MASTER

A methodology for calculating CO2 emissions from transport and an evaluation of the impact of European Union emission regulations

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A methodology for calculating CO_2 emissions from transport and an evaluation of the impact of European Union emission regulations

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Abstract

In this master thesis project a methodology for calculating carbon dioxide emissions from transport and a calculation tool to apply this methodology have been developed. The carbon dioxide emissions of Cargill have been calculated and, based on the results, several carbon dioxide reduction possibilities and European Union regulation scenarios have been evaluated. The outcomes provide insight into the impact and opportunities for Cargill and provide insight into the general effects of the different regulation scenarios.

Management summary

This master thesis project studies the methodology for calculating carbon dioxide emissions resulting from transport, evaluates different carbon dioxide emission reduction possibilities and evaluates the impact of upcoming emission regulations. The project is part of the Carbon Regulated Supply Chains (CRSC) project that has the aim to develop a methodology for calculating the amount of carbon dioxide emissions from transport and to get a deeper understanding of the impact of carbon dioxide emissions on supply chain design. Four master thesis projects have been performed at the same time, all in companies that are a member of the European Supply Chain Forum: Bausch & Lomb, Cargill, Dow Chemical and Unilever.

This project has been performed at Cargill.

Three research questions have been defined:

- *How can carbon dioxide emissions resulting from transport be determined?*
- *How can carbon dioxide emissions resulting from transport be reduced?*
- *How will possible upcoming regulations of the European Union impact transport costs and reduction possibilities?*

Research demarcation

The transport taken into account in this study is all outbound transport within Europe. The transport data is based on the award plans (the overview of the contracts between Cargill and the logistics service providers). Only the transport under the control of Cargill has been taken into account. The products that are picked up by customers are outside the research scope. The total amount of transport taken into account is equal to 5.9 million tonnes per year.

For all transport, only the carbon dioxide emissions are taken into account. Carbon dioxide is the gas that receives most attention by governments and the European Union, because the emissions of carbon dioxide have by far the biggest impact on the environment.

Calculation methodology and calculation tool

Within the CRSC project a methodology for calculating carbon dioxide emissions from transport has been developed by evaluating existing calculation methodologies and extending these with carbon dioxide emissions from cleaning, vertical handling and temperature control. Furthermore, several assumptions have been checked and adjusted if needed. The calculation methodology can be applied to a complete transport dataset using the calculation tool developed in the CRSC project. The tool is able to present the calculation results in a usable way.

Reduction options

Two reduction options have been analysed

- Increasing payload
- Modal shift

By increasing the payload, a transport vehicle can be used more efficiently leading to a reduction in the number of trips needed to transport the same amount of product. This way a reduction of carbon dioxide emissions is achieved.

Switching road transport to intermodal transport (modal shift) reduces the carbon dioxide emissions in two ways: by using less-emitting modes of transport and by increasing the payload. Intermodal transport has been defined as the transport of cargo using multiple modes of transport without any handling of the cargo itself when changing modes. One addition to this definition is that the container (or pallet) is always handled in intermodal transport, thus excluding ferries from the intermodal transport modes. In a lot of European countries, the payload can be increased by 3 to 4 tonnes when using intermodal transport compared to road transport.

EU regulation scenarios

Four possible regulation scenarios have been evaluated:

- Current European Union Emission Trading Scheme (ETS)
- Current ETS including sea transport in combination with diesel tax and Euro-Vignette
- Current ETS including all transport modes
- Current ETS and separate transport ETS

Based on Cargill data it has been shown that the current ETS including sea transport in combination with diesel tax and Euro-Vignette leads to the biggest carbon dioxide emission reduction at minimum costs. However, this scenario behaves in a way opposite to the intentions of the European Union: the lower bound price levels lead to a higher reduction than the upper bound price levels. This is mainly caused by a fixed carbon dioxide price for road transport and a variable carbon dioxide price for all other transport modalities.

The scenario using the current ETS including all transport modes and the scenario using the current ETS and a separate transport ETS give results in line with the intentions of the European Union, but the carbon dioxide emission reduction at minimum costs does not differ significantly from the current situation.

Recommendations

This study leads to the following recommendations for Cargill:

- Modal shifts lead to the biggest carbon dioxide emission reduction and even a cost reduction. Therefore investigating all lanes for which a modal shift seems possible is recommended. Here, technical constraints and costs resulting from solving these should also be taken into account.
- A large carbon dioxide emission reduction can be achieved by optimizing the payload of the bulk liquid transport.
- Other carbon dioxide emission reduction options can be taken into account as well. Transport using inland waterways, and sourcing options are not being considered at the moment.
- Collecting the data needed for a carbon dioxide emission calculation can be integrated with the request for quotation (leading to an award plan). This will save time both for Cargill employees and for logistics service providers.
- The progress of reducing carbon dioxide emissions can be quantified using the tool on a monthly basis. This way, the Green Transport Project can be used for marketing purposes as well.

Furthermore, one recommendation for the tool is given:

- The tool needs to be updated regularly with new emission data.

Preface

This master thesis is the result of my graduation project for the Master of Science program in Operations Management and Logistics at the Eindhoven University of Technology. The project has been performed at Cargill.

At the University I would like to thank Henny van Ooijen for his help and guidance during the project and for his help and criticism needed to structure this report. Furthermore, I would like to thank my second supervisor, Jan Fransoo, for asking valuable questions that made me look at my work from another point of view. Finally, I would like to thank the other three students participating in the CRSC Project, Inge van den Akker, Hakki Ozsalih and Robbie Schers. Together we were able to reflect on our work and develop the methodology needed for this project.

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Finally I would like to thank my parents and my girlfriend for their continuing support and confidence.

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1 Introduction

This master thesis project studies the methodology for calculating carbon dioxide emissions resulting from transport, evaluates different carbon dioxide emission reduction possibilities and evaluates the impact of upcoming emission regulations. The study is part of the Carbon Regulated Supply Chains project (CRSC) which is described in section 1.2, together with the organizations and companies involved. First, a brief description of the background information needed to read this report is given.

1.1 Background

All over the world, people become more aware of the impact of greenhouse gases on the environment. During the last decades, individuals, organizations and governments have come to realise that the emission of greenhouse gases needs to be reduced.

The first large international agreement to reduce greenhouse gases is the Kyoto Protocol. Until now, 83 countries and the European Union have signed the protocol (UNFCCC, 2009). These countries have agreed to reduce their overall emissions by at least 5 percent below 1990 levels in the commitment period 2008 to 2012 (UNFCCC, 1998).

In order to reach the emission reduction target defined in the Kyoto Protocol, a carbon market has been created. Three mechanisms have been put into place: emissions trading, the Clean Development Mechanism (CDM) and Joint Implementation (JI). Emissions trading allows countries that have not emitted the amount of carbon dioxide they are allowed to emit to sell the excess ‘rights to emit’ to other countries. CDM allows countries to implement an emission reduction project in developing countries and use the reduction in emissions in these countries as additional ‘rights to emit’ in their own country. Finally, JI allows countries to implement an emission reduction project in other Kyoto-countries and using this emission reduction as additional ‘rights to emit’ (UNFCCC website, 2009).

The successor of the Kyoto Protocol will be finalized (and signed) in December 2009 in Copenhagen.

Carbon dioxide emissions from production (both goods and energy) have received a lot of attention in research. To be able to meet the long-term climate goals set by the European Union (60-80 percent reduction in 2050 compared to 1990 levels) the transport sector needs to reduce its emissions as well, because without any emission reduction from transport, the transport sector will account for the entire amount of allowable greenhouse gases by the year 2050 (RWS, 2008).

Companies benefit from reducing their carbon dioxide emissions in two ways:

- Cost reduction: by reducing the emissions, companies need fewer allowances in the EU ETS. Also companies can offer benefits to customers, for instance when switching to intermodal transport and using a floating stock in a terminal close to the customer, the lead time can be reduced and the service level can be raised.

- Marketing opportunity: because a lot of people want to become ‘greener’, a reduction in emissions can be used as a marketing statement for and branding of the products of the company.

A third reason for reducing emissions is the need to do so out of regulatory reasons.

1.2 CRSC project and organizations involved

The CRSC project is performed at the Operations Planning and Control department of the Eindhoven University of Technology. The aim of the project is to develop a methodology for calculating the amount of carbon dioxide emissions from transport and to get a deeper understanding of the impact of carbon dioxide emissions on supply chain design. Four master thesis projects have been performed at the same time, all in companies that are a member of the European Supply Chain Forum.

This master thesis project has been performed at Cargill. The other projects have been performed at Bausch & Lomb, Dow Chemical and Unilever.

Part of the research has been done together with the other master thesis projects. Therefore some parts of this report are taken from the general report of the CRSC project (CRSC Project, 2009). Section 3.2 is directly taken from the general report and the scenario descriptions and values are based on the general report. The general report draws more general conclusions based on the findings of all four individual master thesis projects.

2 Company description, demarcation and approach

The first section of this chapter describes the company where this master thesis project is performed. Next, the scope of the research is described and finally the approach of the project is given.

2.1 Cargill

Cargill is an international producer and marketer of food, agricultural, financial and industrial products and services. The company is the world's largest privately held company and employs 160,000 people in 67 countries. In the 2008 fiscal year, Cargill had a turnover of 120.4 billion dollars (Cargill, 2008).

The project has been performed at the European Transport Procurement department (ETP), located in Haubourdin in the north of France. The main tasks of the ETP involve negotiation and contract management with logistics service providers, maintaining and sharing the central transport database and harmonizing procedures in line with Cargill's main processes. All these tasks are performed for multiple business units, seven in total.

In the beginning of 2009, a new project has been started within the ETP: the Green Transport Project. The goal of this project is to reduce the carbon dioxide emissions resulting from transport, mainly by shifting road transport to intermodal transport. Here, intermodal transport is defined as the transport of cargo using multiple modes of transport without any handling of the cargo itself when changing modes. One addition to this definition is that the container (or pallet) is always handled in intermodal transport, thus excluding ferries from the intermodal transport modes.

Transport network
The transport network of Cargill can be described by three types of destinations: customers, terminals and production facilities. Customers throughout Europe are supplied from production facilities throughout Europe. Cargill also uses terminals in between production facilities and customers; the product is transported to a terminal, stored for a specified length of time and then transported to the customer. Other Cargill production facilities are the third type of destination. These are again supplied from production facilities throughout Europe.

2.2 Research demarcation

The transport of interest is equal to the scope of the ETP: outbound transport within Europe. The transport is divided into three types: bulk powder, bulk liquid and packed. All three types have been taken into account in the carbon dioxide calculations. However, analyses are based on bulk powder and bulk liquid because the packed dataset was under development during this study and therefore did not contain information as detailed as in the other datasets.

The transport data has been taken from the award plans. An award plan is the overview of the contracts between Cargill and the logistics service providers. Every three years, the contracts are renegotiated. The time between two consecutive award plans and the number of different award plans (three) indicate that one award plan is negotiated every year. The award plans for bulk liquid and bulk powder were created one and two years ago respectively. The packed award plan was under negotiation during this study.

Most of the products that are sold to customers are delivered by Cargill. However, a part of the products is collected by the customer. For this study, only the products delivered by Cargill are taken into account. The total transport volume (delivered by Cargill) equals 4.7 million tonnes of bulk goods per year and approximately 1.2 million tonnes of packed goods.

For all transport, only the carbon dioxide emissions are taken into account. Carbon dioxide is the gas that receives most attention by governments and the European Union, because the emissions of carbon dioxide have by far the biggest impact on the environment.

2.3 Project approach

Calculating carbon dioxide emissions resulting from transport is not a straight forward task. At the moment of this study, several calculation methodologies, which lead to very different results, existed. A reliable emission calculation depends on a reliable calculation methodology together with reliable data.

Besides the two points mentioned above, this study evaluates different methods for reducing carbon dioxide emissions and evaluates the impact of different regulation scenarios. In addition, during the study, parts have already been implemented into the Green Transport Project at the ETP.

Three research questions have been identified for this study. Each research question is based on one or more of the five points mentioned before: reliable calculation methodology, reliable data, reduction methods, impact of regulations, and implementation.

- *How can carbon dioxide emissions resulting from transport be determined?*
  To determine the carbon dioxide emissions, a reliable calculation methodology is needed together with reliable transport data. A reliable calculation methodology has been developed within the CRSC project. Different existing calculation methodologies have been evaluated and extended where necessary. Based on the calculation methodology a calculation tool has been developed. The tool is able to apply the methodology to a complete transport dataset and present the results of the calculation in a comprehensive way.
  Simultaneously with developing the calculation methodology, transport data has been collected within Cargill. The first part of the data collection focused on the data already available in the ETP. Not all parameters that are needed for the calculation were available. Therefore additional data has been collected using interviews and surveys with logistics service providers and people within Cargill.

- *How can carbon dioxide emissions resulting from transport be reduced?*
  The aim of Cargill is to reduce the emissions from transport. Several reduction options, together with the applicability to Cargill, have been evaluated. The tool has been used to quantify the reduction possibilities with the different reduction options.
  Parts of this project have already been implemented during the project. The calculation methodology and the tool have been used to quantify savings realised by the Green Transport Project and to assess the possible savings on lanes under consideration.

- *How will possible upcoming regulations of the European Union impact transport costs and reduction possibilities?*
  The EU is planning to implement regulations in order to reduce the emissions from transport. At this moment, it is uncertain what this regulation will look like. Therefore, a number of possible scenarios are described, together with the impact these scenarios have for Cargill.

2.4 Report structure

The report follows the project approach. In chapter 3 the calculation methodology and the calculation tool that have been developed are described. Chapter 4 describes the collection of transport data to be used in the carbon dioxide calculation for Cargill. The results of this calculation are described in chapter 5. This chapter also gives some deeper insight into Cargill's transport. The possibilities for reducing carbon dioxide emissions are evaluated in chapter 6. Next, in chapter 7, four possible regulation scenarios are described and the impact for Cargill is evaluated. Finally, chapter 8 draws conclusions and gives opportunities for further research.

3 Emission calculation methodology

The first goal in the CRSC project was to develop an emission calculation methodology. The first step in developing this methodology was to evaluate existing methodologies. This evaluation is described in section 3.1. Next, in section 3.2, the methodology used in this study is described. Section 3.3 describes the calculation tool developed in this study.

3.1 Calculation methodologies to date

As a starting point five emission calculation methodologies have been evaluated. Each of these methodologies is described briefly in this section. Next, the methodologies are compared and the one used for developing the methodology used in this study is chosen.

3.1.1 STREAM

CE Delft is an independent Dutch research and consultancy organization. In 2003, CE Delft, together with RIVM (Dutch National Institute for Public Health and the Environment), presented the study "*To shift or not to shift, that's the question*" (CE Delft, 2003). In this study different transport modes were compared. In September 2008, CE Delft, commissioned by the Dutch ministry of Transport, Public Works and Water Management and the Dutch ministry of Housing, Spatial Planning and the Environment, conducted another study to this topic, titled "*Study on the TRansport Emissions of All Modes (STREAM)*" (CE Delft, 2008 (1)).

In *STREAM*, the 2003 methodology has been used to compare the different transport modes using updated data. Some interesting conclusions were presented in this study. First, the influence of the transport modality is found to be of equal size as the influence of the capacity choice (scale) within a modality. Therefore, the scale of the transport is equally important as the mode of transport. Second, rail transport and inland navigation were found to have slightly lower carbon dioxide emissions on short distance transport and clearly lower carbon dioxide emissions on longer distances compared to road transport. Finally, deep sea navigation is more efficient than other transport modalities only if the vessel is sufficiently large. Short sea navigation is found to be not more fuel efficient than other transport modalities.

3.1.2 GHG Protocol

The Greenhouse Gas (GHG) protocol is an initiative of multiple stakeholders; among others, non-governmental organizations, governments and the World Business Council for Sustainable Development. The aim of the GHG protocol is offering standards and guidelines for organizations preparing a GHG emissions inventory and promoting the broad adoption of these standards and guidelines. Six Kyoto protocol greenhouse gases are covered: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorcarbons (HFCs), perfluorcarbons (PFCs), and sulphur hexafluoride (SF_6) (GHG Protocol, 2004). The protocol is designed around three scopes:

- *Scope 1: Direct GHG emissions*
  GHG emissions from sources that are owned or controlled by the company.
- *Scope 2: Electricity indirect GHG emissions*
  GHG emissions from the generation of purchased electricity consumed by the company.
- *Scope 3: Other indirect GHG emissions*
  GHG emissions from all other (indirect) activities, such as transport.

If a company chooses to report GHG emissions according to the GHG Protocol, scope 1 and 2 are obligatory and scope 3 is voluntary.

For determining the carbon dioxide emissions from transport, the GHG Protocol defines two methods. The most precise one is based on the amount of fuel used. If this information is not available, which is the case in most situations, the emission can be calculated based on the distance travelled and the type of vehicle used. More detailed information (such as load factor) is not included in the calculation (GHG Protocol, 2005).

3.1.3 EcoTransIT

The Ecological Transport Information Tool (EcoTransIT) is an internet tool to compare the environmental impact of different transport modes. The methodology was developed by IFEU (Institut für Energie- und Umweltforschung) in cooperation with a number of railway companies. The data is discussed and harmonized with NTM, discussed in the next section.

EcoTransIT calculates the carbon dioxide emission by defining a number of types of cargo and types of vehicles. For every vehicle it is possible to set the load factor and the empty trip factor (transport needed to position the transport vehicle; see section 3.2.1.3 for more information on this). For every type of cargo and type of vehicle, EcoTransIT has defined average values which are used in the calculations. The internet tool of EcoTransIT is combined with a route planner to enable entering departure and arrival addresses (EcoTransIT, 2008).

3.1.4 NTM

Network for Transport and Environment (NTM: Nätverket för Transporter och Miljön) is a Swedish non-profit organization aiming at establishing common values to be used for calculating the environmental impact of different transport modes. The common values can be used to estimate parameters that are not known within the organization. The more parameters are known the more 'real' data can be used and the more accurate the calculations will be.

For road transport, data of the Handbook Emission Factors for Road Transport (HBEFA) and ARTEMIS are used (NTM Road, 2008). ARTEMIS is a project of the European Union and is described in the next section.

Data for rail transport is based on EcoTransIT (NTM Rail, 2008), discussed in the previous section. For water transport, data of several shipping companies at Lighthouse is used (NTM

Sea, 2008) and the data for air transport is based on computations made by FOI (Totalförsvarets forskningsinstitut) (NTM Air, 2008).

In calculating the environmental impact of different transport modes, NTM defines three levels of detail. Level 1, the smallest level of detail, calculates the average vehicle, engine type, fuel type and load factor for the entire company and assumes all transport is performed with this vehicle. Level 2 adds different types of vehicles and defines an average engine type, fuel type and load factor for every vehicle type. Level 3 adds even more detail and calculates the carbon dioxide emission for every single vehicle of the company (NTM Brief, 2008). This holds for all transport modes.

For level 1 and level 2 calculations a software tool, NTM Calc, can be used. For level 3 calculations, company's specific computer support is needed (NTM Road method, 2005).

3.1.5 ARTEMIS

ARTEMIS (Assessment and Reliability of Transport Emission Modelling and Inventory Systems) is a project aimed at developing a harmonised model for emissions from road, rail, air and water transport. The project has been funded by the European Union.

Prior to the start of the project, other parties had investigated the emissions related to transport. The results of the projects of these other parties differed quite a lot. Because the emission of greenhouse gases is one of Europe's main political concerns, the European Union needed a study that provided emission factors that are reliable, accurate, consistent and credible (ARTEMIS, 2007).

ARTEMIS has been developed to calculate country-specific emissions. Using a software package with a database containing data per country, one can calculate carbon dioxide emissions for road, rail, water and air transport. In these calculations, the level of detail that is needed is very high compared to other methods of calculating emissions.

3.1.6 Comparison

CE Delft is a method for comparing emissions of different transport methods using emissions valid for Dutch transport. The other methodologies describe methods for calculating emissions of specific transport movements. These methods can be ordered in increasing level of detail (for transport related emissions):

- GHG Protocol: makes a very rough estimation of emissions based on the vehicle type and the distance travelled.
- EcoTransIT: uses the parameters as in GHG, but also incorporates the load factor and empty-trip factor into the calculation.
- NTM: uses the data as in EcoTransIT and adds a larger amount of vehicle types, fuel type, fuel quality and the possibility of calculating the emissions on a large number of levels of detail.
- ARTEMIS: uses the data as in NTM, but adds more detail such as traffic situations, operational aspects (e.g. driving conditions) and even more vehicle types.

For this study NTM is used as a basis, because NTM offers the possibility to easily vary the level of detail of the data used and contains the minimum level of detail needed for an accurate calculation. Furthermore, NTM offers the opportunity of adding or changing parameters and values. ARTEMIS is too detailed (contains a lot of parameters that cannot be collected effectively within a company) and cannot be easily adapted to use assumptions, like NTM. Furthermore, ARTEMIS is aimed at calculating emissions of a country and not of a company.

NTM, however, is adapted during the study, because a number of parameters (such as cleaning, heating, etc) is not taken into account in the total emission figure in the NTM methodology. Furthermore, parameter assumption are checked and updated if needed.

3.2 Project calculation methodology

This section describes the methodology that is used to calculate the carbon dioxide emissions resulting from transport. First, general parameters are discussed and then the methodologies to calculate the emissions for the four different transport modalities are given. The calculation methodology is mainly based on the NTM methodology (NTM Air, 2008; NTM Rail, 2008; NTM Road, 2008; NTM Sea, 2008). First the emissions for the total means of transport (truck, train, vessel or aircraft) are calculated and then these emissions are allocated to the cargo of interest.

In the methodology several average values are given and assumptions are made. It is very important to keep in mind that these values and assumptions are only used if no actual data is available. The use of actual data will always lead to at least equally reliable and mostly even more reliable and accurate results.

3.2.1 Transport parameters

Transport parameters that are used for more than one modality are described in this section. Specific issues with these parameters and parameters that are unique to one transport modality are described later on in this chapter.

3.2.1.1 Load factors

For road, water and air transport, load factor is defined as the percentage of the capacity of the vehicle used, where capacity is expressed in weight, lane metres or twenty-foot equivalent units. The way of expressing the capacity for each modality is explained later in this chapter. Because of practical reasons (modularity), load factor is defined differently for rail transport. Here, load factor is defined as the ratio of the net-weight of the cargo to the gross weight of the train.

In road and air transport the value of the load factor is used both in calculating the carbon dioxide emissions and in allocating the emissions to the cargo. In the rail and water transport methodologies the load factor is only used in allocating the overall carbon dioxide emissions to the company cargo.

In the following sections the average load factor values that are used in case no actual data is available are described for each transport modality.

Air transport

Two types of aircrafts are used for cargo transport: dedicated cargo aircrafts and combined passenger/cargo aircrafts. For cargo aircrafts a single load factor indicating the capacity utilisation is necessary. In combined passenger/cargo aircrafts both a load factor for the passenger part of the aircraft and a load factor for the cargo part of the aircraft are needed to divide the emissions between passengers and cargo.

NTM Air (2008) does not give average load factor values. Therefore, field data has been collected. Based on this data, an assumption about the average load factor values for air transport has been made. The load factor for cargo transport is assumed to be 80 percent and for passenger transport the load factor is assumed to be 85 percent. The case study included an airline company and a logistics service provider.

Rail transport

Assumptions for the load factors of trains are based on the data from EcoTransIT (EcoTransIT, 2008, which is also used by NTM) and summarised in Table 1.

Type of cargo	Load factor
Bulk cargo	0.72
Average cargo	0.58
Volume cargo	0.44

Table 1: load factors for rail transport

Road transport

NTM distinguishes between frequent and single shipments and suggests the following load factors for road transport:

- Frequent shipments: the transport is carried out repeatedly on the same route. The load factor is 75 percent.
- Single shipments: the transport is carried out once. The load factor is 50 percent.

Water transport

The load factor of a vessel is calculated according to the unit that is used for expressing the capacity. For tankers and bulk carriers the unit is tonnes, for container vessels it is twenty-foot equivalent units and for Ro-Ro cargo vessels and ferries it is lane meters.

Apart from the different vessel types, vessel transport is subdivided into two categories: water direct and water shuttle. Based on NTM (NTM Sea, 2008), load factors have been set for each category. The load factors are shown in Table 2.

Type of transport	Load factor
Water direct	0.80
Water shuttle	0.50

Table 2: load factors for water transport

3.2.1.2 Terrain factor

Transport in mountainous areas has higher fuel consumption than transport in flat countries. Therefore, a terrain factor is used in the calculations of the carbon dioxide emissions. This terrain factor only holds for rail and road transport, because water and air transport do not have to cope with terrain differences. NTM defines three categories: flat countries (Denmark, Sweden and The Netherlands), mountainous countries (Austria and Switzerland) and hilly or average countries (all other countries in Europe). NTM proposes different terrain factors for rail and road transport.

In the calculation for rail transport, as described in section 3.2.3, the emissions for hilly countries need no adjustment. Emissions increase with 20 percent for mountainous countries and decrease with 20 percent for flat countries (NTM Rail, 2008).

In the calculation for road transport, as described in section 3.2.4, the emissions for flat countries need no adjustment. Emissions increase with 5 percent for hilly countries and increase with 10 percent for mountainous countries (NTM Road, 2008).

3.2.1.3 Positioning

In many cases, the means of transport is not at the same location as the cargo. As a result, the means of transport has to be transported to the cargo location. The distance travelled by the means of transport, in order to reach the cargo location, is called positioning distance. In case of rail, water and air transport, the positioning distance is often zero, because the cargo is transported to the location of the means of transport (terminal or (air)port).

In the next section, the way positioning is included in the emission calculations for the different transport modalities, is described.

Air transport

NTM assumes that air transport is always operated using scheduled flights, which means that there are no positioning distances. Data of the companies included in the case study confirmed this assumption. Therefore, this assumption is used in this project as well.

Rail transport

The NTM methodology does not give any information about including emissions from positioning in rail transport. In academic literature no information about this subject can be found either. Two international rail cargo companies have been asked whether they could give any information about positioning. The rail companies indicated that it was hard to give a reasonable figure for this, but they indicated that in most cases the positioning distance is negligible in comparison to the total distance (because much rail transport is operated on schedule on a fixed route). Therefore it is assumed that there is no positioning in rail transport.

Road transport

For road transport, NTM gives different values for average positioning distances for frequent and single road transport. Transport data of three companies, with each at least 100 lanes (both frequent and direct transport), showed average positioning distances of 25, 24 and 16 percent. This is in line with the NTM assumption of 20 percent positioning distance for frequent road transport.

For single road transport, NTM does not provide a reliable assumption. Based on the company data, without distinction between different transport modes, the assumption of 20 percent is used in this case as well.

Water transport

Water transport is often operated on fixed routes, where there is no need for positioning. However, in some cases there is positioning in case of tramp traffic (transport on non-regular routes). However, tramp traffic does not occur very often and company data, from the case study, does not show any example for tramp traffic. Therefore it is assumed that there is no positioning for water transport.

Allocation

Who should take responsibility for the emissions from positioning can be debated. Some argue that the logistics service providers are responsible for the emissions, using the following reasoning:

- Logistics service providers can combine different shipments, so theoretically they can take a shipment on the route to pick up another shipment. If the logistics service provider does not do this, it is its own responsibility and therefore the logistics service provider is responsible for the emissions resulting from positioning.
- The customer requests a shipment from a certain origin to a destination. Whatever happens before or after the transport is the responsibility of the logistics service provider and the customer cannot influence it.

Others argue that the customers are responsible for the emissions resulting from positioning because:

- The customer chooses the logistics service provider and in this choice the customer can take into account the distance between (the nearest hub of) the logistics service provider and the location where the cargo has to be picked up. This means that the customer can influence the emissions from positioning and is therefore responsible for the emissions.
- The logistics service provider is not able to find a shipment on the route to pick up the customer's shipment in most cases, due to the relatively small positioning distance.

In this study, carbon dioxide emissions resulting from positioning are included in the total emission calculation. Based on discussions with stakeholders it can be concluded that the latter arguments outweigh the former arguments.

3.2.1.4 Empty return trips

After transporting a shipment from the origin to the destination, usually the equipment has to return to the origin where the shipment was picked up or to the logistics service provider. Sometimes another shipment is taken on the way back and sometimes the means of transport is returning empty: the latter is called an empty return trip. During an empty return, no cargo is transported, so the emissions need to be allocated in a different way.

Allocating the emissions from empty return trips is subject to the same discussion as described in the section on positioning. In this project it is assumed that when the transport is dedicated to the customer on request of the customer, the emissions from empty return trips are allocated to the customer. However, if the logistics service provider has the possibility to take another shipment on the return trip, the emissions are allocated to the logistics service provider, no matter whether the logistics service provider takes another shipment or not.

Trade imbalances

In case of container transport sometimes containers have to be transported empty because of trade-imbalances. For example, in general there is more cargo transport from Asia to Europe than from Europe to Asia, which means that there is a surplus of containers in Europe and a shortage in Asia and that containers have to be transported empty from Europe to Asia. As described in the previous section, empty returns are only taken into account if equipment is dedicated on customer's request.

3.2.1.5 Cleaning

In several industries the equipment has to be cleaned prior to usage to prevent contamination. This is the case in most of the bulk food industries where food resources are transported, for example sugar and cacao. Based on a case study involving four members of the European Federation of Tank Cleaning Organisations (the Belgian, Dutch, Italian and Swedish agencies) the conclusion can be drawn that cleaning is in most cases performed using steam. The steam is always generated by burning fossil fuels. Based on the case study it is assumed that an average of 680 Mega Joules of steam (equivalent to 2 cubic metres at 90 degrees Celsius) is needed for cleaning one unit (i.e. container). The process of burning natural gas to get this amount of energy (for cleaning one unit) leads to an emission of 38 kilograms of carbon dioxide. In the calculation of the emissions, this fixed value is used for steam cleaning.

3.2.1.6 Heating

There are several products that need temperature control during or after the transport of the product. The methodologies to determine the extra emissions resulting from temperature control during and after transport are different and therefore they are discussed separately below.

During transport

Certain products need to be kept at a specified temperature because otherwise they can deteriorate or their physical properties can change. There are three methods of temperature control during transport, this can be heating, cooling or freezing. These three categories are discussed separately:

- Heating: products usually are heated to prevent a change of physical property (this occurs if the temperature falls below a certain level). Heating during transport is not used very often and no relevant information is found, so therefore no average value is given. Heating at terminals is not considered as heating during transport.
- Cooling: cooling is a way of temperature control to keep the product within a specific temperature range above zero degrees Celsius. This is often necessary in food, beverage and medical industries where products often deteriorate at higher temperatures. Field values show an average increase in fuel consumption of 25 percent in case of cooled transport and this value is used in the calculations. The calculations take into account that the temperature control is using the truck engine, in reality other methods are available (i.e. auxiliary power unit) but these are not considered in this study.
- Freezing: freezing is a way of temperature control to keep products within a specific temperature range below zero degrees Celsius. This is necessary for all frozen products, like ice-cream. Two average values for the increase in fuel consumption due to freezing during transport were obtained: McKinnon and Campbell (1998) give a value of 26 percent and a logistics service provider gives a value of 20 percent. Therefore an average value of 23 percent is used in the calculations. The value for freezing is smaller than the value for cooling due to colder loading and better isolation.

After transport

Temperature control after transport means that the product is cooled or heated after it has been transported. In practice it hardly occurs that a product is cooled after transport and therefore this is not taken into account in this study. Heating after transport on the other hand is used in several cases in practice. For example, several liquids do not change permanently by the reduced temperature but are hard to extract from the transport equipment at lower temperature due to increased viscosity.

Based on a case study among five service providers it is concluded that the main method of increasing the temperature after transport is steam heating and that a small percentage of containers is heated electrically. The steam is generated by using fossil fuels (i.e. natural gas). Based on the case study an average value of 22 kilograms of carbon dioxide per container has been determined and this value is used in the calculations. In practice this value is subject to several parameters, such as the weight of the product and the temperature increase. However, because no data is available for these different factors, an average value is used.

3.2.1.7 Vertical handling

Intermodal transport is the transport of cargo using multiple modes of transport without any handling of the product itself (like sorting and repacking) when changing modes. In most cases the cargo is packed in containers or on pallets and the containers or pallets are handled. This handling takes place at a terminal and is called vertical handling.

Containers

Normally, vertical handling of containers is operated in one of two ways: by a crane or by a reach stacker. A crane can be powered using electrical energy or using a diesel engine. Reach stackers are powered by a diesel engine in most cases.

Vertical handling itself consumes energy and thus leads to extra carbon dioxide emissions. To assess the importance of taking vertical handling into account, the emissions need to be quantified. Two transport terminals have been contacted to find an average carbon dioxide emission of a reach stacker and this value can be found in the table below. For the emissions of a crane, the average value of a report by IFEU is used (IFEU, 2001) and these values can be found in Table 3 below.

Handling equipment	**Average CO_2 emission (tonne/handling)**
Crane	0.002
Reach stacker	0.007

Table 3: CO_2 emission per handling

To come up with final values that can be used in the calculation, another assumption has been made: moving a container from water transport to road, rail or water transport and vice versa is performed with a crane. All other types of vertical handling are assumed to make use of a reach stacker.

Pallets

In case of pallets, forklifts and pallet jacks are used for handling. For forklifts and pallet jacks, no reliable data could be obtained. It is assumed that this type of vertical handling emits the same amount of carbon dioxide as a reach stacker. The emission per handling (per pallet) is lower, but more handlings are needed to empty or load one truck.

3.2.2 Air transport methodology

In this section the methodology that is used for calculating the carbon dioxide emissions from air transport is described. In this section a general description of air transport is given, followed by air transport specific parameters that are used in the calculation. Next, the calculation formula is given and finally the assumptions that are used are described and discussed.

Air transport is defined as all cargo that is transported by an aircraft through the air. Air transport has the advantage that it is very fast and therefore has a low delivery time for transport over large distances. However, one of the disadvantages is that it has higher fuel consumption and, with that, more carbon dioxide emissions per tonne kilometre compared to the other transport modalities.

Cargo that is transported via air can be transported in two ways:

- In a dedicated cargo aircraft
- In the cargo hold of a passenger aircraft (this is called belly cargo)

The calculation of the carbon dioxide emissions from air transport is, if not stated differently, based on the NTM air methodology (NTM Air, 2008). For the calculation the following parameters are necessary:

- Type of aircraft
- Load factor
- Weight of the shipment
- Distance

The parameters specific to air transport that need additional explanation are described in the next section.

3.2.2.1 Mode specific parameters

If no distance is given but the origin and destination are known, the distance can easily be calculated using the great circle distance (GCD). The formula for this is:

$$D = acos\left(sin(lat1) \cdot sin(lat2) + cos(lat2) \cdot cos(lon1 - lon2)\right) \cdot 6371$$

where:
D Transport distance in kilometres
lat1 Latitude of the origin location
lon1 Longitude of the origin location
lat2 Latitude of the destination location
lon2 Longitude of the destination location

3.2.2.2 Calculation

The emissions during takeoff and landing of an aircraft are relatively high compared to the emissions during the part of the flight where the aircraft is cruising. Therefore, the calculation of the total emission is split up into two parts: the constant emission part (which corresponds with the emissions during takeoff and landing) and the variable emission part (which corresponds with the emissions per kilometre during cruising). The total emission of an aircraft can be calculated using the following formula (NTM Air, 2008):

$$TE = CEF + VEF \cdot D$$

Where:
TE Total Emissions in kilograms
CEF Constant Emission Factor in kilograms
VEF Variable Emission Factor in kilograms per kilometre
D Transport distance in kilometres

The NTM methodology gives different values for the constant and variable emission factors for several aircrafts and for different load factors. In case of dedicated cargo aircrafts the values are given for load factors of 50, 75 and 100 percent.

In order to be able to use load factors that are different than the three given above, NTM provides interpolation formulas. Below the interpolation formula for calculating the constant emission factor is shown (NTM Air, 2008). Interpolation for the variable emission factor is done in the same way.

$$CEF_{x\%} = \frac{CEF_{y\%} + \left(CEF_{z\%} - CEF_{y\%}\right)}{(z\% - y\%) \cdot (x\% - y\%)}$$

In the formula, x is the load factor for which the constant emission factor needs to be calculated, y is the load factor smaller than x for which the constant emission factor is known and z is the load factor larger than x for which the constant emission factor is known.

The total emission calculated above needs to be allocated to the cargo that is transported. In air transport, allocation is based on weight, because weight is the main factor determining the amount of carbon dioxide emissions.

The allocation can be done based on physical weight or on volumetric weight. In the air transport industry the generally used conversion factor for volumetric weight is 167 kilograms per cubic meter. In the cases where the volumetric weight is larger than the physical weight, the volumetric weight is used for the allocation (NTM Air, 2008).

3.2.2.3 Assumptions

The assumptions specific for air transport are described in this section.

Linearity between emissions for different load factors

As was described in the calculation paragraph above, using the interpolation formula assumes linearity between emissions for different load factors. NTM indicates that this actually is not the case. However, because linearity between smaller intervals is used (between 0 and 50 percent, between 50 and 75 percent and between 75 and 100 percent), the effect of this assumption is smaller than assuming linearity between 0 percent and 100 percent.

Type of fuel

It is assumed that all aircrafts use JetA-1 fuel. JetA-1 fuel is the most commonly used fuel in air transport.

3.2.3 Rail transport methodology

Rail transport is defined as cargo transport over land using railroad tracks. There are two types of trains that can be used, either diesel or electricity powered locomotives. At the European continent rail transport is most often carried out by national railway operators active within national borders. In some cases, this means that the train has to stop at the border to switch locomotives (NTM Rail, 2008). Furthermore, not all countries use the same track width and this means that the carts should be changed at the border (this is seen as vertical handling). There are several parameters that influence the emissions during rail transport and these are discussed below, followed by the calculation and the assumptions.

3.2.3.1 Mode specific parameters

General transport parameters were discussed in the beginning of this chapter. Rail transport has several specific transport parameters, which are discussed in this section.

Traction type

The engine type of the locomotive is one of the most influential parameters for the carbon dioxide emissions. Usually it is not known which part of the route is carried out by a diesel locomotive and which part by an electric locomotive. In the assumptions section below it is stated how the methodology deals with this lack of information.

Size of the train

The size of the train is defined as the gross weight of the total train. This is the weight of the train and all cargo on it. In the calculations the specific gross weight of the train is used. If this is not available the user will have to use one of the train sizes as specified in NTM; short (500 tonnes), average (1000 tonnes) and long (1500 tonnes). (NTM Rail, 2008).

Type of cargo

Another factor that should be taken into account is the type of cargo that is transported. For products with a low density, the capacity is limited by volume while the capacity limitation for high density products is weight.

Electricity generation

In case an electric locomotive is used, the emissions during transport depend on the way the electricity is generated. The method of electricity generation varies per country and can lead to significant differences in emissions. In Europe the carbon dioxide emission factors for electricity generation vary between 0.00 kg/kWh (Norway, hydropower) and 0.94 kg/kWh (Poland, coal) (NTM Rail, 2009).

3.2.3.2 Calculation

This section gives the formulas for the emission calculation for both diesel and electrical trains. First the formulas for both calculations are given, followed by the explanation of the symbols used.

The formula used for diesel transport:

$$TE = W_c \cdot D \cdot \frac{EF_{CO_2}}{1 \cdot 10^6} \cdot \frac{153.07 \cdot c_t \cdot W_{gr}^{-0.5}}{LF}$$

For electrical trains, the formula is given by:

$$TE = \sum_z W_c \cdot D_z \cdot \frac{EF_{z,CO_2}}{1 \cdot 10^6} \cdot \frac{675 \cdot c_t \cdot W_{gr}^{-0.5}}{LF \cdot (1 - TL)}$$

Where:

TE	Total emission for the customer's cargo (tonne carbon dioxide)
W_c	Weight of the customer's cargo (tonne)
D	Transport distance (kilometre)
EF_{CO2}	Emission factor for diesel (kilogram carbon dioxide per kilogram diesel)
$EF_{z,CO2}$	Emission factor for electricity generation in country z (kilogram carbon dioxide per kilowatt hour)
c_t	Terrain factor as explained above

W_{gr}	Gross weight of the total train (tonne)
LF	Load factor
TL	Electricity lost due to transportation losses
z	Country

The total emission for diesel trains is based on the weight of the company cargo multiplied with the distance travelled. This is multiplied with the emission factor for diesel. The last part of the formula is the calculation of the energy usage per tonne cargo. This is based on the load factor of the train and the total weight of the train.

For the electric rail emissions the formula is more or less the same, the only difference is that the formula is summed over all the countries. This is done because the emission factor is based on the method for electricity generation in each country.

Eurotunnel train

A special type of train is the Eurotunnel train between Coquelles (France) and Folkestone (Great-Britain) since the total emissions are more or less the same on each trip, slightly varying with the load of the train. The Eurotunnel has a length of 50.5 kilometres. There are two types of trains in the Eurotunnel: passenger trains and cargo trains. Both are electrical trains. Since the beginning of 2008 al electricity is fed from the French electric sub-station.

A cargo train in the Eurotunnel has an average length of 720 metres and weighs maximally 4000 tonnes when loaded. All of the cargo is loaded onto the train in trucks; the cargo is never unloaded from the trucks. The trucks can maximally be 18.75 meters long (with a maximum height of 4.2 meters and a maximum width of 2.6 meters) and the weight of the truck can maximally be 44 tonnes.

3.2.3.3 Assumptions

Most assumptions in the rail transport calculation have been made in the transport parameters section. An assumption specific for rail transport is the amount of electric trains and diesel trains used.

Diesel-electrical split

In most countries in the European Union, electrical locomotives are used. However, some parts of the railway system do not have overhead lines. On these parts, or on entire transport routes containing such parts, diesel locomotives are used. For companies it is often hard to obtain data on the diesel-electrical split of rail transport. Therefore an assumption has been made. Based on European rail transport data of the year 2005 (Eurostat, 2009), it is assumed that 75 percent of rail transport is electrical. This means that if no data is available for the percentage of electrical emissions the emissions will be calculated based on the diesel emission formula multiplied by 0.25 and adding the emissions calculated based on the electrical emission formula multiplied by 0.75.

3.2.4 Road transport methodology

Road transport is defined as transport over road. Road transport services are carried out around the world with vehicles ranging from small distribution vans to long road trains. Road transport has the advantage that it is very flexible and has the ability to reach remote locations. On the other hand, the loading capacity is limited by regulations and there might be increasing congestion problems for some regions.

3.2.4.1 *Mode specific parameters*

In addition to the general transport parameters described in the beginning of this chapter, this section describes parameters specific to road transport.

Vehicle type

Road transport can be operated using different vehicle types. Ten different vehicles are identified, from a small pick-up van to a large 60 tonnes (combined weight of truck and cargo) truck-trailer combination.

Road type

Road transport can be operated on different road types. Based on the NTM methodology (NTM Road, 2008), three road types are used: motorways, urban roads and rural roads.

3.2.4.2 *Calculation*

For each vehicle type on each road type, fuel consumption values for empty and fully loaded vehicles are given. To calculate the fuel consumption of the specific vehicle and load factor, the following formula is used:

$$FC_{LF} = FC_{empty} + \left(FC_{full} - FC_{empty}\right) \cdot LF$$

Where:

FC_{LF}	Fuel consumption at the specified load factor (litres per kilometre)
FC_{empty}	Fuel consumption of the empty vehicle (litres per kilometre)
FC_{full}	Fuel consumption of the fully loaded vehicle (litres per kilometre)
LF	Specified load factor

The total carbon dioxide emission is directly related to the fuel consumption:

$$TE = FC_{LF} \cdot D \cdot EF_{CO_2}$$

Where:

TE	Total carbon dioxide emission
FC_{LF}	Fuel consumption at the specified load factor (litres per kilometre)
D	Distance (kilometres)
EF_{CO2}	Emission factor for fuel (kilogram carbon dioxide per litre fuel)

In case of heating, cooling or freezing during transport, the fuel consumption increases. The values have been described before.

In case the company cargo is only part of the cargo transported using the vehicle, the emissions should be allocated to the cargo. Allocation is either based on weight or on volume (volumetric weight); therefore two steps can be used:

Step 1: Compare the physical weight of the cargo to the volumetric weight (volume multiplied with 250 kilograms per cubic metre)

Step 2: Allocate based on the highest value

3.2.4.3 Assumptions

The assumptions specific to road transport are described in this section. The assumptions described in the transport parameters section are also valid for road transport.

Load factor linearity

A truck that transports a heavier load has higher fuel consumption due to increased rolling resistance and dynamic weight. In this methodology, the increase in fuel consumption is approximated by a linear function.

Traffic situations

The fuel consumption values for different road types is extracted from ARTEMIS and based on multiple roads within each road type. The fuel consumption values are averages for Europe and do not take into account differences between countries or specific traffic conditions.

Idling of the truck

The fuel consumption resulting from idling of the truck is not taken into account in the carbon dioxide emissions calculation from road transport.

Speed and driver behaviour

Speed and driver behaviour influence the fuel consumption. These factors are not considered in this methodology. The reason not to consider this part is because it varies per driver and per route. The values used in the calculations lead to an average emissions under average driving behaviour.

3.2.5 Water transport methodology

Water transport is defined as transport over sea or inland waterways with diesel-oil powered vessels. To calculate the carbon dioxide emissions from water cargo transport, several parameters are taken into account. These parameters are described in the next section.

3.2.5.1 Mode specific parameters

The type of vessel has a large impact on the carbon dioxide emission. Each vessel is unique in its fuel consumption, but since vessel information is often hard to obtain, several general vessel types have been used. These vessel types have been taken from the NTM methodology (NTM Sea, 2008). Most vessels have a main engine that produces the power to move the vessel and one or more auxiliary engines that are used for electricity generation that is used by the crew and passengers.

Real values for load factor and average cruise speed are hard to obtain. Furthermore, the impact of a change in these parameters on the fuel consumption is hard to predict, because this differs for each individual vessel. NTM has chosen to use default values for load factor and speed and to give a vessel's fuel consumption per kilometre based on these default values.

For vessels used in inland waterways, three fuel consumption values are given; upstream transport, downstream transport and an average value.

3.2.5.2 Calculation

Based on the vessel type, the fuel consumption value is given. This fuel consumption value is multiplied by the distance and the carbon content of the fuel and this results in the carbon dioxide emissions for the vessel.

$$TE = FC \cdot D \cdot EF_{CO_2}$$

Where:

TE	Total carbon dioxide emission
FC_{LF}	Fuel consumption (tonnes per kilometre)
D	Distance (kilometres)
EF_{CO2}	Emission factor for fuel (kilogram carbon dioxide per tonne fuel)

The total emission needs to be allocated to the cargo of different companies that is transported by the vessel. Allocation is done in different ways for different vessel categories:

- Bulk vessels: vessels used to transport bulk cargo in tanks or holds. The allocation is based on weight.
- Container vessels: vessels used to transport containers. The allocation is based on the number of twenty-foot equivalent units (TEU), which are containers with a length of twenty feet.
- Roll-on/Roll-off vessels (RoRo): vessels used to transport trucks or train carts which can drive on and off the vessel. The allocation is based on lane metres (lanem), so the length of all lanes on the vessel.

With the basis for allocation known, the allocation is done by dividing the capacity used for the company cargo by the total used capacity (one of the three capacity types as described above) and multiplying this value with the total emission of the vessel calculated in the previous step.

A problem with this way of allocating emissions to cargo occurs if a vessel transports multiple kinds of cargo and/or passengers In this case the total emission is divided equally between the number of decks and for each deck the allocation is done using the method described above.

3.2.5.3 Assumptions

In the above description of calculating carbon dioxide emissions from water transport, four assumptions are used. This section discusses these assumptions.

Load factor and speed are fixed

For each vessel type the fuel consumption is given for a fixed load factor and a fixed average speed. In reality, an increase in load factor or speed will result in an increase in the fuel consumption.

Only main engine taken into account

The main engine is the engine that generates power to move the vessel. This engine consumes most of the fuel. The fuel consumed by the auxiliary engines depends on the vessel size and type. A passenger ferry that offers entertainment to its passengers will consume a lot more energy than a bulk vessel with only a small crew. Taking the auxiliary engines into account will increase the carbon dioxide emission of the vessel.

Allocation of mixed-cargo vessels based on number of decks

Allocating carbon dioxide emissions evenly over multiple decks assumes that the impact on fuel consumption of all decks is equal. It seems obvious that this is not true in most cases, since most of the time a specific deck will have a larger impact. However, specific information on the impact on fuel consumption is missing and therefore the effect of this assumption cannot be estimated.

Inland waterways use average flow conditions

Water transport via inland waterways depends on more parameters than used in the calculation. Besides load factor, speed and auxiliary engines, the flow of the inland waterway also influences the fuel consumption. The flow of an inland waterway, in turn, depends on the season, the depth of the inland waterway, the location in the inland waterway (more upstream the current will be stronger), the direction of travel (upstream or downstream) and the waterway itself. Only the direction of travel is taken into account in the value for the fuel consumption. The values for upstream and downstream fuel consumption are averages of different waterways and different locations on the waterway.

3.3 Calculation tool

A calculation tool has been developed to apply the methodology to a complete transport dataset. In the tool a distinction is made between a lane (from origin to destination), a phase (part of a lane performed with one modality) and a route (different ways to operate a lane). This distinction is shown in Figure 1. This terminology is used in the same way in the remainder of this report.

The tool has been developed using Microsoft Access. To make it easier to use this tool, a user interface has been developed as well. The first screen of this user interface is shown in Figure 2.

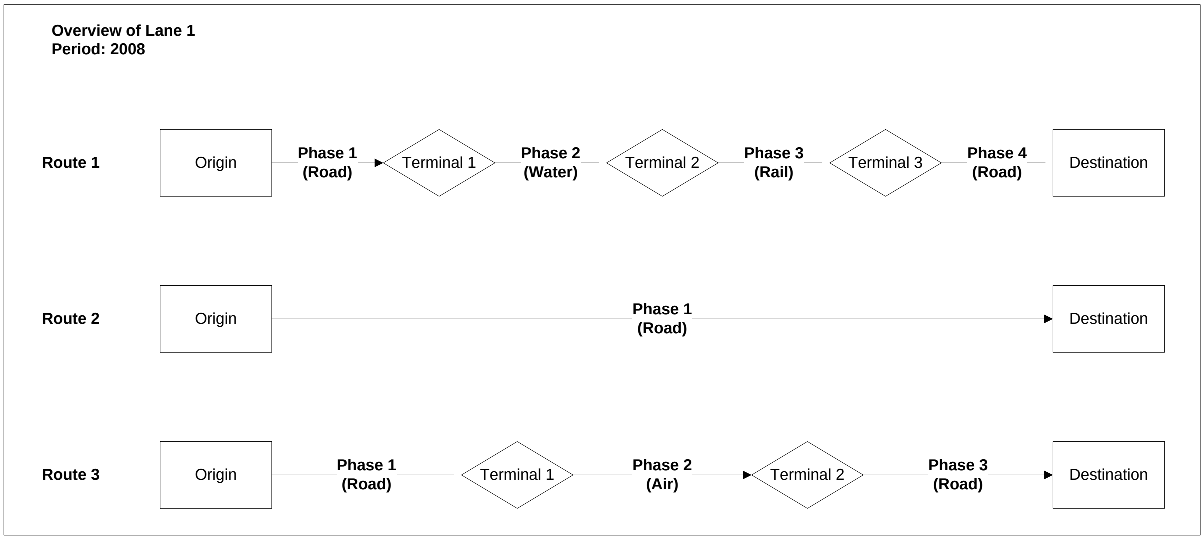

Figure 1: overview of a lane

The functionality of the tool can be summarised by the following points:

- Import dataset from Excel
- Calculate emissions from (imported) dataset
- Show emissions per modality in a report, sorted by lane, destination, logistics service provider, etc.
- Change the parameter values used in the calculation
- Perform a comparison of two routes on a lane

All carbon dioxide emission calculations for this study have been performed using the tool. A complete description and user manual can be found in the general report (CRSC Report, 2009).

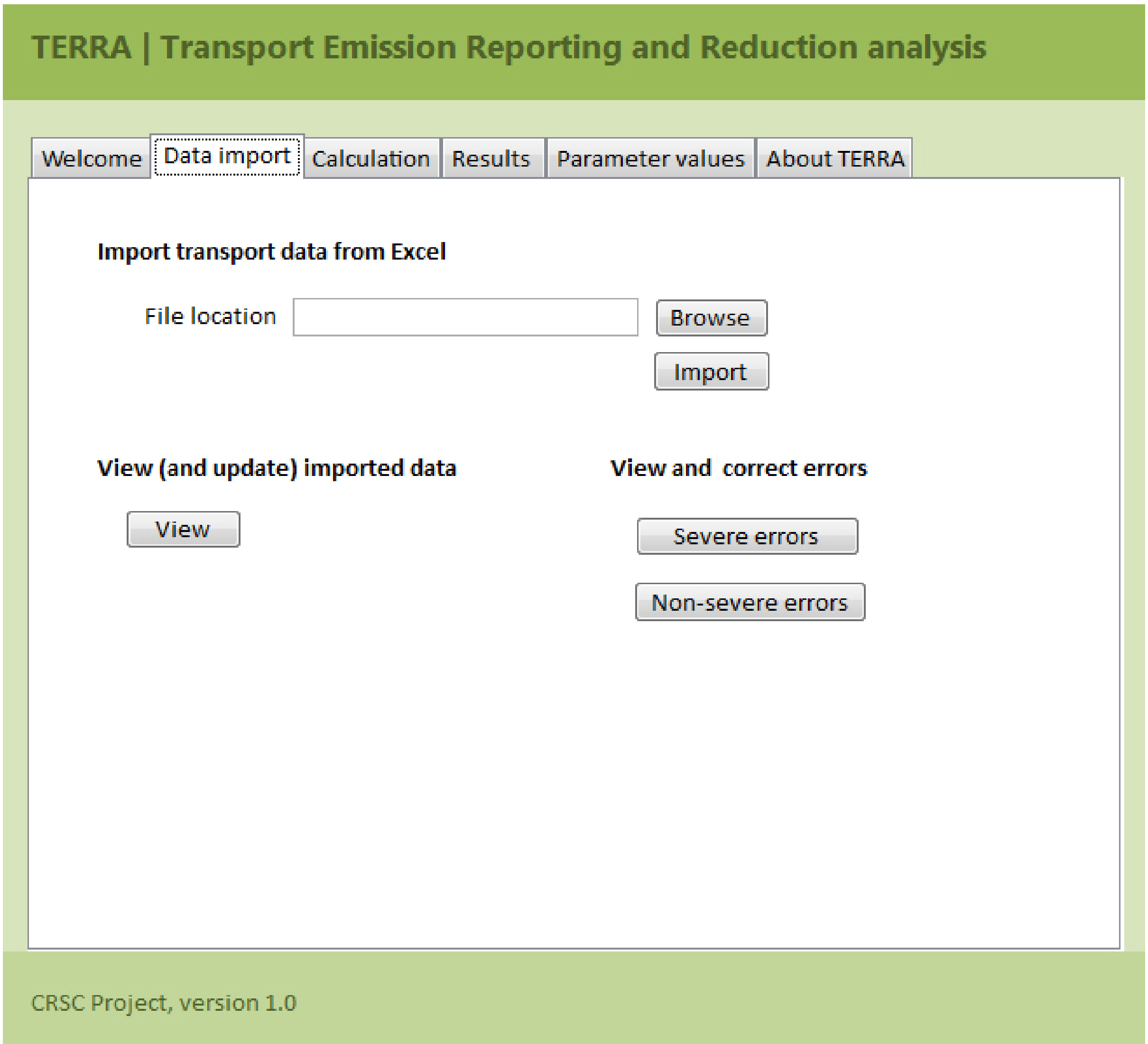

Figure 2: main screen TERRA calculation tool

4 Data collection

In order to make a carbon dioxide emission calculation for Cargill using the methodology described in the previous chapter, data of all Cargill's transport movements is needed.

This chapter describes which data was already available and which data needed to be collected externally. Next, the method used for collecting data and the problems encountered are described.

4.1 Data available and data collected

The calculations are based on the award plans available in the ETP. For each lane, these award plans contain data about the origin, destination, logistics service provider, number of transport movements, annual weight of cargo and transport material (trailer or container). For the bulk products, the award plans contain data about the distances for road transport. For packed goods this data is not available.

4.2 Method for collecting additional data

This section starts with an evaluation of which parameters to collect externally. The method for collecting these parameters is described in the second part.

4.2.1 Parameters to collect

As a first step in collecting additional data, a list of all parameters that could be used in the calculation was created. This list was split into two parts: the parameters that are required for the calculation and the optional parameters that increase the accuracy of the calculation.

The parameters that needed to be collected are the transport mode used and the distance per transport mode.

For the optional parameters, a trade-off needed to be made between collecting as many data as possible on a smaller number of lanes and collecting fewer parameters on all lanes. Collecting all data on all lanes provides the logistics service providers with a lot of work and therefore the response rate was expected to drop. To be able to make this trade-off, the impact of all parameters on the final results has been evaluated using data collected from two logistics service providers (both operating a large number of lanes for Cargill) prior to the data collection of all lanes. The next sections describe all parameters and the trade-offs made. These sections are summarised in Table 4.

Parameter	**Collect/assumption**	**Reason**
Transport mode	Collected	Required for calculation
Distance per mode	Collected	Required for calculation
Transport vehicle	Assumption: only type collected	More specific data unkown
Positioning distance	Assumption: 20 %	Minor influence on result
Empty returns	Assumption: no empty returns	Almost real situation
Heating	Assumption: no heating	Unknown for aggregated data
Cleaning	Assumption: all bulk	Almost real situation

Table 4: parameters to collect / assumptions

4.2.1.1 Positioning distances

The data on positioning collected from the two logistics service providers showed that their average positioning distance is slightly larger than the 20 percent used by NTM: 24 percent. The increase from 20 to 24 percent leads to an increase in the result of 2 percent. This small influence (20 percent positioning distance increase leads to 2 percent emission increase), together with the difficulty of obtaining this data because of the aggregated information used, resulted in omitting positioning distance from the parameters that needed to be collected.

4.2.1.2 Empty returns

Empty returns are only taken into account if dedicated equipment is used, so if the empty return is ordered by the company requesting the transport (Cargill). Cargill uses almost no dedicated equipment. Therefore, empty returns are not taken into account at all.

4.2.1.3 Heating and refrigerating

Cargill uses almost no refrigerating. For some chocolate products, refrigerating is used only when the ambient temperature exceeds 25 degrees Celsius.

Heating is used more often, to be able to unload the product at the destination. Heating can take place during or after transport. The product is loaded at high temperature to prevent heating or reduce heating times. If heating is required, most of the time the product is heated at the customer location. In case of longer transport times, for instance in case of intermodal transport, heating may also take place at terminals and even during transport. A container can be “plugged-in” while transported on a vessel.

The amount of work needed to obtain data on heating, the lack of reliable emission data (as described in the methodology section) and the aggregated data resulted in not taking this parameter into account.

4.2.1.4 Cleaning

Cargill does not use a lot of dedicated equipment. Therefore all containers and trailers need to be cleaned prior to the transport. This is especially important when food products are transported. Therefore, it is assumed that all bulk transport material needs to be cleaned and all packed transport material not.

4.2.1.5 Detailed transport vehicle specifications

For road transport, a truck with a typical gross weight (truck and cargo combined) of 40 tonnes (for international transport) is used on all lanes, with only a very limited number of exceptions. Therefore, the truck type used in the calculations is assumed to be this type of truck for all lanes.

For rail transport, the gross weight of the train and the type of traction (electrical or diesel) influence the calculation result. Based on the lanes of the two logistics service providers, it seems almost impossible to collect data on the gross weight of the train. The type of traction is difficult to obtain as well, especially because the lanes are aggregated.

In water transport, a large number of different types of vessels can be used. According to the two logistics service providers, information on the size of the vessel was not available.

Therefore, only the type of vessel has been taken into account. Each logistics service provider has been asked to choose one of three ship types: container, ferry or RoRo cargo. Here, the difference between ferry and RoRo cargo is that on a ferry the complete truck is loaded and on a RoRo cargo ship, only the trailer is loaded. On a RoRo ship it is also possible to load a train cart.

4.2.2 Data collection method

Based on the above trade-off for all parameters, the lanes have been split into road transport and all other modes of transport. For road transport all data needed to make a calculation was present, but for all other modes of transport, additional data needed to be gathered.

The other modes of transport are road transport using a ferry or Eurotunnel and intermodal transport using either rail or water transport (or both). For these modes of transport, the routing and the distances per transport modality needed to be known, as well as the vessel type for water transport.

Both the lanes of interest and the logistics service providers are known. To obtain the data, all logistics service providers have been contacted by phone. This initial phone call was intended to explain the aim of the study and to obtain contact information of the right persons. Directly after the phone call, an e-mail has been sent to the contact persons with information on the lanes of interest and a further explanation of the data requested. If needed, additional phone calls took place to clarify problems or to remind the logistics service providers of the request.

In total 55 logistics service providers (all operating intermodal transport lanes for Cargill) have been contacted. 45 logistics service providers provided the requested information. One carrier did respond but with data that could not be used (this is not counted as a response) and did not provide the requested information later on. The 10 logistics service providers that did not provide the requested information (either no reaction or wrong data) are logistics service providers that operate a small number of lanes for Cargill. Calculated by number of lanes the response rate was equal to 95.9 per cent. It was not possible to find other similarities between these 10 logistics service providers.

All 45 logistics service providers provided the geographical names of the terminals that are used but not the distances per modality. To obtain the distances, different route planners have been used. For road transport distances Google Maps (Google Maps, 2009) has been used, but where necessary the distances have been calculated using Map 24 (Map 24, 2009), because the coverage of Map 24 is better in Eastern Europe. Rail transport distances per country have been gathered using the route planner from Deutsche Bahn (Rail Distance, 2009) and water transport distances for short sea navigation have been obtained using a World Ports Distances Calculator (Water Distance, 2009).

4.3 Problems

For most logistics service providers, obtaining the requested data was not a problem. Some logistics service providers, however, only shared the geographical names of the terminals and not the type of vessel used. In these cases, the type of vessel was taken from other logistics service providers operating on the same route. This approach has also been used for the lanes where no information was available, because the logistics service provider did not provide this.

During the collection of the data, response times of the different logistics service providers varied a lot. To speed up the data collection, logistics service providers haven been reminded of the request every two weeks. In the end, this resulted in a very high response rate.

5 Emission calculation results

Based on the data and the methodology, both described in the previous chapters, the carbon dioxide emissions for Cargill have been calculated. This chapter describes the results of this calculation and provides some deeper insight into Cargill's transport.

The results are presented in section 5.1. Next, the modal split of the three product groups is evaluated and in the last section, the influence of different parameters is described.

The results for packed goods are based on an award plan in progress. Therefore, the results are presented in sections 5.1 and 5.2, but they are not included in the analyses of section 5.3 because the data is not as complete as the data taken from the other award plans.

5.1 Carbon footprint

The calculation of yearly carbon dioxide emissions is split into the three product groups: bulk liquid, bulk powder and packed. In the next three sections the total emission is given for each of the product groups. In section 5.1.4, the product groups are compared.

5.1.1 Bulk liquid

Bulk liquid transport is operated for 5 business units: Cocoa & Chocolate, Flavor Systems, Bottled Oil, Refined Oil, and Starches and Sweeteners. The total transport volume (delivered by Cargill) is 3.1 million tonnes.

The total yearly carbon dioxide emission for bulk liquid is equal to 74,693 tonnes. Table 5 shows the composition of this total value. The other emissions shown in the table are emissions from cleaning and vertical handling.

Emission source	Emission (tonnes)	Percentage of total
Road transport	65030	87.1 %
Rail transport	688	0.9 %
Water transport	2776	3.7 %
Other emissions	6199	8.3 %

Table 5: composition of bulk liquid emissions

5.1.2 Bulk powder

Bulk powder transport is operated for 3 business units: Malt, Texturizing Solutions, and Starches and Sweeteners. The total transport volume (delivered by Cargill) is 1.6 million tonnes.

The total yearly carbon dioxide emission for bulk powder is equal to 25,316 tonnes. The composition of this total value is shown in Table 6, where other emissions are the emission resulting from cleaning and vertical handling.

Emission source	Emission (tonnes)	Percentage of total
Road transport	18999	75.1 %
Rail transport	579	2.3 %
Water transport	3322	13.1 %
Other emissions	2416	9.5 %

Table 6: composition of bulk powder emissions

5.1.3 Packed

Packed goods transport is operated for 4 business units: Cocoa & Chocolate, Bottled Oil, Texturizing Solutions, Refined Oils, and Starches and Sweeteners. The total transport volume (delivered by Cargill) is 1.2 million tonnes.

The total yearly carbon dioxide emission is calculated using the Starches and Sweeteners data and extrapolated on all business units. The total extrapolated emission is equal to 31,114 tonnes. The split of different emission sources is shown in Table 7. The other emissions are the emissions resulting from vertical handling. Here, cleaning is not needed, because the goods are packed.

Emission source	Emission (tonnes)	Percentage of total
Road transport	25832	83.0 %
Rail transport	100	0.3 %
Water transport	5129	16.5 %
Other emissions	53	0.2 %

Table 7: composition of packed emissions

5.1.4 Overall

The total emission figures presented above are shown in Figure 3 on the left. On the right, the emission factors in gram per tonne kilometre are shown. The emission factor indicates the efficiency of the transport; a lower emission factor can be caused by more intermodal transport or better transport parameters such as payload (amount of cargo per transport vehicle).

The figure shows that the emission factor of bulk powder transport is a lot lower than the emission factor of bulk liquid transport. This is caused by a higher payload and a higher share of intermodal transport.

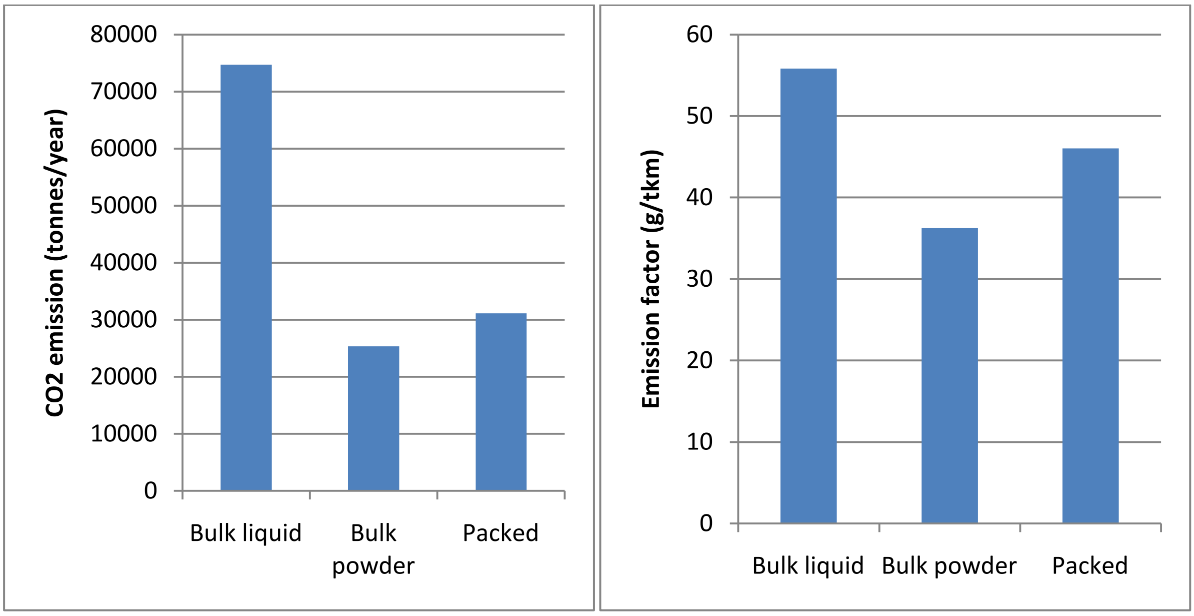

Figure 3: total emission values and emission factors

5.2 Modal split

The modality used for transport is of great influence on the emission factor, as will be shown in chapter 6. This section shows the modal split per product group. The modal split has been calculated based on the number of tonne kilometres.

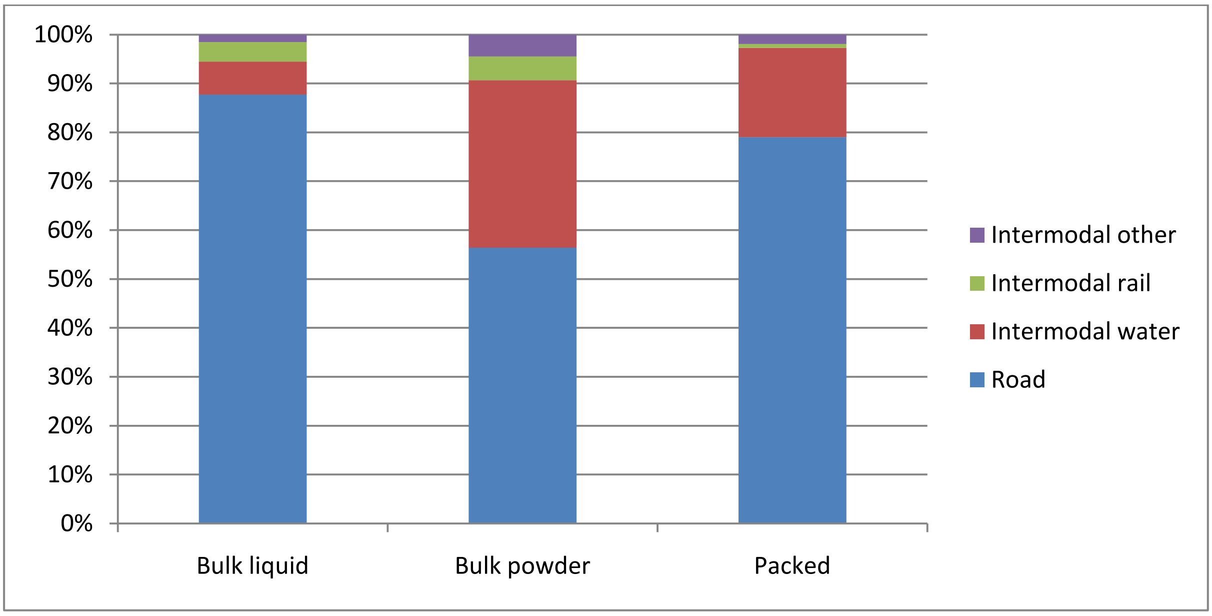

Figure 4: modal split of bulk liquid and bulk powder transport

Figure 4 shows that transport within the bulk powder product group is performed intermodal more often than within bulk liquid. This provides an explanation for the lower emission factor, but it also shows that within bulk liquid more opportunities for reduction may exist. The modal split of packed products is in between the two bulk product groups.

5.3 Parameter influences

The methodology described in section 3.2, provides assumptions in case certain data is not available. Two of these assumptions are checked in this section. First the influence of the real load factor compared to the assumption is evaluated and next the influence of entering the distance per country is described.

5.3.1 Load factor

In the calculation described in section 5.1, the real load factor is used for all lanes. However, in some cases the load factor may not be known and the assumed average load factor from the methodology (75 percent) needs to be used. This section describes the impact of using this load factor instead of the real load factor.

The calculation of section 5.1 has been (re)performed using the assumed load factor and the results were compared. The calculation using the 75 percent load factor results in a total emission figure that is only 1.16 percent lower than the real emission. However, per lane the differences are significantly larger with differences up to 80 percent.

With this analysis it is shown that the assumed load factor of the methodology can perfectly be used to calculate an overall emission figure. In case lanes are evaluated individually, for instance for reduction purposes, the assumed load factor is not usable.

5.3.2 Distance per country

The calculation of section 5.1 is performed using distance information per country for rail transport. For all other modes of transport, only the total distance is given. This section evaluates the impact of not stating the rail transport distance per country.

The total emission figure has been recalculated using the total rail distance (not per country). The result of this calculation is only 0.07 percent lower than the initial calculation. However, to evaluate the difference, only lanes including rail transport should be considered. This increases the difference to 2.37 percent. Here, the range of differences is much larger, just like in the load factor analysis, with differences up to 40 percent.

For calculating an overall emission figure, the distance per country does not seem necessary, but for evaluating individual lanes the distance per country can have a big influence.

6 Carbon dioxide reduction possibilities

A reduction of carbon dioxide emissions from transport can be achieved in multiple ways. This chapter describes three possibilities: increasing the payload, switching to intermodal transport and network redesign. These possibilities are described in the sections 6.1, 6.2 and 6.3 respectively. In section 6.4 combining the different reduction possibilities is discussed.

As in the previous chapter, the analyses have been performed using the bulk liquid and bulk powder datasets.

6.1 Increasing payload

Optimizing the payload leads to a more efficient use of the transport vehicle and to a reduction of the number of trips needed to transport the product. To assess the reduction opportunities for this method, the current payload has been analysed.

The maximum payload depends on the type of transport and the countries the transport is operated. For international transport in Europe, the maximum gross weight of a truck is 40 tonnes. Typically this means that a maximum of 24 tonnes (or 25 tonnes if using lighter trucks) of cargo can be loaded. However, for small transport distances with a terminal as destination, the maximum gross weight may be increased to 44 tonnes. Since all transport for Cargill starts with road transport, the maximum weights for rail and water transport are not of interest.

The average payload for bulk liquid transport is equal to 18.23 tonnes, while for bulk powder this is 25.73 tonnes. These figures show that the payload for bulk powder is above the maximum road level. This can be explained by the large amount of intermodal transport, as was shown in section 5.2. For bulk liquid, however, some improvement seems possible.

Increasing the payload for all bulk liquid lanes to 24 tonnes leads to a carbon dioxide emission reduction of 14.2 percent for bulk liquid. For all transport this results in a carbon dioxide reduction of 8 percent. To increase the payload, however, the customer needs to accept the payload increase because he receives a larger amount of the product at once.

6.2 Modal shift

In the previous chapter it was shown that the largest part of transport is carried out by road. The long distances and high payload of Cargill's transport make it possible to switch part of the road transport to intermodal transport, either by short sea shipping or by rail transport. This section shows the emission reduction possibilities of modal shifts.

First, the analysis performed is described. In section 6.2.2, the results are extrapolated to all Cargill transport using the reduction opportunity score and in section 6.2.3 the problems associated with a modal shift are described.

6.2.1 *Modal shift analysis*

The bulk liquid award plan has been used as a basis for the modal shift analysis. All lanes for which information is known both for road transport and intermodal transport and that are currently performed using road transport have been selected. For these lanes, 626 in total, the possible emission reduction has been calculated. The result of this calculation has been compared to the costs of the modal shift needed to obtain the emission reduction. The results are shown in Figure 5.

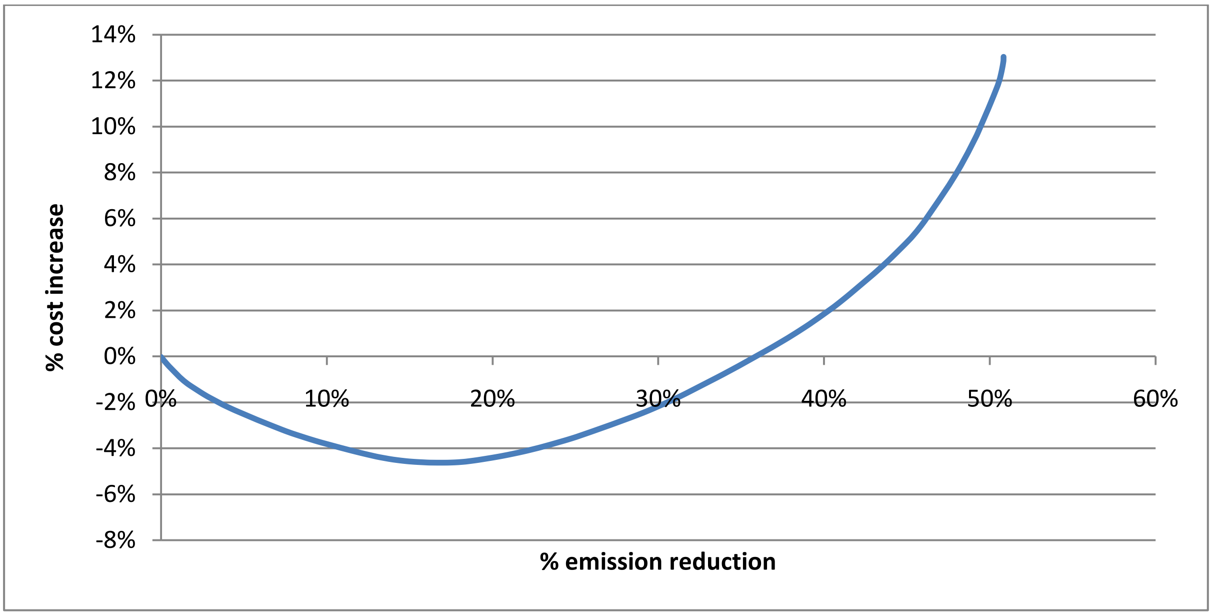

Figure 5: cost increase at specified CO_2 reduction

Based on the lanes for which information is available, it can be seen that reducing carbon dioxide emissions can save costs. The minimum costs are obtained at a carbon dioxide emission reduction of 17 percent and an emission reduction of 35 percent is possible without increasing the transport costs.

6.2.2 *Reduction opportunity score*

This section gives an estimate of the carbon dioxide reduction possibilities for all Cargill transport. This has been done by extrapolating the above results to the entire transport dataset using the reduction opportunity score.

The tool has been used as a starting point to identify lanes for which a reduction in emissions by modal shift seems possible. For all lanes a reduction opportunity score has been calculated, based on the following parameters:

- Current emission factor: the amount of carbon dioxide emitted per tonne kilometre. Based on the complete dataset a lower bound of 40 grams per tonne kilometre has been used. This value is based on the emission factors of road transport and intermodal transport as shown in Figure 6, with road transport values on the left and intermodal transport values on the right. The blue diamonds show the emission factors of the lanes that could be changed cost-effectively and the green triangles show the emission factors of the lanes that lead to an emission reduction but a cost increase. The lanes are ordered by increasing costs per tonne carbon dioxide reduction from left to right, but the horizontal axis is not scaled (the distance on the horizontal axis between two points does not tell anything about the difference in costs). The reason for not scaling the horizontal axis is that only indicating a trend is sufficient for this study and the figures are better readable this way. In Figure 6 it can be seen that no trend exists; therefore it is not possible to conclude anything about the costs per tonne carbon dioxide reduction based on the emission factor.

- Distance: for a modal shift to be effective a minimum distance is needed. A minimum distance of 500 kilometres has been used based on the same dataset as used for the emission factor. Figure 7 shows the distances for lanes that lead to an emission reduction and a cost reduction (blue diamonds) and distances for lanes that lead to an emission reduction but a cost increase (green triangles). The lanes are ordered by increasing costs per tonne carbon dioxide reduction from left to right. Again, the horizontal axis is not scaled. Using the distance of 500 kilometres, a small number of lanes that could not be changed cost effectively has not been considered. A downward trend exists, with smaller distances linked to higher costs.

- Payload: for intermodal transport, a container is used. The use of a container does not make sense if the payload is very low. Therefore the lower bound on the payload is assumed to be 15 tonnes.

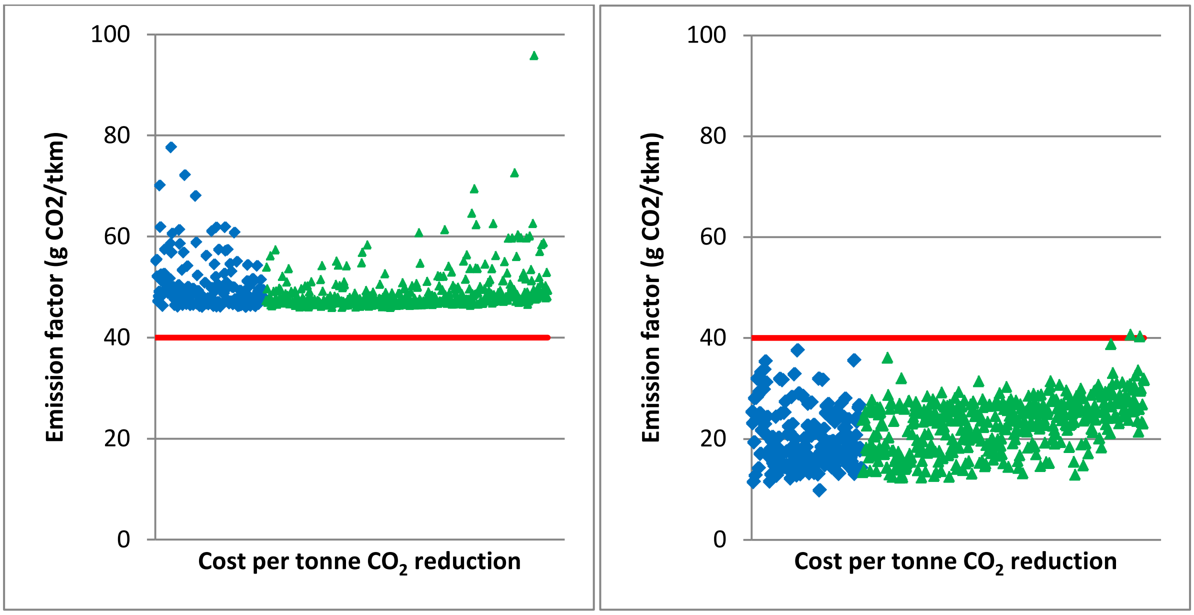

Figure 6: emission factors of lanes with reduction possibility; left before, right after modal shift

For each parameter value above the lower bound, the opportunity score is increased by one. This way, the opportunity score has a value between zero and three.

The reduction opportunity score of the lanes considered in this analysis has been calculated. Values for the reduction opportunity score vary between 2 and 3 (49 times value 2 and 577 times value 3). Lanes with an equal reduction opportunity score are ranked by decreasing distance, based on the trend discussed before.

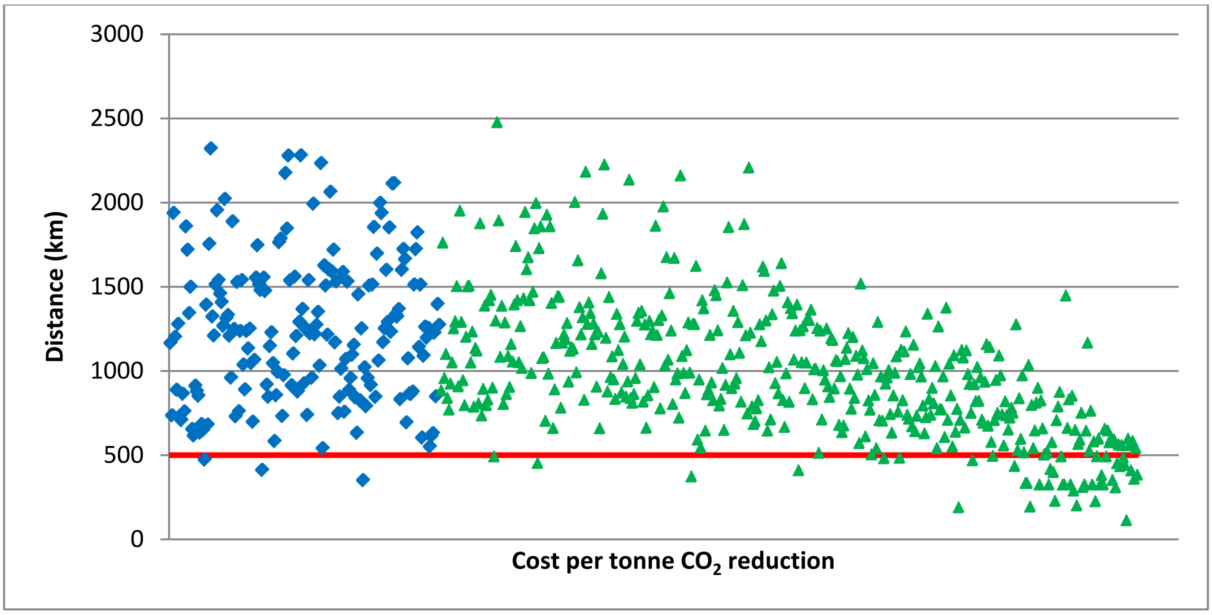

Figure 7: transport distances of lanes with reduction possibility

To extrapolate the analysed dataset to the entire transport dataset (bulk liquid and bulk powder), the reduction opportunity score of all lanes has been calculated. Based on the above figures and a manual inspection of all lanes it is assumed that only lanes with a reduction opportunity score of 3 can be changed to intermodal transport. The extrapolation has been performed using the ratio between the number of tonne kilometres of the analysed dataset and the number of tonne kilometres of the entire dataset, only taking into account the lanes with a reduction opportunity score of 3. The result is shown in Figure 8.

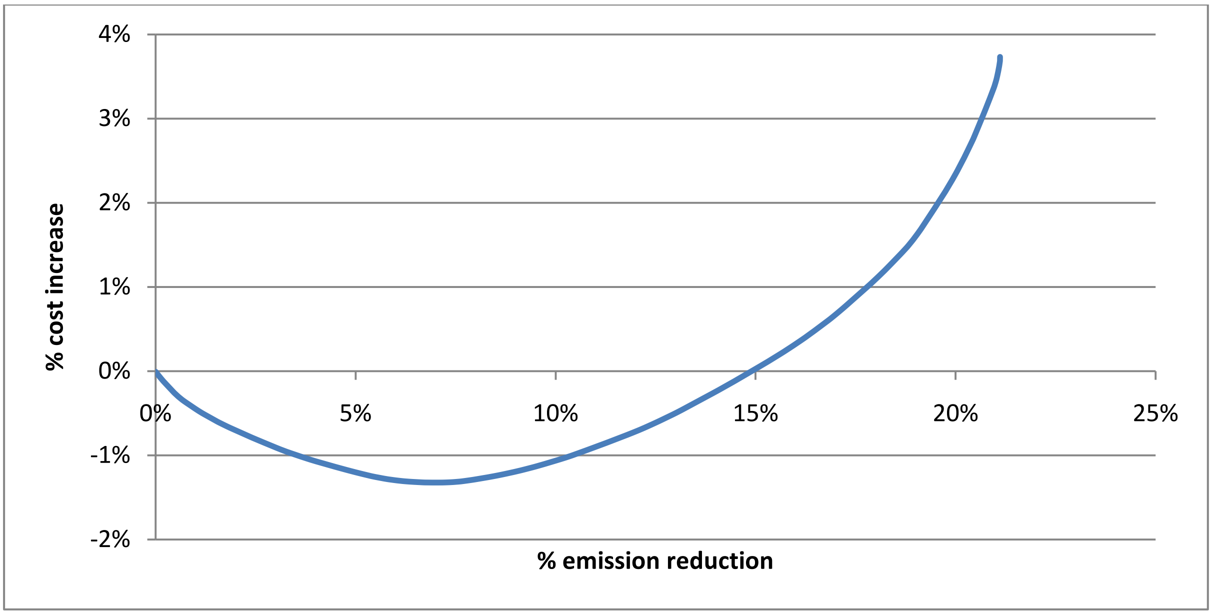

Figure 8: extrapolated result of modal shift analysis

In the figure it can be seen that the point of minimum costs leads to a carbon dioxide reduction of 7 percent. The emission reduction that can be achieved without increasing the costs is equal to 15 percent.

6.2.3 *Problems*

Switching a lane from road transport to intermodal transport can cause several issues that need to be solved. Lead times, temperature and payload are discussed.

Intermodal transport, usually, has a higher lead time than road transport due to handling and waiting times. Due to the longer lead time, the customer needs to place his order longer before receiving the product. This requires some adaptation of the customer.

For products that need temperature control the longer lead time results in another issue: additional heating or cooling. Products that need cooling or freezing during transport need to be ‘plugged-in’ at terminals, raising the energy consumption and thus losing part of the carbon dioxide reduction of the modal shift. Products that need to be heated before unloading cool down further due to the longer lead time, again, leading to increased energy consumption. For some products heating was not required in case of road transport, but is required for intermodal transport. In this case, the possibility of heating the product at the location needs to be investigated.

Part of the carbon dioxide reduction of a modal shift is caused by the payload increase. In case of intermodal transport, the payload can often be raised to 28 tonnes (from 24 or 25 tonnes). This payload increase requires the customer to accept a larger amount of the product at once, which may need some adaptation from the customer.

In order to solve the first and third issue, cooperation from the customer is needed. Cooperation can be obtained by sharing the benefits of intermodal transport.

6.3 Network redesign

A third option of reducing carbon dioxide emissions is network redesign. To optimize the network, decisions about sourcing (which plant produces the product for the customer) and the use of terminals could be reconsidered including carbon dioxide emissions.

Sourcing decisions can lead to smaller transport distances, while terminals can provide the possibility of using high volume transport to the terminal and low volume transport from the terminal to the customer. This way, no adaptations from the customer are needed.

6.4 Combination of multiple reduction possibilities

The reduction possibilities described in this chapter can be combined to make further reductions possible.

If the payload was too low to be able to use intermodal transport effectively, a payload increase can improve the efficiency and enable a modal shift. This may reduce the emission even further than the payload increase itself.

Sourcing decisions can take intermodal possibilities into account. If intermodal transport is not able from one production facility, another production facility may reduce emissions from transport. If intermodal transport is possible from two production facilities, the distance to a terminal, local payload regulations or emissions from power generation (in case of rail transport) may be in favour of one of the production facilities.

7 European Union regulation scenarios

The European Union is planning to reduce the carbon dioxide emissions by enforcing regulations with regard to these emissions. At this moment it is not clear how these regulations will look like. This chapter describes four different scenarios and gives insights into the consequences of these scenarios for Cargill (in terms of costs). All scenarios are based on existing and possible upcoming regulations; this means that other factors that can affect carbon dioxide emissions, such as the oil price, are not taken into account.

One of the initiatives is the European Union Emission Trading Scheme (ETS). This scheme limits the amount of carbon dioxide a company is allowed to emit. The ETS was started in January 2005 as the first international carbon dioxide emission allowances trading system. The system works by supplying companies with emission allowances (the right to emit 1 tonne of carbon dioxide). Companies can either sell their rights if they have not emitted the allowed quantity of carbon dioxide or they can buy extra allowances from other companies if these are needed. The amount of allowances that is supplied to companies (given, sold or auctioned) will decrease each year to reach emission targets (ESCF, 2008).

The current ETS covers the following major industry sectors:

- Power
- Chemical
- Steel
- Paper and Pulp
- Aluminium
- Cement

The inclusion of power generation in the ETS automatically leads to the inclusion of electrical (rail) transport. Here, the ETS makes the power generating companies responsible for the carbon dioxide emissions. It is assumed that the users of electricity will be charged a higher price to cover the costs for emission allowances. In addition to the companies listed above, the EU is planning to regulate the emissions resulting from aviation and sea navigation (both short sea and deep sea) by including these sectors in the ETS in the near future. At this moment there are no concrete plans to include emissions from road and diesel rail transport in the ETS. However, the EU does have other, further developed, plans for road and diesel rail transport: diesel tax and the Euro-Vignette.

The EU plan with regard to the diesel tax is to enforce a law that sets the diesel tax at least equal to the petrol tax. Taxes can still differ between countries but the big difference in diesel and petrol taxes (for example the tax in the Netherlands for 2008 was 0.6943 eurocents for petrol and 0.4116 eurocents for diesel (Factsheet taxes, 2008)) will disappear.

The Euro-Vignette has already been implemented, but not yet for carbon dioxide emissions (EU, 2006). However, the European Parliament already discussed including carbon dioxide emissions in the Euro-Vignette. The goal of the directive is to apply the “polluter pays” principle, where “the variation of the tolls will take into account the environmental burden of the vehicle" (EU, 2006). The member states are free to set the cost for the environmental burden within the boundaries as stated by the EU directive. This means that the emission costs will vary per member state, to be able to implement the scenario regardless of the country where the logistics service provider is based, the decision was made to use European wide values in the scenario analyses.

Another EU initiative is the regulation with regard to the emissions in vehicle engines, the EURO-norms. These norms have been set to reduce the environmental burden of vehicles by setting an upper value to the emissions of a vehicle. The EURO-norms reduce the emission of several greenhouse gases, but not the carbon dioxide emissions as the fuel consumption is not restricted.

The next sections in this chapter describe the scenarios in more detail together with the calculations made using the dataset of Cargill's transport. For each scenario, three price levels are set: the expected price level, a lower bound and an upper bound.

The first scenario is only taking into account the current ETS. This scenario, together with the impact it will have for Cargill, is described in section 7.1. The second scenario, section 7.2, looks at the current ETS including sea transport, the diesel tax and the Euro-Vignette. Next, in section 7.3, all transport modes are included in the current ETS. The final scenario is the current ETS and a separate transport ETS and is described in section 7.4. The chapter ends with a conclusion taking all scenarios into account.

In the sections that describe the four scenarios, the results are discussed briefly. Conclusions are drawn in the last section because in order to draw conclusions the scenarios need to be compared.

7.1 Scenario 1: only current ETS

This scenario takes the current ETS without any additional regulations. The plans of the EU make this scenario not very likely to occur, but it can be used as a base-level to compare the impact of the other scenarios. Furthermore, the result of this scenario is not in line with the intention of the EU. The EU wants to reduce the carbon dioxide emissions, while, for transport, this scenario only regulates the emission from electrical (rail) transport.

The price levels set for this scenario are shown in Table 8. The current emission allowance price is 15 euros (ECX, 2009), which is used as a lower bound. The expected value and the upper bound are based on multiple sources (CE Delft, 2008 (2); Carbon Trust, 2006). For all price levels it is assumed that an amount of 15 euros for electrical rail transport is already included in the current transport price.

Transport modality	Lower bound	Expected	Upper bound
Rail – electrical	€ 15	€ 50	€ 100
Rail – diesel	€ 0	€ 0	€ 0
Road	€ 0	€ 0	€ 0
Water	€ 0	€ 0	€ 0

Table 8: carbon dioxide costs for scenario 1

The impact of this scenario for Cargill has been evaluated using the same data and method as was used in the modal shift analysis. The extrapolated result of the analysis is shown in Figure 9. Here, the current costs are used as baseline to be able to compare the different scenarios.

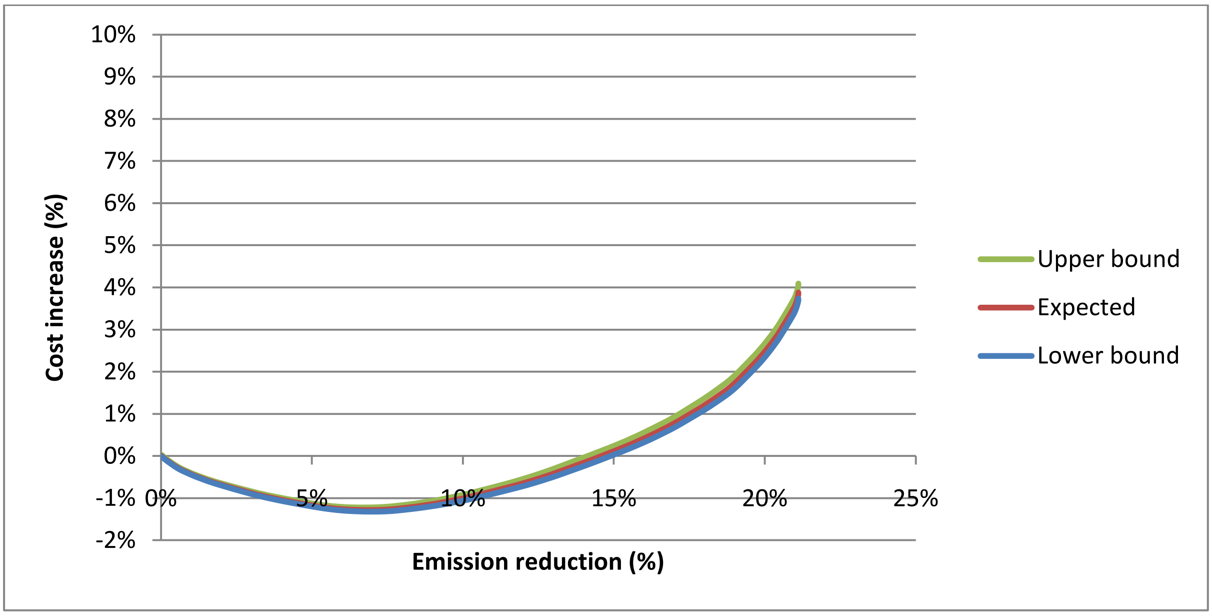

Figure 9: analysis results for scenario 1

The points of minimum costs and the points where the cost increase is equal to the initial phase (“do nothing”) are shown in Table 9.

Price level	**Reduction at minimum costs**	**Reduction at no cost increase**
Lower bound	7.0 %	14.5 %
Expected	6.9 %	14.4 %
Upper bound	6.6 %	14.2 %

Table 9: emission reduction values of scenario 1

The lower bound, expected and upper bound price levels result in very similar figures. This is caused by only putting a price on the carbon dioxide emissions from electrical rail transport. The share of electrical rail transport is small, as was shown in chapter 5.

For all price levels, an optimization of the costs leads to a carbon dioxide emission reduction of (almost) 7 percent, while a reduction of more than 14 percent is possible without raising the costs above the 0 percent level.

7.2 Scenario 2: current ETS including sea transport in combination with diesel tax and Euro-Vignette

The current ETS only includes emissions from electrical (rail) transport, but no emissions resulting from other transport modalities. The ETS used in this scenario includes emissions from sea transport. For road transport, the diesel tax and Euro-Vignette are used and for diesel rail transport, the diesel tax applies.

The prices for the ETS will increase slightly due to the extra emission sources that are added. The lower bound is set to the same price as in the first scenario (the current ETS allowance price), but the expected and upper bound prices are assumed to increase by 10 percent.

Increasing the diesel tax to the same level as the petrol tax, results in a diesel price increase. This price increase will be paid directly by the end-user. Based on the average diesel/petrol prices and the average diesel/petrol taxes of the 27 countries of the EU, the expected price increase has been calculated to be around 30 eurocents per litre. This is equal to a price increase of 110 euros per tonne carbon dioxide.

The price boundary for the Euro-Vignette is set by the EU and each country is free to set its prices within this boundary. Only part of the Euro-Vignette price can be allocated to carbon dioxide emissions. Only this allocated part has been used in this scenario. The allocated part is based on the total social cost of carbon dioxide emissions as determined in the IMPACT study (Maybach et al., 2008). This cost per tonne carbon dioxide is equal to 70 euros.

All price levels are summarized in Table 10. Again it is assumed that an amount of 15 euros for electrical rail transport is already included in the transport price.

Transport modality	Lower bound	Expected	Upper bound
Rail – electrical	€ 15	€ 55	€ 110
Rail – diesel	€ 110	€ 110	€ 110
Road	€ 180	€ 180	€ 180
Water	€ 15	€ 55	€ 110

Table 10: carbon dioxide costs for scenario 2

Application of this scenario to the transport dataset of Cargill gives the results as shown in Figure 10 and Table 11.

The difference between the three price levels is slightly larger than in the first scenario. However, the difference is still small. An explanation for this is that the carbon dioxide price from road transport is relatively high and constant.

The values in Table 11 show that the point of minimum costs leads to a higher carbon dioxide emission reduction than in the first scenario. The reduction that can be achieved at the cost level of ‘doing nothing’ is also significantly higher than in the first scenario.

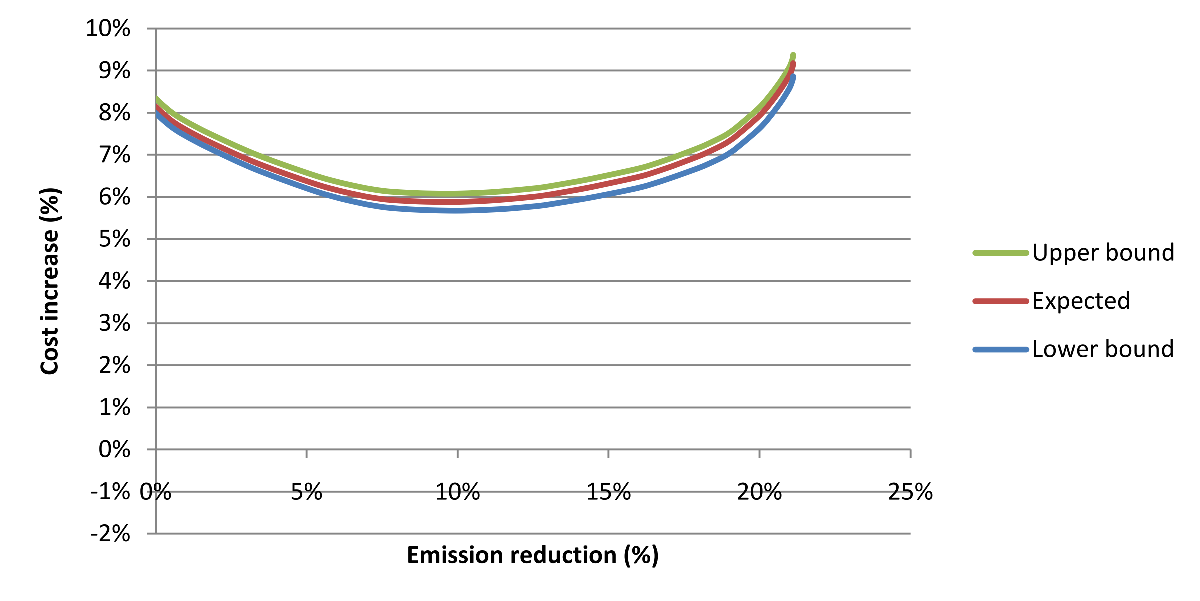

Figure 10: analysis results for scenario 2

Price level	Reduction at minimum costs	Reduction at no cost increase
Lower bound	9.9 %	20.4 %
Expected	9.6 %	20.2 %
Upper bound	9.6 %	20.2 %

Table 11: emission reduction values of scenario 2

7.3 Scenario 3: current ETS including all transport modes

The third scenario includes all transport modes in the current ETS. The result is that companies can choose which emissions (from transport or from production) they want to reduce in order to reach their emission targets. The price is expected to increase with the inclusion of all transport emissions. The price levels are based on a report by CE Delft (CE Delft, 2007) and shown in Table 12.

Transport modality	Lower bound	Expected	Upper bound
Rail – electrical	€ 15	€ 65	€ 130
Rail – diesel	€ 15	€ 65	€ 130
Road	€ 15	€ 65	€ 130
Water	€ 15	€ 65	€ 130

Table 12: carbon dioxide costs for scenario 3

The same analysis as used with the previous scenarios leads to the results of Figure 11 and Table 13.

The three price levels cause a bigger difference compared to the two previous scenarios. This bigger difference is caused by using variable prices for emissions from all modalities. The emission reduction values of this scenario are higher than the values of the first scenario, but smaller than the values of the second scenario.

Interesting to note is that the values increase from the lower bound to the upper bound, as opposed to the values in scenario 1 and 2. This is further discussed in the conclusion of this chapter.

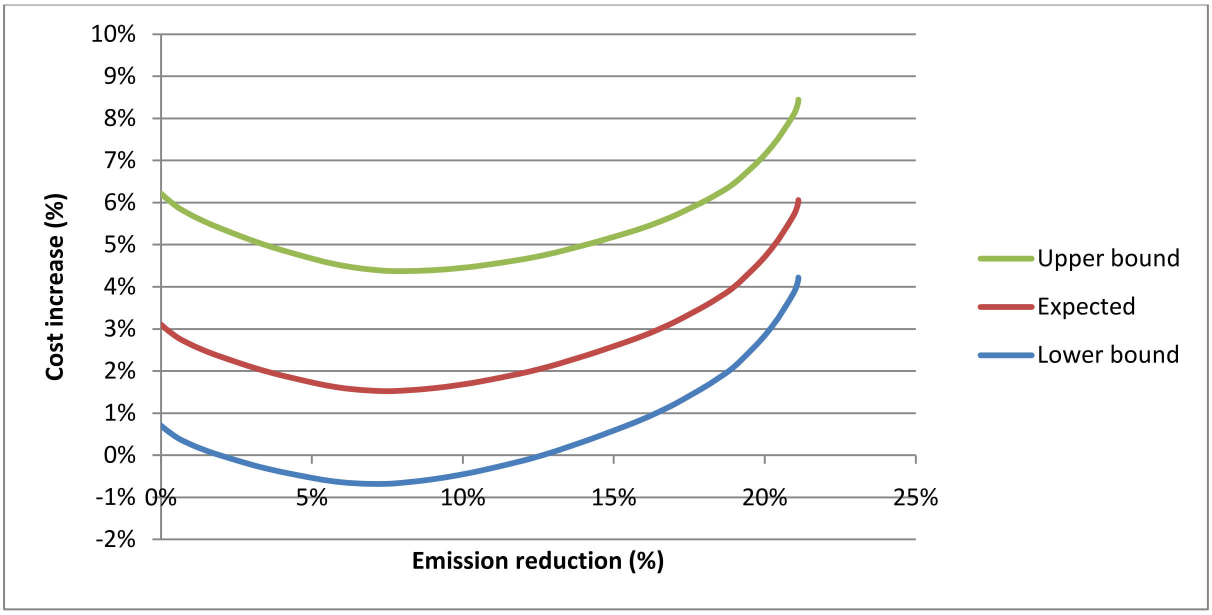

Figure 11: analysis results for scenario 3

Price level	Reduction at minimum costs	Reduction at no cost increase
Lower bound	7.2 %	15.4 %
Expected	7.5 %	16.8 %
Upper bound	7.9 %	18.4 %

Table 13: emission reduction values of scenario 3

7.4 Scenario 4: current ETS and separate transport ETS

In addition to the current ETS that already includes emissions from electrical (rail) transport, a separate transport ETS is created in this scenario. All modes of transport, expect electrical (rail), are included in the transport ETS. Based on a report by CE Delft (CE Delft, 2007) it is expected that prices for emissions from transport will be considerably higher than the prices in the current ETS, because there are fewer transport emissions and a higher price is needed in order to realise a certain reduction. The price levels have been set as shown in Table 14.

Transport modality	Lower bound	Expected	Upper bound
Rail – electrical	€ 15	€ 50	€ 100
Rail – diesel	€ 30	€ 90	€ 180
Road	€ 30	€ 90	€ 180
Water	€ 30	€ 90	€ 180

Table 14: carbon dioxide costs for scenario 4

The results of the analysis are shown in Figure 12 and Table 15.

The emission reduction values of this scenario are comparable to the third scenario, except for the upper bound. This value is closer to the second scenario. The difference between the price levels is bigger than in the previous scenario, because of a bigger range in the carbon dioxide costs.

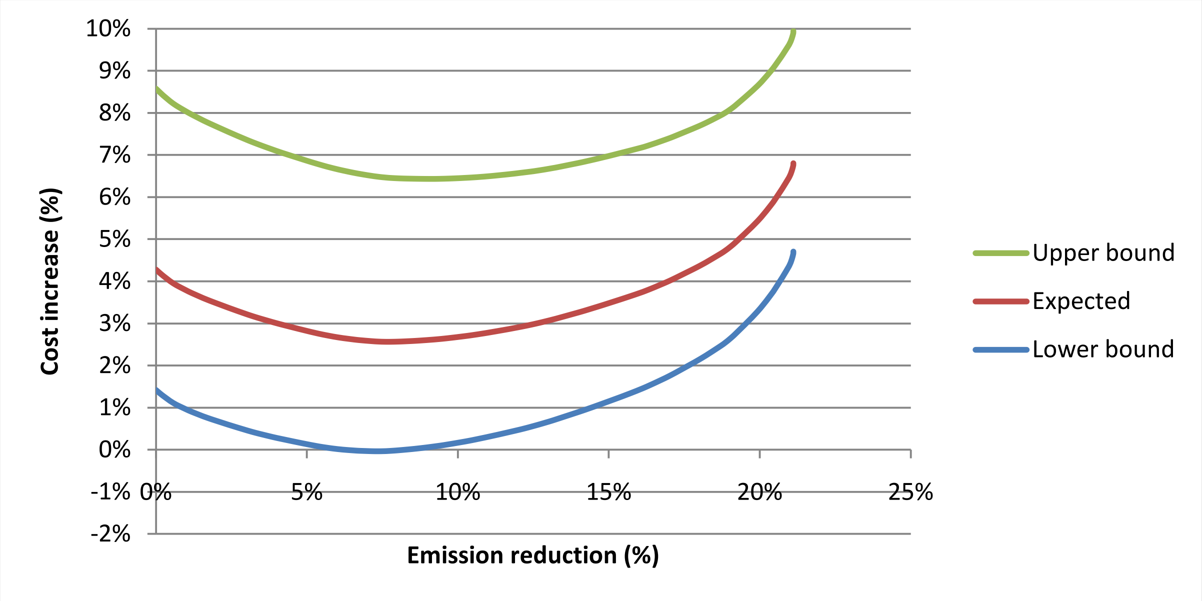

Figure 12: analysis results for scenario 4

Price level	Reduction at minimum costs	Reduction at no cost increase
Lower bound	7.3 %	15.9 %
Expected	7.7 %	17.8 %
Upper bound	9.2 %	19.7 %

Table 15: emission reduction values of scenario 4

7.5 Conclusion

In this section the four scenarios will be compared and the differences will be described into more detail.

The expected values of the four scenarios are shown in Figure 13 and Table 16.

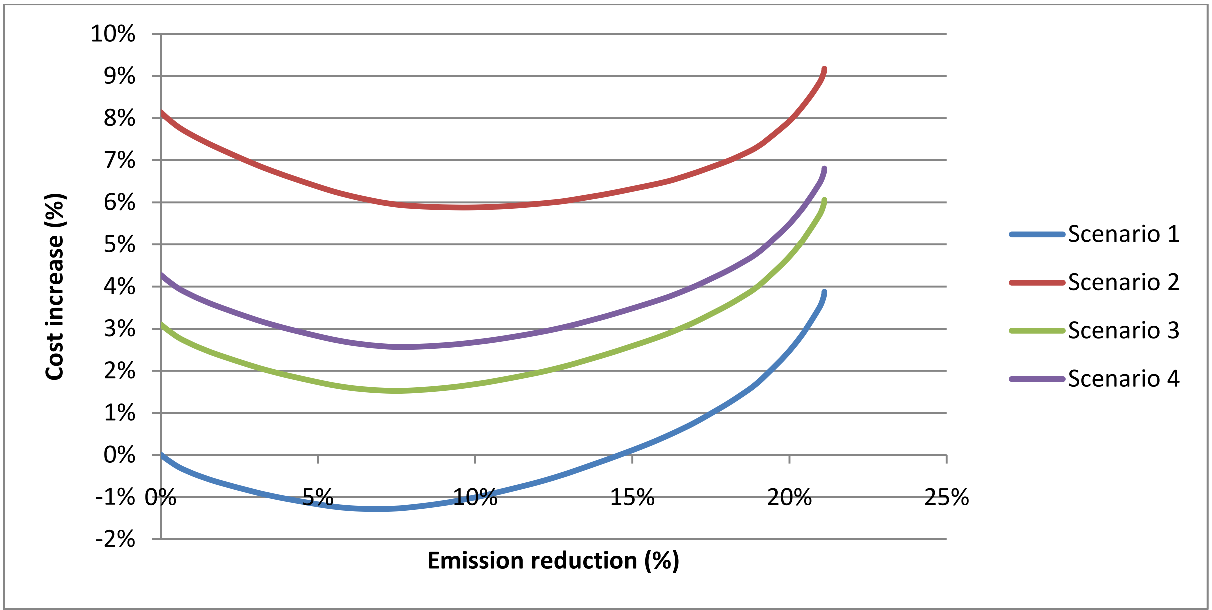

Figure 13: expected values of the four scenarios

Scenario	Reduction at minimum costs	Reduction at no cost increase
Scenario 1	6.9 %	14.4 %
Scenario 2	9.6 %	20.2 %
Scenario 3	7.5 %	16.8 %
Scenario 4	7.7 %	17.8 %

Table 16: expected emission reduction values of the four scenarios

It is clear that the expected emission reduction values of scenario 2 are the highest; at the minimum costs, scenario 2 leads to the biggest carbon dioxide emission reduction. However, scenario 2 also leads to the biggest cost increase.

In section 7.3 it was already discussed that there exists a difference between scenarios 1 & 2 and scenarios 3 & 4. In scenarios 1 & 2 the lower bound price levels lead to a bigger emission reduction than the expected and upper bound price levels. In scenarios 3 & 4 this is the other way around. This can be explained by the carbon dioxide prices for road transport. In scenario 1 & 2 these prices are fixed, while in scenarios 3 & 4 these prices vary with the other carbon dioxide prices. A fixed carbon dioxide road price causes a bigger difference between carbon dioxide prices for road and for other modalities at the lower bound price level. This bigger price difference leads to more emission reduction possibilities for the same costs.

From the EU point-of-view this means that reducing the amount of emission allowances, thus increasing the price for the allowances, reduces the incentives of companies to reduce their carbon dioxide emissions. This is exactly the opposite of the intention of the EU. For scenarios 3 and 4 the result of an increased allowances price is in line with the intention of the EU.

A diesel price increase thus leads to a higher incentive for companies to reduce their carbon dioxide emissions from transport. However, to be able to keep this incentive when the emission allowance price increases, the diesel price needs to be linked to the allowances price in some way.

Apart from the choice for one of the scenarios it can be seen that a company that optimizes its transport network automatically reduces its carbon dioxide emissions from transport by 7 percent (lower bound scenario 1).

8 Conclusions

This chapter describes the main findings of the study. Furthermore it describes the recommendations, limitations and possibilities for further research. First a brief summary of the study is given.

Within the CRSC project, a methodology for calculating carbon dioxide emissions from transport has been developed. This methodology has been applied to Cargill's transport dataset using the calculation tool that has been developed in this study. The results provide insights in the transport of Cargill and show which reduction options are available. In the final part of this study, the impact of several possible European Union regulations has been evaluated.

8.1 Main findings

The methodology developed extents the current methodologies by taking extra parameters into account. Cleaning of transport material, vertical handling and cooling and heating have been added. Furthermore, assumptions on positioning, load factor and empty returns have been checked and adjusted.

Based on the calculation results it can be concluded that Cargill's transport is mainly operated by road transport. Especially for bulk liquid products the share of road transport is large. For bulk liquid products the average load factor is far below the average load factor of bulk powder transport.

Two different reduction options have been evaluated: increasing the payload per transport movement and shifting to another modality. Increasing the payload can lead to a maximum carbon dioxide reduction of 8 percent. However, this maximum is almost impossible to reach because some customers will remain requesting smaller amounts of product.

Modal shift is a reduction option very suitable for Cargill, since the share of road transport and the transport distances are large. A carbon dioxide emission reduction of 15 percent is possible without increasing the transport costs. Interesting to note is that a cost optimisation of transport already leads to a carbon dioxide emission reduction of 7 percent.

The European Union is planning to enforce regulations in order to reduce the carbon dioxide emissions. Since it is not clear how this regulation will look like exactly, four scenarios have been evaluated. The most likely scenarios all lead to a cost increase and only the scenario using the current Emission Trading Scheme (ETS), a diesel tax and the Euro-Vignette leads to a bigger carbon dioxide reduction at minimum costs. However, this scenario behaves in a way contradictory to the intentions of the European Union. If the European Union provides less emission allowances to the companies in the ETS, the price of these allowances will increase. This price increase leads to a reduced incentive for transport companies to reduce their carbon dioxide emissions, because the price of a modal shift increases.

The result of the second scenario can be compared to the result of a “naturally” increased diesel price (for instance due to an increased oil price). A diesel price increase of 25 eurocents is comparable to the carbon dioxide costs of the fourth scenario. Based on this data it is expected that the influence of the diesel price on the intention of the different regulations cannot be neglected. Especially because the effect of the increased diesel price is opposite to the intention of the European Union.

The scenarios that use a single price for carbon dioxide emissions from all modalities result in a lower emission reduction at first hand. However, decreasing the number of allowances, thus increasing the price, results in more incentives for the transport companies to reduce their emissions. This way, the total European carbon dioxide emission from transport can be managed in a more precise way.

8.2 Recommendations

This study leads to the following recommendations for Cargill:

- Modal shifts lead to the biggest carbon dioxide emission reduction and even a cost reduction. Therefore investigating all lanes for which a modal shift seems possible is recommended. Here, technical constraints and costs resulting from solving these should also be taken into account.
- A large carbon dioxide emission reduction can be achieved by optimizing the payload of the bulk liquid transport.
- Other carbon dioxide emission reduction options can be taken into account as well. Transport using inland waterways, and sourcing options are not being considered at the moment.
- Collecting the data needed for a carbon dioxide emission calculation can be integrated with the request for quotation (leading to an award plan). This will save time both for Cargill employees and for logistics service providers.
- The progress of reducing carbon dioxide emissions can be quantified using the tool on a monthly basis. This way, the Green Transport Project can be used for marketing purposes as well.

Furthermore, one recommendation for the tool is given:

- The tool needs to be updated regularly with new emission data.

8.3 Limitations and further research

Limitations of this study are presented in this section. These limitations lead to possibilities for further research.

Not all reduction options are taken into account. Especially sourcing and using terminals or floating stock (a container in a terminal used as stock) can lead to additional emission reductions. It is interesting to conduct research with a wider scope; not only looking at carbon dioxide emissions from transport, but looking at the complete supply chain.

For a more accurate emission calculation, the values of several parameters can be investigated in more detail. For cleaning and vertical handling more specific values can be used and heating can be made time-dependent.

Further research into the regulation scenarios can show how the scenarios will react to different price levels and to parameters not taken into account in this study. To show the real impact of regulations, data from different companies needs to be combined. A start is made in the general report (CRSC Report, 2009). Here, more general conclusions are drawn.

9 References

ARTEMIS, 2007. "ARTEMIS: Assessment and reliability of transport emission models and inventory systems. Final report". *TRL limited*, 2007.

Carbon Trust, 2006. Grubb, M. "Carbon Confusion: The EU ETS and the Future; Presentation to Green Alliance conference on the EU ETS". *Carbon Trust*, 2006.

Cargill, 2008. "2008 Summary Annual Report: A Closer Look at the Big Picture". *Cargill*, 2008.

CE Delft, 2003. Essen, H.P. van, Bello, O., Dings, J.M.W. and Brink, R. van den. "To shift or not to shift, that's the question". *CE Delft*, 2003.

CE Delft, 2007. "Price effects of incorporation of transportation into EU ETS". *CE Delft*, 2007.

CE Delft, 2008 (1). Boer, L.C. den, Brouwer, F.P.E. and Essen, H.P. van. "STREAM, Studie naar Transport Emissies van Alle Modaliteiten". *CE Delft*, 2008.

CE Delft, 2008 (2). Blom, M.J., Kampman, B.E. and Nelissen, D. "Price effects of incorporation of transportation into EU ETS". *CE Delft*, 2008.

CRSC Report, 2009. Akker, I.J.G. van den, Loo, R. te, Ozsalih, H., Schers, R., "General report CRSC Project (work in progress)", *Eindhoven University of Technology*, 2009.

EcoTransIT, 2008. "EcoTransIT: Ecological Transport Information Tool. Environmental Methodology and Data". *EcoTransIT*, 2008.

ECX, 2009. http://www.ecx.eu

ESCF, 2008. Tekiner, G. "EU Emission Regulations: Current Situation, Scenarios and Impacts on Supply Chain. A White Paper of the European Supply Chain Forum". *European Supply Chain Forum*, 2008.

EU, 2006. "Directive 2006/38/EC of the European Parliament and of the Council of 17 May 2006". *European Union*, 2006.

Eurostat, 2009. http://epp.eurostat.ec.europa.eu/portal/page/portal/transport/data/database

Factsheet taxes, 2008. "Factsheet belastingtarieven 2008". *Dutch Ministry of Finance*, 2008.

GHG Protocol, 2004. "The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard. Revised Edition". *GHG Protocol*, 2004.

GHG Protocol, 2005. "Calculating CO2 Emissions from Mobile Sources". *GHG Protocol*, 2005.

Google Maps, 2009. http://maps.google.nl

IFEU, 2001. Knörr, W. et al., “Comparative Analysis of Energy Consumption and CO_2 Emissions of Road Transport and Combined Transport Road/Rail”, *IFEU*, 2001.

Map 24, 2009. http://www.nl.map24.com

Maybach et al., 2008. Maybach, M., Schreyer, C., Sutter, D., Van Essen, H., Boon, B., Smokers, R., Schroten, A., Doll, C., Pawlowska, B. and Bak, M., *Handbook on estimation of external costs in the transport sector*, 2008.

McKinnon and Campbell, 1998. McKinnon, A. amd Campbell, J. “Quick-response in the frozen food supply chain: The Manufacturer’s perspective”. 1998.

NTM Air, 2008. “Environmental data for international cargo and passenger air transport”. *NTM*, 2008.

NTM Brief, 2008. “The NTM methodology in brief”. *NTM*, 2008.

NTM Rail, 2008. “Environmental data for international cargo transport – rail transport”. *NTM*, 2008.

NTM Road, 2008. “Environmental data for international cargo transport – road transport”. *NTM*, 2008.

NTM Road method, 2005. “Method of emissions calculation for road transport”. *NTM*, 2005.

NTM Sea, 2008. “Environmental data for international cargo transport – sea transport”. *NTM*, 2008.

Rail Distance, 2009. http://dium.bahn-net.de/dium/index.jsp

RWS, 2008. “Een prijs voor elke reis: een beleidsstrategie voor CO_2-reductie in verkeer en vervoer”. *Dutch Advisory Council for Transport, Public Works and Water Management; Dutch Council for Housing, Spatial Planning and Environmental Management; and Dutch Energy Council*, 2008.

UNFCCC, 1998. “Kyoto Protocol to the United Nations Framework Convention on Climate Change”. United Nations Framework Convention on Climate Change, 1998.

UNFCCC, 2009. “Kyoto Protocol Status of Ratification”. United Nations Framework Convention on Climate Change, 2009.

UNFCCC website, 2009. http://unfccc.int/kyoto_protocol/items/2830.php

Water Distance, 2009. http://www.distances.com