveckling/Miljo/Miljokalkyl/ [Accessed 26 March 2011].

Green Cargo, 2010. *Miljösmarta transporter*. [Online] Available at: http://www.greencargo.com/sv/Om-oss/ [Accessed 26 March 2011].

Green Cargo, 2011. *Års- och hållbarhetsredovisning 2010*. Green Cargo.

Green Cargo, 2011b. *Mätmetoder för Green Cargos Hållbarhetsredovisning 2010*. [Online] Available at: http://ar2010sv.greencargo.com/Menu/Ovrigt/Nedladdningar/Matmetoder2010_2 [Accessed 26 March 2011].

Gudmunsson, H., 2004. Sustainable Transport and Performance Indicators. In R.E. Hester, ed. *Transport and the Environment*. Royal Society of Chemistry. pp.35-63.

Halldorsson, Á., 2010. The sustainable agenda and energy efficiency. *International Journal of Physical Distribution & Logistics Management*, 40(1/2), pp.5-13.

Holmberg, J. & Robèrt, K.-H., 2000. Backcasting from non-overlapping sustainability principles - a framework for strategic planning. *Journal of Sustainable Development and World Ecology*, 7, pp.291-308.

Holmberg, J., Robèrt, K.-H. & Eriksson, K.E., 1996. Socio-ecological Principles for a Sustainable Society - Scientific Background and Swedish Experience. In R. Costanza, ed. *Getting down to Earth: Practical Applications for Ecological Economics*. Washington DC: Island Press. pp.17-48.

IEA, 1999. *Automotive Fuels for the Future*. Report. International Energy Agency.

IEA, 2000. *IEA Statistics, Statistics of OECD countries 1997-1998*. Paris: International Energy Agency.

IL Recycling, 2010b. *Hållbarhetsredovisning 20009*. Il Recycling.

IL Recycling, 2010. *IL Recycling*. [Online] Available at: http://www.ilrecycling.com/sv/om-il-recycling/Om-IL-Recycling/ [Accessed 03 April 2011].

Jensen, C., 2004. *Evaluation of operational functionality, energy use and fuel consumption*. Renova AB.

Maibach, M. et al., 2007. *Handbook on estimation of external cost in the transport sector*. Report. Delft: CE Delft.

Mason, B.J., 2006. Green House Gases Effects. In J.R. Pfafflin & E.N. Ziegler, eds. *Encyclopedia of Environmental Science and Engineering*. Fifth edition ed. CRC Press. pp.427-38.

Mitchell, G., May, A. & McDonald, A., 1995. PICABUE: a methodological framework for the development of indicators of sustainable development. *Sustain. Dev. World Ecol.*, (2), pp.104-23.

Murray, J., 2009. *EA accused of "deliberately" undermining global renewables industry*. [Online] Available at: http://www.businessgreen.com/bg/news/1806340/iea-accused-deliberately-undermining-global-renewables-industry [Accessed 1 March 2011].

Naturvårdsverket, 2009. *Marknära ozon i luft*. [Online] Available at: http://www.miljomal.se/Systemsidor/Indikatorsida/?iid=104&pl=1 [Accessed 01 March 2011].

Naturvårdsverket, 2010 a. *2. Frisk luft*. [Online] Available at: http://www.miljomal.se/2-Frisk-luft/ [Accessed 28 February 2011].

Naturvårdsverket, 2010 b. *Kvävedioxid i luft*. [Online] Available at: http://www.miljomal.se/Systemsidor/Indikatorsida/?iid=90&pl=1 [Accessed 28 February 2011].

Naturvårdsverket, 2011 b. *Energiinnehåll och densitet för bränslen*. [Online] Available at: http://www.naturvardsverket.se/sv/Start/Klimat/Utslappsminskning/Berakna-utslapp/Energiinnehall-och-densitet-for-branslen/ [Accessed 25 April 2011].

Naturvårdsverket, 2011. *Utsläpp av flyktiga organiska ämnen*. [Online] Available at: http://www.miljomal.se/Systemsidor/Indikatorsida/?iid=82&pl=1 [Accessed 01 March 2011].

Nilsson, M., 2000. *LCI för biogas som fordonsbränsle - en systemstudie*. Examensarbete. Kalmar: Högskolan i Kalmar.

OECD, 1997. *The Environmental effects of freight*. Report. Paris: Organisation for economic co-operation and development.

OECD, 2002. *OECD Guidelines towards Environmnetally Sustainable Transports*. Report. Organisation for economic co-operation and development.

Piecyk, M.I. & McKinnon, A.C., 2010. Forecasting the carbon footprint of road freight transport in 2020. *International Journal of Production Economics*, 128(1), pp.31 - 42.

Posten Norden, 2011b. *Posten Norden Sustainability Report 2010: Accounting principles*. [Online] Available at: http://www.postnord.com/Global/Document/Om-Oss/Responsibility/Sustainability/Posten_Norden_Redovisningsprinciper%20ENG.pdf [Accessed 25 March 2011].

Posten Norden, 2011. *Sustainability Report 2010*. Posten Norden.

Posten, 2006. *Klimatekonomisk DR*. [Online] Available at: http://www.posten.se/c/klimatekonomiskdr [Accessed 27 March 2011].

Posten, 2011. *Posten Klimatekonomisk DR*. [Online] Available at: http://www.posten.se/img/cmt/PDF/klimatekonomisk_dr_saljbroschyr.pdf [Accessed 27 March 2011].

PostNord, 2011b. *Vårt ansvar*. [Online] Available at: http://www.postnord.com/sv/Om-oss/Vart-ansvar/ [Accessed 27 March 2011].

PostNord, 2011. *PostNord*. [Online] Available at: http://www.postnord.com/sv/Om-oss/Post-Nord/ [Accessed 27 March 2011].

Ragn-Sells, 2010b. *Ragn-Sells Miljöredovisning 2009*. Ragn-Sells.

Ragn-Sells, 2010c. *Utbildning*. [Online] Available at: http://www.ragnsells.se/Vara-tjanster/Basutbud/Konsult-och-statistik/Utbildning [Accessed 03 April 2011].

Ragn-Sells, 2010. *Om Ragn-Sells*. [Online] Available at: http://www.ragnsells.se/Om-foretaget/Om-Ragn-Sells/ [Accessed 03 April 2011].

RenoNorden, 2011b. *Miljø og miljøpolitik*. [Online] [Accessed 04 April 2011].

RenoNorden, 2011c. *Våra tjänster*. [Online] Available at: http://renonorden.no/v-ra-tj-nster [Accessed 04 April 2011].

RenoNorden, 2011d. *Miljö/Kvalitetsmål*. [Online] Available at: http://renonorden.no/milj-kvalitetsm-l [Accessed 04 April 2011].

RenoNorden, 2011. *Om RenoNorden*. [Online] Available at: http://www.renonorden.dk/om-renonorden/ [Accessed 04 April 2011].

Richardson, B.C., 2005. Sustainable transport: analysis framework. *Journal of Transport Geography*, 13(1), pp.29-39.

Schade, W., 2003. Transport noise: a challenge for sustainable mobility. *International Social Science Journal*, 55(176), pp.279-94.

SITA, 2011b. *Att ta sitt samhällsansvar*. [Online] Available at: http://www.sita.se/Ovrigt/om-sita/Vart-samhallsanavar/ [Accessed 07 April 2011].

SITA, 2011c. *Miljö*. [Online] Available at: http://www.sita.se/miljo/ [Accessed 07 April 2011].

SITA, 2011d. *Miljöcertifiering*. [Online] Available at: http://www.sita.se/miljo/Miljocertifiering/ [Accessed 06 April 2011].

SITA, 2011. *Om SITA*. [Online] Available at: http://www.sita.se/Ovrigt/om-sita/ [Accessed 05 April 2011].

Sjödin, Å. et al., 2010. *Wear particles from road traffic - a field, laboratory and modeling study*. Göteborg: IVL Swedish Environmental Research Institute Swedish National Road Vehicle Emission Research Programme EMFO.

SPI, 2011b. *Miljöklasser för dieselbränsle*. [Online] Available at: http://spi.se/wordpress/wp-content/uploads/2011/05/Specifikation-diesel-2011-05-01.pdf [Accessed 28 April 2011].

SPI, 2011. *Energiinnehåll, densitet och koldioxidemissioner*. [Online] Available at: http://spi.se/faktadatabas/artiklar/berakningsmodeller [Accessed 03 April 2011].

Stena Recycling, 2011 b. *Hållbara Affärer*. [Online] Available at: http://www.stenarecycling.se/Om-Stena-Recycling/Hallbara-affarer/ [Accessed 05 April 2011].

Stena Recycling, 2011 c. *Miljöutbildning*. [Online] Available at: http://www.stenarecycling.se/Produkter-och-Tjanster/Utbildning/Miljoutbildning2/ [Accessed 05 April 2011].

Stena Recycling, 2011 d. *The Climate Wheel*. [Online] Available at: http://www.stenarecycling.se/en/Innovative-recycling/The-climate-wheel/ [Accessed 05 April 2011].

Stena Recycling, 2011 e. *The Stena Metall Group's Environmental Goals*. [Online] Available at: http://corporate.stenametall.com/Sustainable-business/Environmental-goals/ [Accessed 05 April 2011].

Stena Recycling, 2011. *Om Stena Recycling*. [Online] Available at: http://www.stenarecycling.se/Om-Stena-Recycling/ [Accessed 05 April 2011].

Suez Environment, 2011. *Identity*. [Online] Available at: http://www.suez-environnement.com/en/profile/about-us/identity/identity/ [Accessed 06 April 2011].

Swedish Energy Agency, 2011. *Sverige tar samlat grepp om förnybara drivmedel*. [Online] (1) Available at: http://www.energimyndigheten.se/sv/Press/Pressmeddelanden/Sverige-tar-samlat-grepp-om-fornybara-drivmedel/ [Accessed 7 March 2011].

Swedish Environmental Protection Agency, 2011. *National Inventory Report 2011*. Sweden: Swedish Environmental Protection Agency.

Sydkraft, 2000. *Livscykelanalys - Miljöpåverkan från Sydkrafts elproduktion 1999*.

Tapani, A., 2003. *Trafikledning för bättre miljö*. Report. Linköping: VTI Väg- och transportforskningsinstitutet.

TFK, 1998. *Environmental handbook for transport purchasing*. Stockholm: TFK.

Trafikverket, 2010. *Fakta om utsläppen*. [Online] Available at: http://www.trafikverket.se/Privat/Miljo-och-halsa/Halsa/Luft/Fakta-om-utslappen/#kolvatenochflyktigaorganiskaamnen [Accessed 02 March 2011].

UNFCCC, 2011. *Global Warming Potentials*. [Online] Available at: http://unfccc.int/ghg_data/items/3825.php [Accessed 16 May 2011].

Uppenberg, S. et al., 2001. *Miljöfaktabok för bränslen, Del 2. Bakgrundsinformation och Teknisk bilaga*. Stockholm: IVL Svenska Miljöinstitutet AB IVL Svenska Miljöinstitutet AB.

UPS, 2010. *Deleviring the World - Sustainability at UPS 2009*. UPS.

UPS, 2011b. *Climate change programme*. [Online] Available at: http://www.climatechange.sgs.com/home_climatechange_v2/voluntary_activities/ups.htm [Accessed 02 April 2011].

UPS, 2011. *Decision Green*. [Online] (Decision Green) Available at: http://www.ups.com/bussol?loc=sv_SE&WT.svl=PriNav [Accessed 02 April 2011].

WBCSD, 2004. *Mobility 2030: Meeting the challenges to sustainability*. Report. World Business Council for Sustainable Development.

World Commission on Environment and Development, 1987. *Our Common Future*. Oxford, UK: Oxford University Press.

Wu, H.-J. & Dunn, S.C., 1995. Environmentally responsible logistics systems. *International Journal of Physical Distribution & Logistics Management*, 25(2), pp.20 - 38.

Appendix A

DSV

Background: DSV is a logistics management company with its roots in Denmark. Its road logistics division operate throughout Europe and employs roughly 10 000 people. It currently uses a mix of their own fleet of vehicles and licensed suppliers (DSV, 2011b).

1: DSV does not have a policy for sustainability. Instead it uses the concept of CSR to communicate its profile. Their definition of CSR is divided into human right, labour standards, environment and anti-corruption. The environmental part focuses on CO_2 emissions from vehicle combustion (DSV, 2011).

Reading DSV's environmental report several environmental concerns that can be linked to transport operations are acknowledged by DSV such as noise, air pollution, acidification, global warming and harm to the countryside. Environmental and economical efficiency is pointed out as a way of combating these issues (DSV, 2009).

2: DSV offers a service called 'DSV ECO Transport' for their road transports. The service increases flexibility in the logistic system by incorporating a five day pick-up interval where DSV is free to put it into the schedule when it is most convenient for them. When the pick-up is scheduled, the customer is notified. This increases utilization rate of the vehicles as well as lowering fuel consumption and costs (DSV, 2011c).

3: The DSV ECO Transport service is offered at a reduced price of up to 7% than that of the normal delivery services and adds to the environmental profiling of the customer according to DSV (DSV, 2009b).

4: DSV declares numbers for CO_2, NO_X and HC emissions from their transport. As DSV is focused on efficiency, they also report on average load capacity utilisation by transport type and country, share of drivers trained in eco-driving and share of vehicles in each Euro class. They also report on the amount of material waste that the road division of the company produces (DSV, 2009).

CO_2 emissions are derived from fuel consumption with a value of 2,65 Kg CO_2 per liter fuel. The other emission calculations capacity utilisation calculations are not declared

5: No external sources are declared for the calculations of environmental performance, the values for CO_2 emissions are declared on the company's web page but are not linked to any source.

6: The transparency of calculation methods and the environmental reporting is somewhat vague. Some of the calculations methods are described but they are not linked to any source material making it difficult to analyse their validity.

Geodis Group

Background: The Geodis Group is a worldwide freight management company with 26 500 employees. The group consists of a number sub companies that all work with managing freight operations through sub supplier hauling companies (Geodis, 2011).

1: Geodis has developed its own sustainability program called 'blue attitude', where blue refers to the company's blue profile colour as well as the oceans of the world as a representation of the environment and the earth, and attitude signalling commitment by everyone involved in the programme. The programme is divided into five parts; customers, people, environment, partners and community. The customer and community parts are involved with creating successful and close relationships with customers and the communities where Geodis is operating. The partners and people parts have to with creating well working solutions for staff and suppliers (Geodis, 2011b).

The environmental parts is focused on decreasing CO_2 emissions by improving logistic operations and staff training as well as by updating the vehicle fleet and by calculating CO_2 emissions and setting CO_2 reduction targets (Geodis, 2011c).
2: Geodis has an environmental program called "GreenService", it consists of six services; an online emissions calculator shipments, periodic emission reports that give customers a summary of total emissions caused by their transports with Geodis during a certain time period, online environmental education, seminars and workshops about environment and logistics, environmental revisions as well as environmental logistics optimisation (Geodis Wilson. 2011).

3: The online calculator, the periodic reports and the online training is available to all customers for a fee. This so called "GreenService fee" is collected into a fund dedicated to external research project and internal improvement projects in the environmental field. The remaining part of the services; the seminars and workshops, environmental revisions and logistic optimisation is offered as stand-alone services with custom pricing (Geodis Wilson. 2011).

4. Geodis is mainly concerned with controlling CO_2 equivalent emissions. In the company's' sustainability report they measure vehicle fuel use, CO_2 from fuel combustion and CO_2 from electricity use. The calculation on CO_2 is said to be based the GHG protocol inititative with 2,681 Kg CO_2 equivalents per litre used fuel and 0,2019 Kg CO_2 equivalents per kWh of used electricity and an atmospheric duration time of a 100 years (Geodis, 2008).

5. Geodis refers to the GHG protocol initiative for the calculation of CO_2 emissions, they also note however that there is no industry standard for evaluating environmental loads from transport activities and state that they are developing their own method, no further details are given on this topic (Geodis, 2008).

6. Generally, the documentation of what the environmental services entail and how environmental loads are calculated could be clearer. Geodis claims to base their calculation on the GHG protocol initiative but it is unclear to what extent, and it also unclear how their own in-house calculation methods are performed.

Posten Norden

Background: Posten Norden is a joint venture between the Swedish Posten AB and the Danish Post Danmark A/S. The company has about 40 000 employees and work within the areas of postal, logistic and IT services (PostNord, 2011).

1: Posten Norden defines sustainability according to the triple bottom line where the economic responsibility is said to be to create value for customers and owners by creating a profiting, efficient, stable competition on the market. The social responsibility includes caring for employees and the society at large. The environmental responsibility is defined as “actively working to lowering the environmental impact of the company and by doing so being the right environmental choice for customers”. Their environmental work involves their transport and facilities. On the transport side they have ongoing projects to try out new kinds of fuels and technologies to decrease emissions and the dependency on fossil fuels. They also list a number of measures already taken to increase sustainability, among them are maximising the cargo capacity utilisation, using eco-driving and optimizing routes. Emissions of CO_2 are noted as their biggest concern, but also their use of chemicals and noise from transport operations (PostNord, 2011b).

2: In Sweden Posten Norden offeres customers an environmental service called “climate economic direct marketing”. It is an offer for companies wanting to send out marketing leaflets and other printed material. When using the service Posten Norden uses only ISO 14001 certified suppliers and paper quality that is certified with the Nordic Ecolable known as “svanen” in Sweden. The delivery of the marketing material is then climate compensated through the CDM-system. By using the service the delivery will be marked with Postens’ own lable, strengthening the environmental profile of the sender according to Posten (Posten, 2006; Posten, 2011).

3: The climate economic direct marketing service is offered to customers free of charge. The cost for climate compensation is paid by Posten, with the claim that the benefits of the environmental gains are shared between both parties when the service is used. Customers wanting to use the service needs to contact Posten individually (Posten, 2006; Posten, 2011).

4: Posten notes air pollution from combustion, noise, fuel and energy use as environmental concerns. They do calculations on CO_2 CO, SO_2, NO_X, VOC and PM emissions on their transports with the NTM method according to their sustainability report (Posten Norden, 2011; Posten Norden, 2011b).

5: Posten Norden uses the NTM method for calculating emissions from their activities, and refers to the UN CDM-system for their climate compensation (Posten Norden, 2011b).

6: Posten uses the GRI guidelines for sustainability reporting which generally gives a very good overview of what aspects of sustainability that are considered and what methods are used. This is also the case for Posten Norden.

UPS

Background: World leading package delivery service with 400 000 employees, the majority working in the U.S. delivering roughly 16 million packages and letters every day.

1: UPS divides sustainability into four categories; community, environment, marketplace and workplace. Fuel use and combustion emissions are at the heart of their environment focus. Most of the environmental part of their sustainability report is focused on these issues. It lists actions that have been taken to decrease the both fuel use by logistic operations and improved driving behaviour as well as decreasing emissions by using modern technology in combination with biofuels. They also briefly acknowledge water use and loss of biodiversity as issues relevant in the context of sustainability (UPS, 2010).

2: The company has a green service package called “Decision Green” consisting of two services. The first one is “UPS carbon neutral”, which is a carbon compensation programme that employs the CarbonNeutral Company as well as SGS as external verification sources. The second one is called “Eco Responsible Packaging Program”, a labelling system for customers choosing to work with UPS on reducing weight and dangerous chemicals of packaging. The packaging programme is also certified with SGS as well as two other third party certifiers, the BSR and the Sustainable Packaging Coalition (UPS, 2011).

3: The UPS carbon neutral service is offered to customers on a per package fee rate that will be reinvested in four different carbon compensation programs around the world. In addition UPS matches the yearly investments up to $1 million. The packaging program involves an evaluation process of the customer, if the customer scores enough points it is free to use the UPS certified labels on their packages (UPS, 2011).

4: To calculate CO_2 equivalent emissions UPS uses its own self developed emissions model that has been certified by SGS. The model takes into account direct emissions from vehicle use of vehicles owned or rented by UPS (UPS, 2011b).

5: For reliability of calculating how large the CO_2 emissions are UPS refers to the SGS certification which claims that the calculation model provides a “reasonable level of assurance” (UPS, 2011b).

6: UPS uses the GRI reporting guidelines but the methods for calculating environmental loads are proprietary and not disclosed to the general public. Instead UPS refers to third party organisations to validate their methods which can be seen as lacking.

FedEx

Background: FedEx is a global network of companies providing services as transportation, e-commerce, and business services. The company has over 290 000 employees worldwide and has over 8.5 million daily shipments and over 80 000 motorized vehicles (FedEx, 2011).

1: The company has launched a program called 'Earth Smart' that explain the company's view on sustainability. The program consists of three activities; Earth Smart Solutions, Earth Smart Outreach, and Earth Smart @ Work. The activities cover responsibilities to the environment and economy, society, and employees respectively. The vision of the Earth Smart program is according to FedEx that it "encourages innovation, learning and action that make our business and the world more sustainable, both economically and environmentally" (FedEx, 2011 b).

2: FedEx does not provide any green services to its customers. The company has a large fleet of hybrid and fully electrical vehicles and these are used to market FedEx as an environmental beneficial company. Vehicles that meet or exceed the sustainability standards set by FedEx get the internal company label 'Earth Smart Solution' (FedEx, 2011 b).

3: FedEx market their green alternatives by labelling them as 'Earth Smart Solutions'. However it cannot be seen as a green alternative per se since customers do not have the choice to make or get deliveries with specific vehicles.

4: The focus of the Earth Smart Solutions is to reduce CO_2 emissions with technology solutions. By replacing gasoline and diesel trucks with hybrid solutions or fully electrical solutions, CO_2 emissions decreased. Calculations on emissions reductions by using these solutions have not been found.

5: FedEx presents figures on Scope 1, 2, and 3I emissions in the Global Citizen Report. The emission factors and conversion factors is calculated by using the Green House Gas Protocol (FedEx, 2010).

6: The company presents figures for the scope 1, 2, and 3 emissions. However, what FedEx includes and not includes in the optional Scope 3 emissions is not specified.

IL Recycling

Background: IL recycling is a Swedish waste management company where IL Recycling AB is the mother company of a number of sub companies in the recycling business. It is owned by SCA, Stora Enso, Fiskeby Board and Smurfit Kappa Kraftliner, it has 600 employees and operate in 24 locations across Sweden. It also does business internationally by selling recycled paper. IL currently owns roughly 150 vehicles of different kinds, and employ about another 150 vehicles (IL Recycling 2011; IL Recycling 2011b).

1: Based on their website and their sustainability report IL Recycling adopts the triple bottom line approach to sustainability, within the frame of that concept they have developed three focus areas; customers and suppliers, coworkers and environment and climate impact as a combined third area. As IL is a recycling company much of their attention is directed toward material recycling and waste management, and less focus is put on the transport activities within the company. The environmental work that has currently been done is efficient logistics planning and educating drivers in eco-driving. Overall the environmental impacts from transports are not in focus based on the published material from IL (IL Recycling 2011c).

2: IL currently offers education in the fields of environment and recycling for companies and private households. They also offer additional services in the field of recycling like cleaning containers and maintenance of waste disposal rooms. They currently have no additional green services or products related to their transport activities.

4: The company acknowledges climate change as an environmental issue, the focus within this topic is put on the environmental savings that can be achieved from recycling materials instead of using virgin materials. Energy savings throughout the organisation are also lifted as an area where efforts have been made to improve. There are currently no information, estimations or calculations that quantify the environmental loads of the activities of IL Recycling (IL Recycling, 2011b).

5: IL refers to its ISO 14001 certificate to claim that it is in the forefront in the environmental field of the market.

6: The company accounts well for the activities they are performing, and publishes a yearly sustainability report. Since much of the company's attention is directed toward waste management there is little information available on its transport operations.

Ragn-Sells

Background: Ragn-Sells is a privately owned company operating in the recycling industry with activities in Sweden, Norway, Denmark, Poland, Estonia and Latvia. With about 1700 employees in Sweden and 2300 throughout the company, they collect and treat waste from private households as well as from industry. They currently employ roughly 880 road vehicles of different kinds (Ragns-Sells, 2010, Ragn-Sells, 2010b).

1: Ragn-Sells does not have a stand-alone policy for sustainability, but they do express their way of working in terms of economy, social and environmental issues much like the traditional TBL approach. Reading their environmental report they highlight their commitment to recycling and the benefits of recycling much like IL Recycling does, i.e. that it is both environmentally and economically sound. The environmental part of the report is divided into three sections dealing separately with transport operations, waste management and energy use. The use of fossil resources is highlighted as a concern for them, as are emissions of CO_2 and vehicle noise. As a part of this they report on using route optimisations, eco-drive training for staff as well as trying out hybrid vehicle and increasing their use of biofuels. In the energy use section they recognise that the use of energy involves environmental concerns and that the source of energy is important, because of that they are increasing their share of electricity from renewable sources (Ragn-Sells, 2010b).

2: Ragn-Sells has a consulting sub-company called “Ragn-Sells Miljökonsult AB” dealing with delivering services beyond waste management. They offer customers a web portal with statistics on how much waste that has been transported and are working on implementing air pollution statistics. This service helps customers collect data in order to increase their environmental profile according to Ragn-Sells. They also offer a variety of educations for drivers like eco-driving and safe-handling of hazardous cargo (Ragn-Sells, 2010c).

3: The educations are offered at custom pricing as is the customer web portal (Ragn-Sells, 2010c).

4: The statistics that is currently available is the annual diesel and gas consumption for their heavy vehicles as well the corresponding CO_2 emissions. They also report their annual electricity use, but do not specify where it is used (Ragn-Sells, 2010b).

5: The calculation of CO_2 emissions from vehicle use are based on fuel conversion factors supplied by the Swedish Petroleum Institute (SPI), who list the potential CO_2 emissions from various fuels based on the amount of fossil carbon content. It should be noted that renewable fuels do not contain fossil coal and therefore get a zero emission value of CO_2 with this calculation method (Ragn-Sells, 2010b; SPI, 2011).

6: The transparency of how Ragn-Sells perform environmental load calculations is generally clear as proper sources are given. As the provided information on environmental actions taken by the company is extensive but only few concrete results are measured or analysed, the discrepancy between what they claim to be issues of importance and what actions they actually take to deal with them is hard to evaluate.

RenoNorden

Background: RenoNorden is a Norway based waste management company also operating in Denmark and Sweden with a combined workforce of 925 people. The company was founded in 2000 and is focused on providing waste disposal services for municipalities (RenoNorden, 2011).

1: RenoNorden does not provide a definition of sustainability for the comapany. They state in their environmental description that efforts have been put into establishing safe and responsible environmental and workplace conditions. Furthermore they are focused on reducing environmental impacts and resource use as well as meeting requirements in the areas of operation according to their website (RenoNorden, 2011b).

2: The company does not provide any services other than their commitment to waste management services for municipalities and municipality companies (RenoNorden, 2011bc).

3: RenoNorden is focused on waste management and does not provide any additional green services to be marketed.

4: The environmental impact of the company is not estimated or quantified in any of the information provided by the company.

5: The company refers to their ongoing certification process of ISO 14001 environmental management as an indicator of their commitments (RenoNorden, 2011d).

6: Compared to other waste management companies RenoNorden provides very little information on their activities. Based on the information that is currently published, very few of the sustainability aspects, services and working methods employed by other companies have been implemented in RenoNorden.

SITA

Background: SITA is one of the bigger actors in the waste management industry in Sweden, with roughly 1100 employees and 60 offices around the country. The company is a part of the much bigger mother company SUEZ Environment. Originated in France, SUEZ Environment has a global presence committed to waste and water management with a combined workforce of almost 80 000 (SITA, 2011; Suez Environment, 2011).

1: SITA profiles itself as a part of the SUEZ consortium with the same overall goals. As such it states that sustainable development is core in its business model. Sustainability is defined as running the business with environmental and social issues in mind, much like the concept of TPL. Several issues and engagements are listed as examples of important areas of sustainability; protecting and providing sources of clean water, protecting biodiversity and soil as well as promoting production of renewable electricity and efficient use of materials and technology. Emissions of green house gases, limitations of the natural resource base and specifically the use of fossil fuels are expressed as focus areas when describing their environmental work. The uses of energy and transport operations are also mentioned. Regarding transports specifically, air emissions, particles and noise are recognized as environmental issues. SITA currently uses eco-driving, bio gas vehicles and route optimisation to decrease the impacts caused by their transports (SITA, 2011b; SITA, 2011c).

2: SITA does not provide any additional green services connected to their transport operations. The services they have are geared towards management regarding storage, organisation and disposal of different kinds of waste.

3: As the focus of the company's operations is geared toward waste management there are no green services to be marketed or offered.

4: SITA does not provide any information or quantification on the levels of environmental impact that the company imposes other than expressed environmental gains from recycling materials instead of using virgin material.

5: The company refers to its ISO 14001 certification when claiming that it is systematically working to decrease the environmental impact of its operations (SITA, 2011d).

6: SITA relies on the main organisation of SUEZ Environment for much of its environmental publications and statistics, however since SUEZ does not provide specific information on the operations of its sub companies the transparency of SITA is quite low.

Stena Recycling

Background: Stena Recycling is a recycling company and part of The Stena Metal Group. Stena Recycling has close to 200 recycling facilities operating in Sweden, Norway, Denmark, Finland and Poland. The company collects and recycles all types of wastes from all types of industry businesses, hospitals, and municipalities. By offering customized recycling solutions to customers Stena Recycling has the goal to increase the value of its customers operations (Stena Recycling, 2011).

1: Stena Recycling has no expressed policy for sustainability. Much like IL and Ragn-Sells, Stena Recycling is highlighting the environmental and economical benefits of recycling and waste management. The company sees itself as an important player in the development towards a sustainable society and by doing sustainable business, where customer benefit, profitability, environmental benefit, and safety go hand in hand, Stena Recycling see themselves contributing to the conservation of limited resources (Stena Recycling, 2011 b).

2: Stena Recycling is offering customers services as environmental education and statistical information of customers recycled waste, e.g. calculated saved CO_2 emissions for recycled material. The focus is put upon recycling and waste management, and the transport activities are left out (Stena Recycling, 2011 c). The company also offer a type of online emission calculator called ‘The Climate Wheel’, used to inform visitors on environmental benefits of recycling (Stena Recycling, 2011 d). Stena Recycling is improving the environmental performance of transports by logistical solutions, such as route planning, and training drivers in fuel efficient driving (Stena Recycling, 2011 e).

3: The environmental education is available for all customers and can be designed to fit the specific organisation of the company. The statistical information can be accessed through the web-portal and is available to all customers free of charge. The online emission calculator is available to all visitors for free.

4: Stena Recycling does not provide any information or quantification on the levels of environmental impact that the company imposes. Focus is put upon the environmental benefit of recycling materials instead of using virgin material. Information on the calculations of saved CO_2 emissions for recycled material, provided to customers through the web-portal, has not been found.

5: The only guarantee on the environmental work performed by Stena Recycling is the certification according to ISO 14001.

6: Stena Recycling claims that the environmental benefit of recycling materials is their biggest contribution to sustainability. The saved CO_2 emissions from recycling materials instead of using virgin materials can be found on their web page. However, details on the calculations have not been found.

DB Schenker

Background: DB Schenker is the Transport and Logistic division of Deutsche Bahn Group and has over 91 000 employees worldwide. The company has two divisions, Rail and Logistics that together provide road and rail transports across Europe, worldwide air and ocean freight and contract logistics (Deutsche Bahn AG, 2010).

1: DB Schenker states that sustainability is an integral part of their strategy and that it is “firmly anchored in the corporate Mission Statement” (Deutsche Bahn AG, 2009). By reading the Mission Statement one can see that DB Schenker express their responsibilities in general agreement of the TBL approach in terms of economic, social, environmental sustainability (Deutsche Bahn AG, 2009 b). On their webpage however, most focus is put upon the environmental part of sustainability focusing on minimizing their carbon footprint. The Deutsche Bahn Group has developed group wide environmental protection program, with the goal of reducing the emissions of carbon by 20 % from 2006 to 2020. The main focus of DB Schenker approach to reduce their emissions are intelligent use of multi-modal transports, technical solutions, intelligent logistics, and training drivers in fuel efficient driving (Deutsche Bahn AG, 2009 c).

2: DB Schenker does not have a “green” alternative available. However, they can provide their customers with an emission report service available at the E-portal ‘mySCHENKER’. The company has developed a tool called ‘Emission Report’ that enables the customers to get a comprehensive report of the emissions, energy use, fuel consumption, etc related to their land-based shipments. Besides the Emission Report customers can also use the EcoTransIT calculator to make prior estimates of the emissions from their shipments and to compare different types of transport modes (DB Schenker, 2011).

3: The Emission Report tool is free service available through the E-portal mySCHENKER for European customers. The results can be seen on total for a selected period, month or largest traffic.

4: The Emission Report tool uses three sources of information for calculating the emissions:

1. Information about the customer shipment details (starting point-endpoint, cargo weight)
2. Information about DB Schenker's network transports, vehicle types, distances, cargo capacity utilization etc.
3. Usage of the NTM method to calculate fuel consumption, emissions per vehicle type etc.

The tool calculates the fuel consumption and emission values for each type of transport involved in the shipment and sums it up into a total. The cargo capacity utilization is based on yearly averages that DB Schenker has for each vehicle class/size and the distance is calculated using the Route LogiX Proffessional software.The Emission Report tool then presents values for following categories (DB Schenker, 2010):

- Transport work (tonkm)
- Energy use (kWh)
- Fuel consumption (l)
- Emissions of CO, CO_2, HC, NO_x, PM, SO_2 (kg)

5: For the Emission Report DB Schenker uses the NTM method and for estimates made by customers the EcoTransIT calculator is used.

6: DB Schenker presents the calculation method in a comprehensive and transparent way by having an online manual on how the Emission Report tool is constructed. The company clearly states that the results of the calculations are an assessment of the real emissions and gives an explanation on the prerequisites needed for a more exact calculation (DB Schenker, 2010).

Green Cargo

Background: Green Cargo is a logistics company owned by the Swedish ministry of enterprise, energy and communications. It employs about 2700 people and delivers complete logistic supply capabilities but with heavy reliance on railway for its operations. According to their website its business idea is to provide logistics solutions with social responsibility, environmental care and economic profitability (Green Cargo, 2009; Green Cargo 2009b).

1: Sustainability is defined by Green Cargo according to the triple bottom line and according to six areas of operations which they have defined themselves; finance, customer, co-workers, security, environment and society. The description of the environmental part highlights CO_2 emissions, energy use and fossil fuel use as focus areas. The company is currently measuring CO_2, NO_X, HC:s, particles, fossil and renewable energy from transports as a part of their sustainability reporting (Green Cargo, 2011).

2: The company offers customers' so called 'Green Cargo Climate Certificates' if the they can reach the limit of 10 grams CO_2 per ton cargo and kilometre on their transports activities. The certification process is performed by Green Cargo by evaluating the logistic operations of the customer with calculations based on NTM data. If the customer cannot reach the limit value a CO_2 report is issued instead. According to Green Cargo this helps the customer to strengthen its environmental profile. Green Cargo is one of the founders of EcotransIT and also offers the EcoTransIT web tool for emissions calculations on their webiste for all visitors to use (Green Cargo, 2010b).

3: For the climate certificate customers need to contact Green Cargo for a customised evaluation. The EcotrasIT tool is available on Green Cargo's website with the additional possibility of becoming a member to feature the calculator on the customer's own website (Green Cargo, 2010b).

4: The calculation methods used by Green Cargo are based on data from NTM and SPI. They include CO_2 emissions from combustion and from fuel and electricity production (Green Cargo, 2011b).

5: CO_2 emissions from road transport combustion and fuel production are calculated by multiplying the used volumes of diesel with emission factors from SPI and then adding WTT data from NTM. CO_2 emissions from electricity production are calculated with NTM data based on Swedish water power (Green Cargo, 2011b).

6: The transparency of the calculation methods used by Green Cargo is quite clear and well presented as all of their methods are published in a separate document that can be found on their website (Green Cargo, 2011b).

DHL

Background: DHL employs 310 000 people worldwide operating in four divisions (Express Division, Global Forwarding and Freight Division, Supply Chain Division, and Global Mail Division) and is part of the logistics group Deutsche Post DHL.

1: DHL has three focus areas of sustainability; environment, employees, and interaction with society. DHL has through their program GoGreen developed a framework for how DHL should respond to the environmental impact of their actions. It revolves around minimizing resource use and emissions (mainly CO_2) through optimized planning, use of alternative fuels and innovative technology. Through the program quantified CO_2 efficiency targets have been set for 2020. The key activities related to area of employees are promoting learning from one another through Group-wide networks, ensuring safe workplaces, and promoting a working environment free from discrimination. In the area of society DHL is, besides assisting airports with logistics expertise in case of natural disasters, involved in supporting non-profit organisations in education, the environment, and disaster management (DHL DP, 2010; DHL, 2011).

2: As a part of the GoGreen program DHL is offering their DHL Express customers to purchase an optional service called 'GOGREEN', a carbon neutral transport service where the transport related emissions of carbon dioxide are calculated and compensated for through external climate protection projects (Deutsche Post, 2011).
Also under the GoGreen program DHL has a service called PACKSTATION available to private customers in Germany. The PACKSTATION service consists of several self service parcel stations spread around Germany where customers can send and receive parcels any time of the day. DHL claims that the service reduces traffic significantly and thereby emissions of CO_2, PM, and other pollutants compared to employing home delivery (DHL, 2011b).

Another green service is the optional service called "Gröna Ton" available in the EUROCONNECT product portfolio the DHL Freight Division. Customers pay an extra charge for their transport making sure that corresponding transport volume is performed with renewable energy within DHL's transport system. The cost for the service is 0.40 SEK per ton/km and customers choose how much of the transport volume they want to pay for which is then converted into ton/km by DHL through a conversion key. On the DHL webpage a list of the most "green" companies can be found (DHL Express, 2010; DHL Express, 2011).

3: The GOGREEN service is an optional service only available at DHL Express and comes with a fee corresponding to 2% of the transport cost. Customers using the service get the 'GOGREEN' label on their packages and receive yearly certificates showing the total amount of carbon dioxide that has been compensated for on their behalf (DHL Express, 2010b).

The PACKSTATION service is available to private customers in Germany and DHL attracts customers by applying a bonus point scheme where customers collect points for sent and received parcels. The points can be used as payment for future shipment, shopping vouchers, gifts, or donations (DHL, 2011b).

4: The CO_2 emissions caused by transporting a GOGREEN item from sender to receiver is calculated in line with the certified procedure ISO 14064 by the Deutsche Post DHL Carbon Management department. Included in the calculations are, besides the CO_2 emissions connected to fuel use of the actual transport, also the energy consumption at intermediate warehouses and nodes (Deutsche Post DHL, 2011).

5: The emission calculations are in line with the ISO 14064 procedure and the climate compensation projects are yearly verified by the independent third party SGS Group in Switzerland (Deutsche Post DHL, 2011).

6: The calculations of the emissions are comprehensive but the transparency is to some extent limited. The emission calculation tool is said to be based on the NTM method but further specifications such as system boundaries and allocation methods cannot be found.

Dachser

Background: Dachser is a family owned business and one of Europe's leading logistics providers. The company has 19 250 employees worldwide working in the business segments European Logistics, Air & Sea Logistics, and Food Logistics. The focus is to provide customers with intelligent combination and integration of logistical network services (Dachser, 2011).

1: Dachser defines sustainability according to the TBL approach with economic, social, and environmental responsibilities. The economic responsibilities are to promote future growth and stability in the company which is done by reinvesting profit into the network considering knowledge and future technologies. The social responsibilities are both internal and external. Education programs, health programs, and a company pension scheme has been developed to ensure that employees are well looked after and Dachser supports external social projects, e.g. to secure schooling for Indian children. The environmental responsibilities are to reduce emissions and to use less energy, mainly through intelligent logistics (Dachser, 2011b).

2: Dachser does not provide their customers with a “green” service or product, neither in Sweden, nor in Europe. Dachser focuses on intelligent logistics in order to maximize capacity utilization. Drivers are trained in fuel efficient driving and the company chooses commercial vehicles according to low emission criteria.

3: No green services are offered to customers. Dachser is a member of the German working group for the CO_2 standard and involved in designing a Europe-wide standard for measuring energy consumption and greenhouse gas emissions incurred by transport services. By being involved in the process Dachser claims that customers “benefit from the environmental and resource management know-how that Dachser is acquiring in the process” (Dachser, 2011c). The development of the standard is a work in progress and the outcome of it is yet to be seen.

4: The environmental impact of the company is not estimated or quantified in any of the information provided by the company.

5: The only guarantee on the environmental work performed by Dachser Sweden that can be found is the certification according to ISO 14001 of the company’s environmental management system (Dachser, 2011d).

6: Dachser presents very little information of the company’s activities. The environmental responsibilities raised in the sustainability policy are not backed up with any kind of measurements or results.

Appendix B

Calculation of emission factor for SO_x

Reaction:	S	+	O_2	->	SO_2
Moles:	0,0625				0,0625
g/mole:	16			32	
g:	1				2

Relation S to SO_x: $R_S = 2$

Sulphur content diesel Mk1: S_D = 10 mg/kg (SPI, 2011b)

Energy content diesel Mk1: E_D = 43,2 MJ/kg (Uppenberg et al., 2001)

Emission factor SO_x: $E_{SOx} = SD/ED*R_S$ = 0,00046 g/MJ

Appendix C

Calculation of emission factors for electricity production

Table C.1: *Sources for electricity production. Swedish average energy mix (IEA, 2000)*

Sources	**Energy (GWh)**	**Share (%)**
Hard coal, coke oven & blast furnaces	3155	1,99
Liquid fuels (e.g. oil) refinery gas	3264	2,06
Natural gas, gas works gas	431	0,27
Lignite sub bituminous coal, peat	60	0,04
Nuclear energy	73583	46,5
Geothermal	0	0
Solar	0	0
Combustible renewable wastes	3088	1,95
Hydro energy, pumped storage excluded	74328	46,98
Tide, wave, ocean	0	0
Wind	317	0,2
Other fuel sources	0	0

Table C.2: *Emission factors for different sources of energy (IEA, 2000)*

Emission factors (general)	**Hard coal**	**Oil**	**Fuel gas**	**Lignite**	**Nuclear**	**Biofuel**	**Hydro electricity**	**Wind**
CO_2	275,833	229,38	245,831	370,979	3,605	8,964	1,045	4,578
SO_x (SO_2)	1,06207	2,3594	0,05829	3,62353	0,0251	0,0427	0,00286	0,01904
NO_x	0,4517	0,5046	0,40844	0,558	0,009599	0,252	0,003196	0,009845
N_2O	0,00179	0,00553	0,0015	0,0018	0,0008	0,0136	0,000015	7,55E-05
CO	0,0566	0,07515	0,08197	0,0451	0,00601	0,18789	0,00579	0,03461
NMVOC	0,0339	0,588	0,062	0,0126	0,00393	0,0458	0,000947	0,01054
CH_4	1,0035	0,307	0,3737	0,03149	0,01026	0,01369	0,00239	0,01528
PM	0,32159	0,09687	0,01613	0,25766	0,00708	0,0294	0,00209	0,01216

Table C.3*: Calculated emission factors for Swedish mix of electricity*

Emission factors	**Hard coal**	**Oil**	**Fuel gas**	**Lignite**	**Nuclear**	**Biofuel**	**Hydro electricity**	**Wind**	**Total**
CO_2	5,489077	4,725228	0,663744	0,148392	1,676325	0,174798	0,490941	0,009156	13,37766
SO_x (SO_2)	0,021135	0,048604	0,000157	0,001449	0,011672	0,000833	0,001344	3,81E-05	0,085231486
NO_x	0,008989	0,010395	0,001103	0,000223	0,004464	0,004914	0,001501	1,97E-05	0,031608284
N_2O	3,56E-05	0,000114	4,05E-06	7,2E-07	0,000372	0,000265	7,05E-06	1,51E-07	0,000798707
CO	0,001126	0,001548	0,000221	1,8E-05	0,002795	0,003664	0,00272	6,92E-05	0,012161656
NMVOC	0,000675	0,012113	0,000167	5,04E-06	0,001827	0,000893	0,000445	2,11E-05	0,016146381
CH_4	0,01997	0,006324	0,001009	1,26E-05	0,004771	0,000267	0,001123	3,06E-05	0,033506673
PM	0,0064	0,001996	4,36E-05	0,000103	0,003292	0,000573	0,000982	2,43E-05	0,01341348