REPORT

# Abatement costs for carbon dioxide reductions in the transport sector

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## Summary

In the process of developing policy instruments to reduce the emissions of greenhouse gases (GHG) it is important to know the abatement costs. The purpose of this report is to examine the abatement costs for measures that reduce the emissions of fossil carbon dioxide from the transport sector. Interviews were made with Swedish companies that may affect these emissions. Six measure categories have been examined. Only measures that the companies have implemented or are planning to implement are included in the study. The data provided by the companies have formed the basis for calculations of abatement costs and reduction potentials.

The abatement costs and reduction potentials depend to a large extent on the assumed fuel prices and emission factors. Fuel prices including taxes (but excluding VAT[1]) and emission factors based on LCA[2]-data from literature are used in the report. A sensitivity analysis with other fuel prices and emission factors, reflecting the importance of these input parameters, has been performed.

In this study abatement costs for 26 carbon dioxide reducing measures, grouped into six different categories, have been calculated. The majority of the measures are included in the categories "investment in new vehicles" and "ecodriving". The overall result shows that efficiency measures are cheaper than fuel-shift measures. The cheapest fuel-shift measure (low blending of bio fuels) has a negative cost (about -1500 SEK / ton $CO_2$) when taxes are included, while most other fuel-shift measures are considerably more expensive. Most efficiency measures had abatement costs far below 0 SEK / ton $CO_2$. The abatement costs for fuel-shift measures are much higher in the transport sector than in the energy sector, under comparable circumstances.

No national reduction potentials have been calculated for the measures in this study, neither has any MAC[3]-curves been constructed. This was not in the scope of this study. Further studies are recommended to include these aspects, preferably based on the measures in this report. In addition to descriptions of abatement costs, descriptions of the road transport categories and the measures provide valuable insights into the transport sector. The differences between the road transport categories, e.g. between road freight transport and buses, provide different possibilities to implement carbon dioxide reducing measures.


[1] Value added tax
[2] Life cycle analysis
[3] Marginal Abatement Cost

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# 1 Introduction

## 1.1 Background

In order to assess the cost for reducing GHG[4] emissions it is important to know the abatement costs of GHG reducing measures in different sectors. The importance of calculating the abatement costs for GHG reducing measures in the transport sector has increased because of the discussion about including the transport sector into the EU ETS[5]. Knowledge of abatement costs facilitates evaluation of the consequences of including the transport sector into the EU ETS (Holmgren et al, 2006).

## 1.2 Purpose

The purpose of this study is to determine abatement costs for reducing fossil carbon dioxide emissions in the Swedish transport sector by in-depth interviews with various transport companies influencing the emissions of carbon dioxide from the transport sector.

# 2 Methodology

Six fossil carbon dioxide reducing measure categories have been examined by in-depth interviews with selected companies. The interviews focus on measures implemented or planned by the companies to reduce the fossil carbon dioxide emissions from the transport sector. Only measures that the companies have implemented or plan to implement and that have been possible to quantify in an abatement cost calculation have been included in this study. Therefore not all possible measures for reducing fossil carbon dioxide in the transport sector have been included.

In Table 1 the numbers of companies interviewed in each sub-sector of the transport sector are presented. The names of the companies are not shown because it is sensitive business information.

Table 1: Number of interviewed companies in the different categories in the transport sector and an indication of the quality of data provided (5 is the best).

| Category of interviewed companies | Number of interviewed companies | Quality of data provided (1-5) |
|---|---|---|
| 1A, Taxi companies | 1 | 5 |
| 1B, Bus companies | 2 | 3 |
| 1C, Public transport companies | 1 | 2 |
| 1D, Goods transport companies | 4 | 3 |
| 1E, Airlines | 1 | 2 |
| 1F, Maritime shipping | 1 | 3 |
| 2. Fuel suppliers | 1 | 2 |
| 3. Education companies for e. g. ecodriving | 1 | 3 |

[4] Greenhouse Gas
[5] European Emission Trading Scheme

## 2.1 Abatement cost calculation

The abatement costs (AC) (SEK per ton reduced fossil $CO_2$) are calculated by equation 2. The calculations are performed by adding the costs and then dividing the sum by the emissions reduced by the measure ($CO_2$). The costs that are added together correspond to the differences between before and after the measure in yearly cost for fuel (FC), maintenance and repairs (MRC), income from side effects[6] (E), as well as the annualised investment cost ($I^{an}$).

The investment is annualised over the economical lifetime of the measure according to equation 1.

$$I^{an} = I * \frac{(1+r)^{lt} * r}{(1+r)^{lt} - 1} \qquad \text{(Equation 1)}$$

$I^{an}$ Annual investment [SEK/year]
$I$ Investment [SEK]
$r$ Real rate of interest [%]
$lt$ Economical lifetime [year]

$$AC = \frac{FC + MRC + I^{an} - E}{CO_2} \qquad \text{(Equation 2)}$$

## 2.2 Data collection

Information and data about the measures have been collected through the interviews. In some cases the companies have provided information about investments, changed operation- and maintenance costs, and changed fuel consumption. These data have then formed the basis for calculations of abatement costs and reduction potentials. However, in most cases the companies have not been able to provide all data, either because they do not have the information or because they do not want to provide it. In many cases it is possible to apply the same values for all measures, e. g. fuel prices and emission factors. In some cases information from many companies is combined to one common measure. Combining data from different companies and in some cases from other sources have made it possible to calculate the abatement costs as presented in the result chapter.

The fuel prices and emission factors described above are used in all calculations.

# 3 Assumptions and comments

## 3.1 Emissions

Emission factors for fuels relevant to this project are listed in Table 2. Three different values are presented for each fuel, which are used in the five different cases presented in the sensitivity

[6] Read more about the side-effects that are included in the calculations for each measure in chapter "Descriptions of measures".

analysis chapter. In the base case[7] (column 1 in Table 2) LCA-data from Miljöfaktaboken (Uppenberg et al, 2001) are used.

LCA-data for bio fuels vary substantially between different references, especially regarding ethanol, which has lower emissions in Uppenberg et al (2001) than in other international references e.g. SPI (2006). The reason is probably that the emission factors in Uppenberg et al (2001) are based on ethanol produced in Sweden where energy sources with very low $CO_2$ emissions are used for the ethanol production. A sensitivity analysis with other emission factors has been done because of these uncertainties. One of the cases in the sensitivity analysis includes only direct emissions (bio fuels are assumed to have zero fossil carbon dioxide emissions) (column 2 in Table 2) and one uses a $CO_2$ efficiency of 50% for the bio fuels compared to the fossil fuels (column 3 in Table 2).

Table 2: Fossil carbon dioxide emission factors relevant to this project (Naturvårdsverket, 2006-11-18; Uppenberg et al, 2001). See the sensitivity analysis for explanation about the different cases.

| kg $CO_2$ equ[8] / litre or $Nm^3$ | Base case | Case 3 in the sensitivity analysis | Case 4 in the sensitivity analysis[9] |
|---|---|---|---|
| Diesel (0% FAME[10]) | 2.77 | 2.60 | 2.77 |
| Petrol (0% ethanol) | 2.57 | 2.36 | 2.57 |
| Diesel (5% FAME) | 2.68 | 2.47 | 2.69 |
| Petrol (5% ethanol) | 2.46 | 2.24 | 2.48 |
| Biogas | 0.91 | 0.00 | 1.55 |
| E85 (80% ethanol in average)[11] | 0.81 | 0.47 | 1.19 |
| E95 (95% ethanol) | 0.48 | 0.12 | 0.93 |
| FAME (100% RME[12]) | 0.98 | 0.00 | 1.30 |

## 3.2 Costs and prices

### 3.2.1 Fuel prices

Fuel prices for fuels relevant to this project are listed in Table 3. Three different values are presented for each fuel (the columns marked with "Used in this study (prices in Sweden 2006-10-30)" except the column with "Incl taxes and VAT"), which are to be used in the five cases presented in the sensitivity analysis chapter. The other columns with fuel prices in Table 3 are included for comparison with other studies.

In this study fuel prices at the filling stations excluding VAT on the 30$^{th}$ of October 2006 are used in the base case. Prices at the filling station are chosen to represent the companies' situation.

[7] In the base case a selection of input parameters that are assumed to be the most appropriate for this study have been used.

[8] Equivalent (Emissions of other GHG than CO2 are converted to CO2-equ to facilitate comparison)

[9] The emissions from bio fuels are assumed to be 50% compared to the fossil fuel that they replace (the volume energy considered).

[10] Fatty Acid Methyl ester

[11] In the winter most fuel suppliers only use 75% ethanol in E85 (instead of 85%) because it may be difficult to start the car in very cold weather with too high percentage of ethanol. As an average value E85 is assumed to include 80% ethanol.

[12] Rapeoil methylester. RME is the type of FAME (Fatty Acid Methylester) that is used in Sweden.

Usually companies, and often also private drivers, get discounts. However, these discounts have not been considered.

In Table 3 three prices for ethanol are presented. Firstly, the price (for E85) at the filling station without VAT, secondly the price for pure ethanol calculated from the price of E85 and petrol (E5[13]) and thirdly the production price for pure ethanol from crops (Agroetanol, pers. comm. 2006). The price difference between the cases with pure ethanol is assumed to originate from the extra costs for building up a new distribution net. The higher price is used for making E85 whereas the lower is used for calculating the cost of blending ethanol into the petrol (0% ethanol) to get E5. The price for RME that is used to calculate the cost of blending FAME into diesel is assumed to have the same price as ethanol[14].

Table 3: Fuel costs from a selection of sources. The column "incl taxes and VAT" under "Used in this study (prices in Sweden 2006-10-30)" represents the prices (for diesel, petrol, biogas and ethanol) provided by one of the interviewed companies. One of the ethanol prices (100%) has been provided by Agroetanol (pers. comm. 2006). The other prices used in this study have been calculated from theses values. The other prices have been included for comparison with other studies.

| Price (SEK / litre or Nm$^3$) | Used in this study (prices in Sweden 2006-10-30) | | | | Gröna bilister "miljöbästa bilar 2006" (2006) | The Swedish Consumer Agency (2006-12-12) | Ekström et al 2006 |
|---|---|---|---|---|---|---|---|
| Fuel | Incl taxes, excl VAT | Excl taxes and VAT | Incl taxes and VAT[15] | Decreased price on bio fuels (-30%) | Incl taxes, excl VAT | Incl taxes, excl VAT | Incl taxes, excl VAT |
| Diesel (5% FAME) | 8.59 | 4.92 | 10.74 | 8.59 | 9.20 | 8.59 | 7.35 |
| Petrol (5% ethanol) | 8.57 | 3.83 | 10.71 | 8.57 | 9.60 | 8.81 | 8.09 |
| Biogas | 7.71 | 7.71 | 9.64 | 5.40 | 7.60 | 7.30 | |
| E85[16] | 6.91 | 5.91 | 8.64 | 4.84 | 6.40 | 6.91 | |
| Diesel (100%) | 8.75 | 4.89 | 10.94 | 8.75 | | | |
| Petrol (100%) | 8.73 | 3.74 | 10.91 | 8.73 | | | |
| RME (100%) | 5.50 | 5.50 | 6.88 | 3.85 | | | |
| Ethanol (100%) (calc from E85 and petrol prices)[17] | 6.47 | 6.47 | 8.09 | 4.53 | | | |
| Ethanol (100%) (approximated price according to Agroetanol (2006) | 5.50 | 5.50 | 6.88 | 3.85 | | | |

The fuel prices have large impact on the abatement costs for reducing fossil carbon dioxide emissions and therefore a sensitivity analysis is carried out. See further the sensitivity analysis chapter about which fuel prices in Table 3 that has been used in the different cases in the sensitivity analysis.

[13] Petrol with 5% ethanol

[14] Due to lack of data RME is assumed to have the same price as crop ethanol.

[15] These prices are not used in the study, but are included because these prices can be compared to the prices one can see at the filling stations.

[16] The price for E95 (ethanol used in diesel engines include larger proportion of ethanol) is assumed to be the same as for E85.

[17] These prices are not used in this study, but are included in order to make the comparison between the price of E85 and the price provided by Agroetanol (pers. comm. Agroetanol, 2006).

### 3.2.2 Investments

An annuity formula (see Equation 1 below) has been used in order to distribute the investments over the lifetime of the measures. In most cases this report defines the measure's lifetime is defined as the economical lifetime. This approach result in shorter lifetimes than used in other studies about abatement costs for reducing $CO_2$ emissions in other sectors, e.g. the IVL studies (Särnholm et al, 2005; Holmgren et al, 2005 ; Stripple et al, 2005). This is due to the fact that it is difficult to estimate the technical lifetime for measures in the transport sector.

The real rate of interest is set to 4% for all measures to represent the society cost, although 6% is used in corresponding studies such as Ekström et al (2006), Holmgren et al (2005) and Stripple et al (2005).

## 3.3 Fuel consumption

### 3.3.1 Cars

Table 4 shows the fuel consumption for taxis and private cars according to the references specified in the table. The values used in this study for all measures involving cars are the values in column 1. These values are provided by a taxi company[18] and represent cars with transmission [19]. The fuel consumptions according to the European test cycle presented in column 2 in the table are lower than the values in column 1. However, taking in consideration the factor of 1.195 that according to Smokers et al (2006) should be multiplied to the European test cycle to represent the fuel consumption in real life conditions that is presented in column 3, the values provided by the taxi company is reasonable. The only value provided by the taxi company that is not in the range between the European test cycle values (column 2 in the table) and the European test cycle values compensated according to Smokers et al (2006) (column 3 in the table) is the value for Toyota Prius. However, according to the Table 4 and the thoroughly measurement made by the taxi company, the value for the Toyota Prius in the European test cycle is probably too low. Not even the correction factor will provide a value that is valid for real life conditions. The values provided by the taxi company will be used both for taxi companies and private cars to better reflect real life condition, even if private cars usually do not have transmission.

[18] Except the values for Saab 9-3 that are calculated from the values for Saab 9-5 and values from the EU test cycle (column 2 in the table).

[19] These values are thoroughly measured by the taxi company themselves and are according to them reliable.

Table 4: Assumed fuel consumption for a selection of cars from various data sources. The EU values for Saab 9-3 come from Saab (2006-12-22).[20]

| Fuel consumption (litre or $Nm^3$ per 100 km) | Real life conditions, automatic gearbox (provided by a taxi company) | According to the EU test cycle[21], manual gearbox (The Swedish Consumer Agency, 2006-12-12) | Corrected EU test cycle values[22], manual gearbox |
|---|---|---|---|
| Volvo V70 (diesel) | 7.5 | 6.8 | 8.1 |
| Volvo V70 (petrol) | 11.0 | 9.2 | 11.0 |
| Volvo V70 (biogas) | 10.5 | 9.4 | 11.2 |
| Saab 9-5 (diesel) | 8.0 | 6.8 | 8.1 |
| Saab 9-5 (petrol) | 10.5 | 9.2 | 11.0 |
| Saab 9-5 (ethanol) | 14.0 | 12.9 | 15.4 |
| Toyota Prius (petrol) | 5.5 | 4.3 | 5.1 |
| Saab 9-3 (petrol 175 hk) | 9.5 | 8.3 | 9.9 |
| Saab 9-3 (petrol 150 hk) | 9.0 | 7.9 | 9.4 |

### 3.3.2 Buses and lorries

The fuel consumption is an important economical factor for bus- and freight companies, and always strongly considered in the manufacture. This might be a reason why the difference between various brands is not as large as it is for cars. There is no standard calculation of fuel consumption for buses and lorries as there is for cars. Buses and lorries differ a lot in size and load capacity and it is not possible to assume fuel consumption valid for all buses and lorries. E. g. the fuel consumption of a bus can vary between 20 and 70 litres of diesel per 100 km only depending on route (flat or hilly),number of passengers and weather conditions. The values used in this study (see Table 5) are not statistically proven, but they have been provided by the interviewed companies. It is important that the information about fuel consumptions for diesel and bio fueled vehicles originate from the same source of information.

Table 5: Fuel consumption for buses and lorries.

| Fuel consumption (litre / 100 km) | (Ethanolbus, 2006-12-08) | (Goods transport company) |
|---|---|---|
| Bus (diesel) | 40.1 | |
| Bus (ethanol) | 69.7 | |
| Lorry (diesel) | | 41 |

## 3.4 Distances and lifetimes

The yearly emissions from a vehicle depend on the fuel consumption as described above, but also on the travelled distance. Table 6 shows the yearly average travel distances for different vehicles.

[20] The numbers for real life conditions for Saab 9-3 have been calculated based on the EU value, using the same proportions between the real life conditions and the EU-value as for Saab 9-5 (petrol)

[21] According to a European directive all new cars sold in EU need a labeling telling the fuel consumption according to a standardized test cycle. These values represent mixed driving conditions (driving in cities and in the country side).

[22] These values are the European test cycle values multiplied with a factor of 1.195. The values will then according to Smokers et al (2006) represent the fuel consumption in real life conditions.

Table 6: Yearly average travel distances for different vehicle categories. References are presented in the text below.

| Distance travelled | (km / year) |
|---|---|
| Taxi car | 120 000 |
| Bus | 80 000 |
| Lorry | 137 500 |
| Private car | 14 360 |

According to the interviewed taxi company, a good approximation of travel distance for taxi cars is about 360 000 km in a three-year-period. Standard service contracts for taxi cars are three years or 360 000 km and after this period most taxi car owners sell their cars.

Two different bus companies approximate their travel distance to be about 80 000 km per year. Buses usually travel 1 000 000 to 1 200 000 km during 12-14 years before they are sold. In a comparison between three ethanol buses and three diesel buses the average distance travelled per year was 73 770 km (Ethanolbus, 2006-12-08), which is in line with the approximation of 80 000 km per year. Dickinson et al (2002) assume that buses in town travel 45 000 km per year, buses on the countryside 120 000 and 65 000 km as an average value.

Lorries travel, according to the road freight companies, about 1 000 000 to 1 200 000 km in 6 to 10 years before they are sold. That corresponds to a travel distance of 100 000 to 200 000 km per year. With an assumed average travel distance of 1 100 000 km and a lifetime of 8 years the average travel distance per year is 137 500 km.

Cars travel 14 360 km per year in average according to SIKA (2006-12-08). This number includes both taxi cars and all private cars. The average value would be lower if taxi cars were excluded, but on the other hand, new cars (that are included in the measures described in this study) travel more than the average car per year. Consequently, the two effects partly compensate each other and are assumed to equalise each other in this study.

## 3.5 Other assumptions

The measures included in this study are only examples of measures available in the transport sector. The aim with the study have been to calculate abatement costs for measures that the interviewed companies already have implemented or is planning to implement. For some measures it has not been possible to calculate abatement costs and some measures that exist and will exist in the transport sector do not appear for the interviewed companies and is therefore not included in this study.

Positive and negative effects on other emissions have not been included. Reducing fuel consumption usually decreases all emissions. Some measures, such as ecodrivning, will probably decrease emissions of e.g. $NO_x$ and particles to a greater extent than carbon dioxide emissions. There are also trade-offs between reductions of some emissions. Some $NO_x$ - reducing measures will e.g. increase the fuel consumption and thereby also the emissions of carbon dioxide, according to one of the bus companies. Due to emission restrictions, the corresponding $CO_2$ reducing measure is therefore not an option for the companies since this will lead to an increase in other emissions. Therefore these types of emission reduction measures are not included in this study.

The transported volume of goods or passengers and in most cases the travelled distances[23] have been kept constant in this study. This assumption is used even if it is not completely true. Changed price for a service (in this case transport) will affect the demand of that service. E.g. efficiency measures make the price for transport cheaper and the demand of transport will then increase. However, this effect, also called re-bound effect, has not been included in this project.

One studied measure is selecting a more fuel-efficient car, e.g. an electrical hybrid instead of a conventional car. The brand, size and standard of these cars differ, but in this study they are assumed to fulfil the same need. The reason for this assumption is that both selections are possible choices for the taxi car owner according to the taxi company. For private persons the same measure is included.

Choosing smaller and more fuel-efficient cars instead of bigger cars with larger emissions per km is not included although it has a large reduction potential. The reason is the difficulty to quantify the experienced benefits of different cars. However, one measure with selection of a smaller engine for the same car model is presented.

# 4 Description of transport categories

## 4.1 Taxi companies

The structure of the taxi business can be explained by dividing it into four groups; the customer, the taxi companies, the taxi car owners and the taxi drivers. Taxi companies[24] are mainly communication centres that distribute the customers to the taxi cars that are connected to the taxi company[25]. The owners of the taxi cars are smaller companies, which usually only have one taxi car each. The owner of the taxi car (who e. g. pay the fuel and other maintenance) usually drives the car him- / herself and hire one or two other persons who help him / her to drive. 2-3 drivers per car are the most optimal according to one of the interviewed taxi company. All these four groups have different options available to affect the emissions of fossil carbon dioxide.

The customers can also be divided into different groups; public companies or organisations (e. g. "Färdtjänsten" and "Stockholms Stad"), large private firms, small private firms, and private persons. Public companies and organisations as well as large private firms usually procure taxi services to reduced prices, whereas small firms and private persons do not have that possibility.

In the procurements, the public companies / organisations and large private firms can negotiate about environmental concerns and decreased climate impact.. The procurement may then include ecocars[26] (either always or e. g. if the costumer can wait up to 5 min[27] more), extra payment per km travelling with ecocars, or ecodriving guarantees.

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[23] For the measure category "efficient logistics" the transported distances are changed.
[24] E. g. Taxi Stockholm, Taxi kurir and Taxi020
[25] A taxi company may have thousands of associated cars.
[26] Flexi fuel cars (filled with ethanol (E85) or biogas) and electricity hybrids are in this case defined as more ecological . Flexi fuel cars that use biogas need to use at least 80% biogas to be called ecocar by the taxi companies.
[27] This is solved in the same way as when the costumer asks for a large car. If there is no ecocar available or nearby at the moment and it will take too long time, the customer is offered a conventional car instead.

In year 2006 there are taxi companies in Stockholm (Sweden) that see advantages in offering ecotaxis. They inform the large customers (as public companies / organisations and large private firms) how they can request environmental concern during the procurements and they give the car owners economical incentives to buy ecocars.

It is difficult for the taxi company to influence the fossil carbon dioxide emissions from taxi cars because the cars are not owned by the company. However, they can encourage and give economical incentives to the taxi car owners to buy ecocars or provide ecodriving courses to the drivers to improve the value of their trademark and to comply better with the customers' requirements. Of course, the profitability of this strategy depends on requirements in future procurements.

The taxi car owners have larger possibilities to influence the fossil carbon dioxide emissions. They can switch to an ecocar or a more fuel efficient car and in other ways improve fuel efficiency, e. g. by using right tyre pressure, low rolling resistant wheels, low viscosity motor oils and proper maintenance of the vehicle. It is also possible to improve efficiency by ecodriving and teaching ecodriving to the other drivers (of the same vehicle). However, there is a risk that the actual car owner only continues ecodriving because s/he can make a profit (s/he pays the fuel and directly saves money with lower fuel consumption), whereas the other drivers (of her/his car) may need some bonus or part of the saved money to be encouraged to continue with ecodriving. In the next chapter some abatement costs for choosing an ecocar, a more fuel efficient car and for using ecodriving are presented. Other measures for reducing fossil carbon dioxide emissions in the taxi business are not included since they are difficult to quantify, mainly because of bad monitoring methods of fuel consumption.

Fuel consumption and emissions of fossil carbon dioxide are not measured at company level, neither as a total nor per km travelled. The reason for this being that it is the car owners that pay the fuel and it is, according to one of the taxi companies, considered too expensive to calculate the total fuel consumption and especially to relate this to the distance travelled.

## 4.2 Bus companies

The structure of the bus business can be explained by dividing it into four groups; the customer (travelling by bus), the public transport companies[28], the bus companies (owners of the buses) and the bus drivers. All these groups have opportunities to affect the emissions of fossil carbon dioxide[29]

The public transport companies together procure most of the bus traffic in Sweden. They have large possibilities to influence the emissions from the bus traffic e. g. by demanding ethanol buses, especially because there is no explicit competition on the public transport market[30]. In other words, the public transporting companies have the possibility to pay extra for an alternative that decreases the emissions if the politicians decide so[31]. The public transport companies can also decrease their emissions by replacing buses by new subways, trams etc. The most positive impact on the total emission level though is if the public transport gains market shares of the total transport from the

[28] Most common, but it can also be e. g. travel agencies that organise bus trips.

[29] However, the customers have rather small possibilities except selecting other modes of transport, e. g. trams and trains.

[30] Of course they compete with other modes of transport such as cars, but not with any other public transportation companies.

[31] The public transport companies are controlled by politicians..

car traffic. RTK (The Office of Regional Planning and Urban Transportation, Stockholm) has made forecasts about how the planning of infrastructure can affect the emission levels of carbon dioxide in the future (RTK, 2002).

The bus companies are large actors in the transport sector and therefore also large emitters of fossil carbon dioxide. The bus sector in total is smaller than the road freight sector, but the bus sector is more concentrated to a few big companies. The big bus companies in Sweden are Swebus, Connex (called Veolia Transport since the end of 2006) and Busslink. The bus companies, as do all vehicle owners, have large opportunities to influence the emission levels. They can convert diesel buses to bio fueled buses, buy bio fueled buses instead of diesel buses, select more fuel efficient buses, and in other ways improve fuel efficiency, e. g. by using right tyre pressure, low rolling resistant wheels, low viscosity motor oils and proper maintenance of the vehicles. It is also possible to improve the fuel efficiency by ecodriving[32]. Because of the big size of the bus companies they have the possibility to take part in research programs e.g. to increase the low blending of bio fuels in conventional fuels from 5% (today's level) to 10%[33]. In the next chapter there are further descriptions of the measures and assumptions made in the cases where it has been possible to calculate abatement costs.

In the last years the monitoring of the buses' fuel consumption has been improved. With increased fuel prices and better monitoring technology and evaluation tools it has been more important and easier to monitor each bus' fuel consumption. One of the large bus companies controls the fuel consumption every morning. Buses that have increased fuel consumption are maintained as soon as possible. Increased monitoring and better follow up systems increase the possibility to quantify efficiency measures and to verify if it is profitable to invest in different fuel saving activities. Many of the measures mentioned above are not possible to quantify, mainly due to lack of monitoring data[34].

## 4.3 Road freight companies

The structure of the road transport business can be explained by dividing it into four groups; the customer (who wants something transported), the logistic companies, the road freight companies (owners of the lorries) and the lorry drivers. All these groups have opportunities to affect the emissions of fossil carbon dioxide.

Depending on the size of the customer s/he has different possibilities to affect the emissions from the transported goods. Large customers may have their own logistic company and can therefore directly influence their emissions, as the logistic company described below. Large customers also have the possibility to specifically ask for e.g. train transport. Small customers may now also affect their emission level, as one logistic company offers a service where the customer can pay extra to receive a climate neutral[35] transport. This company uses the extra income to reduce their own

[32] It is the bus company that saves money on ecodriving. However, it is the driver who can select using ecodriving or not. The bus company therefore has to provide education to the drivers and to create incentives for the bus drivers to use ecodriving.

[33] Only 5% is allowed in 2006, but discussions are going on concerning the possibilities to increase that to 10%.

[34] Even if it may be possible to measure in some cases today, there is a lack of historical data to compare with.

[35] The transport will not result in any increase of GHG emissions.

emissions e.g. by financing biogas lorries or buying emission reductions from others[36]. The transported goods itself will not be transported without fossil carbon dioxide emissions, but in this way the logistic company takes responsibility for the emissions.

The logistic companies[37] may reduce their emissions of carbon dioxide by offering services like the one above or they can demand environmental improvements from the road freight companies they have engaged. They can also demand environmental certification according to ISO14001. However, because they act on a market with competition they do not have the same possibility as the public transport companies to pay extra for transports with lower emissions if the customer does not want to pay extra. The logistic companies do not have the same possibilities as the taxi companies, possibly because there are less emission reduction options (e.g. ecocars) that are economically equal to the conventional alternatives.. The logistic companies may influence where the distributional centrals are situated though (which affects the carbon dioxide emissions) and in some cases they may also influence the choice between road- and railway transport.

There are only a few road freight companies, and they consist of many small companies (where many companies only have one lorry)[38]. The big companies can reduce fossil carbon dioxide emissions by e. g. converting diesel lorries to bio fueled lorries, buy bio fueled lorries instead of diesel lorries, select more fuel efficient lorries, and in other ways improve fuel efficiency, e. g. by using right tyre pressure, low rolling resistant wheels, low viscosity motor oils and proper maintenance of the vehicles. It is also possible to improve the efficiency by ecodriving[39]. In some cases (depending on the size of the company) the distinction between the logistic company and the road freight company is not very clear and the road freight company also has the possibility to choose whether the goods should be transported by lorry or by train. In the next chapter there are further descriptions of the measures and assumptions made in the case it has been possible to calculate abatement costs.

The monitoring of fuel consumption has, as for buses, increased significantly the last years. This will facilitate evaluation of different measures for fuel efficiency in the future.

## 4.4 Maritime shipping companies

The structure of the maritime shipping sector is similar to the goods transportation on land. The major difference is that the transport to a larger extent is international and that larger vehicles make the transport[40].

The maritime shipping companies do not have to pay fuel taxes and that makes them more sensitive to fuel price changes. An increased e oil price will result in a higher increase in percentage for the maritime shipping companies compared to the road transport companies (who pay fuel- and energy tax). The ambition to find more fuel saving measures has increased dramatically since the oil price started to rise. One of the maritime shipping companies succeeded to save 5% fuel per ship

[36] E. g. buy emission allowances in the European Emission trading scheme or from CDM or JI projects, or to buy emission reductions from tree planting schemes.
[37] DHL, Schenker and Posten AB are large logistic companies in Sweden.
[38] The largest road freight companies are Posten åkerier and Schenker åkerier.
[39] It is the road freight company that saves money on ecodriving. However, it is the driver that can choose using ecodriving or not. The road freight company therefore has to provide education to the drivers and to create incentives for the lorry drivers to use ecodriving.
[40] A ship takes a lot more goods than a lorry, but it usually has lower emissions per transported ton per km.

per departure during one year. The measures included many things, such as switch to energy efficient light bulbs, better protection against algae that stick on the outside of the ship, better heat treatment and changed propellers. All energy that was saved on board also resulted in reduced fuel consumption, as the fuel used in the engines produces the electricity and heat used on board. Each of these measures alone has limited impact on the emission level, but together the reduction may be substantial. The most important of the measures that have been possible to quantify has been changing propellers, see next chapter for further information.

The single most efficient measure would be to decrease the speed of the ships. However, for some customers speed is important and it is therefore difficult to decrease speed according to the shipping companies.

## 4.5 Aviation companies

The structure of the aviation companies is different from the other transport sectors. The sector can not be divided into groups.[41].

The situation for the aviation companies is similar to the maritime shipping companies. E. g. neither of them pay fuel taxes, and both have vehicles that use more fuel per vehicle compared to the road transport companies. The largest operator in Sweden (SAS) emits about 4 M ton of fossil carbon dioxide yearly for all their flights, including international flights (SAS, 2006). This should be compared to the biggest road transport company, Posten (The Swedish Post Company) that emits 185 000 ton per year. Improved technology decreases the fuel consumption with 1-2 % per passenger, km and year. The ambition of the aircraft industry is to decrease the fuel consumption by 50% per passenger km until year 2020.

Ecodriving is a possibility for aircrafts too. Flying a little bit faster when flying with the wind and a little bit slower when flying towards the wind, saves both time and fuel (about 3-4% of the fuel consumption). Direct communication between the airport and the autopilot of the airplane can also save fuel because the airplanes can go directly from travelling on a high level to landing instead of going down stepwise. By doing so 100-300 litres of fuel could be saved per landing, which corresponds to 3-10% of the total consumption for an airplane flying from the Northern parts of Sweden to Stockholm. Better air traffic management (e.g. more straight routes and less circulations before landing) including this measure can decrease the emissions in Europe by about 10-12%.

One of the aircraft operators suggests blending bio fuels (RME) in the conventional fuel for airplanes. Their fuel is rather similar to diesel fuels but it has to be cleaner. However, this could only be realized if a fuel supplier could guarantee the quality of the fuel.

## 4.6 Private car owners

The category private car owners differ from the other sectors mainly because it is not a business. The structure is also different as the "customer", the owner of the vehicle and the driver in most cases is the same person or belong to the same family.

[41] The airlines do not always own the airplanes but they pay the fuel costs and have the possibility to change airplanes. For this study it does not matter if the airplanes are owned by the airline or only leased.

The possible measures for reducing the emissions are similar to the ones for the taxi business. However, the reduction potential is smaller per car and year because the private cars are only used about one 10th as much as the taxi cars in average.

# 5 Description of measures

Table 7 below shows the measures explained by the interviewed companies. Many of these measures have not been easy to quantify neither in reduction potential nor in cost. The measures are described below and when it has been possible to quantify reduction potential and / or cost the relevant assumptions are presented. Be aware that this is not a complete list of measures possible in the transport sector. Only measures that are considered by the interviewed companies are included.

Table 7: All measures in this study divided into different categories.

| Category group of measures | Relevant in transport group(s) |
|---|---|
| Blending bio fuel (FAME or Ethanol) into petrol or diesel | Taxi (Ethanol in petrol since a couple of years, FAME in diesel since Aug 1st 2006)<br>Bus (FAME in diesel since Aug 1st 2006)<br>Road freight transport (FAME in diesel since Aug 1st 2006)<br>Aviation (will be possible within a few years)<br>Private cars (Ethanol in petrol since a couple of years, FAME in diesel since Aug 1st 2006) |
| E85 (85% Ethanol and 15% petrol),FAME or biogas used instead of petrol or diesel (without investment in new vehicle, assumption that the investment in a flexifuel car is already done). | Taxi (E85, biogas)<br>Bus (E95, biogas)<br>Road freight transport (biogas)<br>Private cars(E85, biogas) |
| Select of a more fuel efficient vehicle or "eco-vehicle" when buying a new vehicle. | Taxi (E85, biogas, electrical hybrid)<br>Bus (converting diesel to ethanol, E95)<br>Road freight transport (biogas)<br>Aviation (future technology improvement)<br>Private (E85, biogas, electrical hybrid) |
| Ecodriving | Taxi<br>Bus<br>Freight transport<br>Maritime shipping (drive slower)<br>Aviation<br>Private cars |
| Tyre pressure control | Taxi<br>Bus<br>Freight transport<br>Private cars |
| More efficient logistics | Bus (in terms of modal split; from cars to buses and from buses to subway, tram or railroad)<br>Freight transport (in terms of distribution centrals and modal split; using railroad instead of lorries).<br>Maritime shipping (in terms of modal split; using shipping instead of lorries). |
| Various efficiency measures | Aviation (more efficient air traffic control)<br>Maritime shipping (electricity savings, defence against algae, change of propeller) |

## 5.1 Bio fuels

### 5.1.1 Low blending of bio fuels (5%)

Since the end of 2006 all petrol and diesel produced for road traffic in Sweden include 5% bio fuels[42]. The most problematic step in investigating the abatement costs for this measure has been to determine the fuel prices, both for pure conventional fuels and for bio fuels. The price for pure bio fuels (both ethanol and RME) has been assumed to be equal to the production price of ethanol produced from crops according to Agroetanol (pers. comm. 2006). The production price for bio fuels is used in this measure instead of the price for E85 because the higher price for E85 is assumed to include the extra costs for distribution (that is not necessary for low blending). The production price for bio fuels and the prices for petrol (with 5% ethanol) and for diesel (with 5% RME) have been used to calculate the prices for pure petrol and diesel. See the assumption chapter above for more information about the assumed prices.

No investment costs are assumed because no extra distribution system is needed for distributing low blended bio fuels. The investment to blend fuels is assumed to be neglectable. The reduction potential has been calculated based on the petrol- and diesel consumption in Sweden 2005 provided by SPI (2006-12-28).

### 5.1.2 High blending of bio fuels

The number of flexifuel cars sold in Sweden has increased rapidly during 2006. Flexifuel cars and bio fueled buses stand for the vast majority of the bio fuel demand in Sweden (E85, E95 and biogas)[43]. The abatement costs for choosing bio fuel instead of conventional fuels are calculated without investment cost. If the investment in a flexifueled vehicle already has been made is it no investment cost to switch between bio fuels and conventional fuels. The measures have been exemplified by calculating the abatement costs for one taxi car (see the assumption chapter for information about average fuel consumption and mileage per year).

Inputs for these calculations have been the prices and emission factors described in the assumption chapter above for diesel (incl 5% RME), petrol (incl 5% ethanol), E85, and biogas. No change in investment or maintenance costs has been assumed. The only parameters that influence the abatement costs are different fuel prices and fuel consumption per 100 km.

## 5.2 Investment in new vehicles

This category of measures includes investments in bio fueled and more fuel efficient vehicles, including conversion of buses.

[42] Volume percent

[43] These are the major bio fuels at the market today, excluding the low blended bio fuels.

### 5.2.1 Taxi companies

Taxi car owners usually change cars each third year, because the car starts to be worn-out and it is expensive to prolong the service contract after three years. When selecting a new car some basic needs have to be fulfilled:

- Automatic gearbox due to work environment.

- A certain size is needed. The taxi company would like to offer cars with a certain standard size so the customer knows what s/he gets. E. g. the Toyota Prius is slightly too small for most taxi companies. However, some taxi companies have allowed Toyota Prius anyway because it is an "ecocar".

- The service contract and guarantee are important to a taxi company. This can be problematic for cars with alternative fuels and new technologies. For example the standard guarantee for an electrical hybrid car is not sufficient (only 160 000 km) and needs to be renegotiated. A good service contract for the whole economical lifetime is needed to avoid economical problems if the car gets broken. The average income for a taxi car is approximately about 3000 SEK / day so it is important to get the car repaired fast if it gets broken

Automatic gearbox, size limitation and the standard needed in the taxi car all decrease the number of cars available for taxi owners. Five different measures concerning selecting a more fuel efficient or bio fueled car instead of a conventional car are presented in the result chapter. Two of these measures imply selecting a diesel car instead of a petrol car[44]. The Volvo V70 (diesel) is one of the most common taxi cars in Stockholm, but the ecocars are rapidly increasing. The Volvo V70 (biogas) has been the dominating ecocar but as Volvo declared that they will stop the production of biogas cars, Saab 9-5 biopower (E85) is now the most common choice even if it is much more expensive than Toyota Prius. The reason is probably that the taxi owners are more used to the standard and size of the Saab and Volvo even if the Toyota Prius fulfil the requirements for taxi cars. However, some taxi owners have seen economical benefits when buying an electrical hybrid such as Toyota Prius.

In the calculations of the abatement costs for the five measures concerning new vehicles in the taxi business,, investment costs of new cars as well as operation- and maintenance costs have been provided by the taxi company. The investment cost for all cars is lower for taxi companies than described by The Swedish Consumer Agency below because taxi companies get discounts on new cars. Other assumptions for the calculations as fuel consumption, travelled distances for taxi cars per year, fuel prices and emission factors can be found in the assumption chapter above.

### 5.2.2 Bus companies

Bus companies usually change buses each 12-14 years. However, the increasing demand for improving environmental concern from the public transport companies is decreasing the lifetime of the buses. SL (the public transport company in Stockholm) has renegotiated the contracts with the bus companies so that they can now introduce ethanol buses. To respond to this request of fast introduction of ethanol buses the bus companies have chosen to convert some of their vehicles to ethanol buses.

[44] Petrol cars are rather uncommon as taxi cars because of the lower fuel price for diesel cars.

One of the bus companies has provided an approximation of the cost for converting a bus[45]. The bus company sometimes has extra cost for refilling ethanol buses. Because of the risk of explosion they cannot refill the bus indoors where they clean and check the vehicle as they can do with the diesel buses. With the ethanol buses they have to drive to a special pump outdoor, which takes extra time for the drivers and increases the costs. Because the ethanol bus uses more fuel (about 70% more according to the assumption chapter above) it has to be refilled more frequently (up to three times a day compared to a diesel bus that usually only needs to be refilled once a day). The extra trips to the fuel depot also influence the efficiency of the ethanol buses.

An alternative to converting the bus is to buy a new ethanol bus. The extra cost is less than the cost for converting a diesel bus (in the calculations this extra cost is assumed to be 2/3 of the cost for the conversion)[46]. The only company that produces ethanol buses in Sweden is Scania. The low degree of competition makes it more expensive to buy ethanol buses than it could have been otherwise[47].

Two calculations of abatement costs for ethanol buses are presented in the result chapter. One representing the conversion of a diesel bus to an ethanol bus and the other investment in a new ethanol bus instead of a conventional bus. The maintenance cost for the ethanol buses is increased partially because of the extra time that it takes to refill the bus[48]. The economical lifetimes for the investments are assumed to be 13 years for investment in a new bus[49] and 8 years for conversion of a bus (assumed to be 5 years old). The assumptions for fuel consumption, distances driven per year, emission factors, and fuel prices are presented in the assumption chapter above. The higher fuel price for E85 is used and not the production price for the ethanol. The reason is that the extra costs SL has for the fuel depots and distribution could be assumed to be included in the price for E85.

According to SL it has been rather expensive to renegotiate existing contracts to include ethanol buses because of the lack of competition. The first procurement including ethanol buses from the beginning is due in the end of 2006. Probably this will be less expensive for SL. According to SL's internal calculations it is 8-22% more expensive to use ethanol buses than conventional buses.

In Sweden there are a couple of hundred biogas buses. Unfortunately no bus company provided data for calculations of biogas buses and that measure is therefore excluded in this study.

It has not been possible to compare fuel efficiency for different buses. A comment from the bus companies is that the fuel consumption has increased in new buses. The reason is partially that stronger engines, originally developed for lorries, are used. Another explanation is that AC (air condition) and other comfort is included that request more fuel.

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[45] This number is unfortunately not public, because it is sensitive business information.
[46] However, if the company does not need a new bus, it is probably cheaper to convert the vehicle.
[47] Even if this gives Scania a good opportunity to get large profit for ethanol buses they where planning to stop their production of ethanol buses in 2007. However, with massive protests from SL (Stockholm public transport) Scania changed their decision and will continue to produce ethanol buses in the next generation of buses that starts to be delivered in 2007.
[48] Differences in maintenance costs come from Ethanol bus (2006-12-08). One bus company approximates the cost to refill the buses, however this number is not public.
[49] Average of 12 and 14 years that the bus companies claim to be the usual lifetime for buses.

### 5.2.3 Road freight companies

In the interviews with the road freight companies only a few bio fueled vehicles have been mentioned. No lorries using ethanol, but a couple of lorries using biogas, exist in Sweden. Some of these biogas vehicles have been part of a validation project of biogas lorries by a large consortium of transport buyers, transport companies and lorry manufacturers. The validation showed that the biogas lorries were very costly. Partly as a result of the report Volvo has now stopped their production of biogas lorries and Scania does not produce any biogas lorries either. Some of the reasons are that (results from this study):

- The operation and maintenance was expensive and time consuming because the ordinary staff could not do it because it was a non-standardised vehicle.
- Decreased possibility to move the vehicle between different cities if demand of transport increased or decreased[50]. Biogas does not exist in all cities.
- The value on the second hand market is unknown for bio fueled vehicles.
- The investment cost of bio fueled vehicles is higher. For biogas lorries the investment cost is up to 60% higher (according to one of the transport companies).

The abatement costs for one lorry and one van are calculated. The assumptions for mileage, differences in investment- and maintenance costs have been provided by one of the transport companies. The mileage provided by the company is lower than the mileage for lorries in this study, probably because these lorries are only used for distribution traffic and not long distance transport. The fuel consumption is assumed to be about 1.5 times higher with biogas (in Nm3) than with diesel (in litre) per km[51]. The lifetime of the investment is 8 years in the calculations.

The calculations of investment costs in more fuel efficient vehicles are more difficult for lorries and buses than for cars. One reason is that there is no standard test cycle for bigger vehicles as there is for cars. Hybrids could be an option, but it is not an abatement option for any company today. No abatement costs have been possible to calculate for investments in more fuel efficient lorries.

### 5.2.4 Maritime shipping companies

More fuel efficient ships or bio fueled ships have not yet been discussed by the maritime shipping companies as a measure for reducing fossil carbon emissions. The fuel efficiency is very important though, and fuel efficiency is improved in every new generation of ships. The main reason for the increased efficiency is larger ships that decrease fuel consumption per transported tonne of gods.

It has not been possible to calculate any abatement costs for investments in bio fueled ships or more fuel-efficient ships.

### 5.2.5 Aviation companies

Bio fueled airplanes are mentioned by one of the interviewed companies as a measure for reducing fossil carbon emissions. Fuel efficiency is very important and always desirable. The main reason for the increased efficiency that we have seen so far is larger vehicles that decrease fuel consumption per transported person.

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[50] The total transport demand in the city will probably not decrease, but a certain transport company may increase or decrease its market shares.

[51] Calculation based on the extra fuel costs provided by the transport company.

It has not been possible to calculate any abatement costs for investments in bio fueled airplanes or more fuel-efficient airplanes.

### 5.2.6 Private cars

Private persons have about the same possibilities to select an eco car or a more fuel efficient car as the taxi car owners. However, the consequences are different because of different mileage per year and different investment costs.

The specific assumptions used for the abatement cost calculations for private cars are found in Table 8. The fuel price, fuel consumption (same as for the taxi cars), yearly mileage, and emission factors are presented in the assumption chapter above. The economical lifetime is assumed to be 15 years (average lifetime of a car according to Gröna bilister (2006)).

Table 8: Investments costs and yearly maintenance costs for some vehicles according to The Swedish Consumer Agency (2006-12-12) (excluding VAT). The maintenance- and tyre costs are the average values per year, based on the first 10 years according to The Swedish Consumer Agency. The investment costs for Saab 9-3 are provided by Saab (2006-12-22). The maintenance- and tyre costs for Saab 9-3 is assumed to be equal for the two different Saab 9-3 models.

| | Investment (SEK) | Maintenance (SEK/year) | Tyres (SEK/year) |
|---|---|---|---|
| Volvo V70 (diesel) | 244 000 | 4 672 | 2 200 |
| Volvo V70 (petrol) | 218 400 | 4 008 | 1 728 |
| Volvo V70 (biogas) | 234 400 | 4 672 | 2 200 |
| Toyota Prius | 218 400 | 3 480 | 1 184 |
| Saab 9-5 (petrol) | 210 400 | 4 616 | 2 080 |
| Saab 9-5 (ethanol) | 217 600 | 3 960 | 1 632 |
| Saab 9-3 (petrol, 175 hk) | 198 880 | - | - |
| Saab 9-3 (petrol, 150 hk) | 190 320 | - | - |

For taxi companies one measure was changing from diesel car to an ethanol car. For private persons the same measure is based on a switch from a petrol car instead. The reason is that petrol cars are more common for private persons and diesel cars more common for taxi owners. For private cars the measure of selecting a more fuel efficient (and less powerful) engine is included.

## 5.3 Ecodriving

Ecodriving has a large potential to reduce fuel consumption and carbon dioxide emissions (5-15% for cars, lorries and buses). Ecodriving also has positive side-effects such as less accidents, better work environment (less stress), and less need for maintenance.

Even if ecodriving has large positive effects it is not commonly applied. The reasons are mainly problems to monitor the effects. It is difficult to verify the improvement and to give the drivers direct feed back, e. g. by sharing the profit from the fuel saving. If the drivers cannot get feed back they might forget what they have learned about ecodriving. In the last years technical instruments have entered the market that has made it easier to monitor fuel consumption and there has been an increase in interest for ecodriving. The interest for ecodrivning is different for the different categories of transport companies partly because of the structure of the categories.

The assumptions for the abatement cost calculations for all ecodrivning measures are found in the assumption chapter above and in Table 9 below.

### 5.3.1 Taxi companies

The advantage of ecodriving for the taxi companies is that the drivers usually own the car and pay the fuel. Therefore s/he gets feed back of decreased fuel costs directly. However, the car owner has low possibilities to monitor each driver´s consumption because many drivers can share the same tank. This problem could maybe be solved, but the car owners usually only have a few cars and they cannot invest a lot of time and money to develop monitoring systems.

The encouragement for ecodriving instead comes from the customers through procurements or from the taxi company that provide ecodriving courses because they see the benefit of it and understand that the customers would like drivers that drive more careful and fuel efficient.

### 5.3.2 Bus companies

The benefit of ecodrivning would probably be large for the bus companies because, especially when driving in cities, the bus drivers have to break and accelerate a lot. However, the monitoring problem is even larger than for the taxi business. The bus companies are large and have the economical resources to develop systems, but it is very difficult to give feed back individually to the drivers as a bus usually have about 3-4 different drivers during one day before it is filled up with fuel. Tight timetables make the bus drivers stressed, which makes ecodriving more difficult.

### 5.3.3 Road freight companies

Implementing ecodriving has been more successful in the road transport companies, at least for the larger companies. The main reason is that the larger companies have resources to develop a strategy and to invest in monitoring systems. Compared to buses there are also fewer drivers involved per vehicle. The road transport companies have also included better follow up systems for keeping the speed limit of 80 km/h, which decreases the fuel consumption. Many persons used to drive 90 km/h before, even if it was not allowed. Some companies presented numbers telling that the fuel efficiency and sometimes even the travel time decreased if the maximum speed was 80 km/h instead of 90 km/h because of better possibility to plan the driving.

### 5.3.4 Maritime shipping companies

Ecodriving was not discussed during the interview. However, decreased speed is the major fuel saving option for the maritime shipping companies. The problem is that the customers do not want longer travel times.

### 5.3.5 Aviation companies

Ecodriving is possible even in the aviation sector. Flying a little bit faster when flying with the wind and flying a little bit slower when flying towards the wind decreases the fuel consumption with about 3-5% and it also decreases the travel time.![52] During 2006 it is estimated that more efficient flying saved about 4% or 160 000 ton $CO_2$ emissions (250 million SEK) for SAS (SAS, 2006). However, they do not provide any investment cost (such as cost for educating the pilots) so the calculation of the abatement cost is done without investment cost.

### 5.3.6 Private cars

Private persons get feed back directly because the owner and the driver is usually the same person or belong to the same family. However, the knowledge about the effect is not very well known and very few people invest money in ecodriving courses. The cost for the course is different for private persons because no cost for loss of income is assumed.

### 5.3.7 Assumptions for abatement cost calculations of ecodriving

Assumptions for the calculations of abatement costs such as cost forthe course, cost for the drivers loss of work time when they attend the course, fuel savings, distance driven by each driver, and lifetime of investment is presented in Table 9. The fuel prices and emission factors are presented in the assumption chapter.

Table 9: Assumptions for the calculation of abatement costs. The values "distance per driver" are provided by a taxi company. Concerning the bus it is assumed that two people in average are employed to drive one bus. For lorries one person is assumed to be employed per lorry, and the number of private cars is assumed to be one driver per car in average. The fuel savings for taxis and private cars originate from the taxi company[53] and the fuel savings for buses and lorries originate from a road freight company[54]. The costs for the courses are derived from Sparcoach (pers. comm. 2006). The economical lifetime for ecodriving is probably longer with investments in follow-up systems and the assumed lifetimes could be much shorter without any follow-up systems. VAT is excluded.

| Ecodriving | Course (SEK) | Cost for the drivers' time (SEK) | Total investment cost (SEK) | Economical lifetime (years) | Distance per driver (km / year) | Fuel saved |
|---|---|---|---|---|---|---|
| Taxi (Volvo V70 diesel) | 1 500 | 1 280 | 2 780 | 1 | 8 000 | 12% |
| Bus (diesel) | 3 000 | 2 000 | 5 000 | 1 | 4 000 | 7% |
| Lorry (diesel) | 3 000 | 2 000 | 5 000 | 1 | 13 750 | 7% |
| Private (Volvo V70 diesel) | 1 500 | | 1 500 | 1 | 1 436 | 12% |

Some parameters have not been included in the calculations. This includes; costs for follow-up equipment, computer programs, extra time (for administration personal), follow-up courses, savings in maintenance and savings because of fewer accidents and more healthy drivers. The effects, that have not been possible to include, would both affect the total cost positively and negatively. With the short economical lifetime in mind and the fact that these effects more or less equalise it can be assumed that the calculations of abatement costs is relatively correct. To learn more about ecodriving, read (NTF Konsult AB et al, 2005).

[52] According to the interviewed aviation company.

[53] The average value for 74 drivers when the fuel consumption was compared before and after attending an ecodriving course (the same route both times). The long-term reduction is probably much less if monitoring systems do not exist.

[54] A test made for lorry traffic between two cities over some time. In this case monitoring equipment existed and the effect will probably continue.

## 5.4 Tyre pressure

Using correct tyre pressure has the potential to save up to 5% fuel. However, the result depends on how low the tyre pressure is before the measure. One of the bus company claims that the potential is between 1 and 2% fuel savings. A positive side effect is increased lifetime of the tyres. Negative side effects are that the journey may become bumpier and the breaking distance might increase. According to the instruction book for the new Saab cars it is recommended to have higher tyre pressure than normally suggested (Saab, 2006).

As an alternative, instead of checking the tyre pressure frequently, one can fill the tyres with $N_2$-gas. $N_2$-gas will keep the tyre pressure constant and refilling is not needed. The investment is according to a bus company 100 SEK / tyre.

Abatement costs for tyre pressure have been calculated for buses. The assumptions are a reduction of fuel consumption on 1.5%, an investment of 2000 SEK (10 wheels, 100 SEK / wheel and 1000 SEK for extra work time[55]) and an economical lifetime of one year. The other assumptions as mileage, fuel consumption and emission factors etc are found in the assumption chapter above.

## 5.5 Efficient logistics

Efficient logistics include a wide range of measures, which have relatively large potentials to reduce fossil carbon dioxide emissions. However, these measures are usually difficult to implement and may take many years to plan.

The most obvious measure might be to optimize the placement of the distribution centrals for goods. However, moving distribution centrals is often very difficult because many different needs and wills should be fulfilled. Usually the distributing company will not have access to the most optimal place because the municipality have other plans on that site or does not want increased traffic at that point. Which site that is the best also changes over time due to the development of infrastructure such as roads and railways and because of the regions development of businesses and residential areas. One road transport company placed their distribution central in Stockholm when the so-called "Ringleden" (a circle road around Stockholm) was planned to be built, 15 years ago. So far it has not been the optimal solution, because only some parts of the road project have been finished. The "environmental zones"[56] in some cities also affect the placement of distribution centrals. The zones could result in localisation of the distribution centrals further away from the city centre, which would be less fuel efficient (even if other environmental impacts will decrease). No company had any example of effects from a redistribution of a distribution central and it has therefore not been possible to calculate any abatement costs for this measure

The transporting companies continuously try to make the transportation as efficient as possible. They usually use different computer programs to optimize the traffic according to some parameters such as minimising travel distance and driving time, which are usual parameters for bus companies. The big procurements for bus traffic make it unnecessary to update this process regularly (only about each fifth year when the procurement is open for competition). The situation for goods transport companies is different because the transported volume changes continuously which makes it more difficult to plan. However, one of the interviewed road freight companies succeeded

[55] Probably it does not take any extra working time.

[56] Local rule for decreasing mainly the emissions of particles in the city centers.

to remove 25 lorries when they used a new methodology and software to optimize the traffic. The company has provided the investment (in working time) to develop the software and the size of the reduction. The economical lifetime has been assumed to be five years in the abatement calculations.

This study also includes infrastructural measures identified by the interviewed companies in the category efficient logistics. The regional planning and public transports have large possibilities to impact the fossil carbon emissions in a region. RTK (2002) makes this type of planning for the Stockholm region. Last time it was done they examined different options to decrease the climate impact from the transport and energy sectors by different alternatives. RTK is in the middle of a new process that will deliver an update in year 2008. In this version the climate impact issue will be of increased importance. In some places new subways, trams or trains constitute the best option to improve the public transport and in other places it could be better to focus more on new buses to make the public transport gain market shares of the total passenger transport. Tendencies that would decrease the public transport market share is that people want to live less dense and move out of town (e. g. from apartments to houses) and that they go shopping in supermarkets outside the city where they travel by car. It has not been possible to calculate any abatement costs for this type of measures because of difficulties in quantifying and finding clearly defined measures.

One bus company has also commented that increased efficiency sometimes can be reached by small changes in the streets that increase the possibilities for the buses to decrease travelling time. The bus companies also discuss variations in timetables during rush hours to avoid driving too fast by bus. This could make it easier to apply ecodriving which would save large amounts of fuel, see above. Because of difficulties to estimate the effects and to estimate the costs for these small and individual measures it has not been possible to calculate any abatement costs.

## 5.6 Various efficiency improvements

As the name of this group of measures indicates this is a wide category of efficiency measures. Most of them are small measures, but together they can have large impact.

The only measure where it has been possible to calculate an abatement cost is for change of propellers at ships. The ships where the propellers were changed were built for 21 knots, but used only in 18 knots. Change of propellers to propellers optimised for 18 knots resulted in large fuel savings. The abatement calculation assumes the change of propellers on one ship. Unfortunately the investment cost is not public and to avoid the possibility to calculate the investment cost the fuel cost is also left out. The fuel cost for bunker fuels for ships is substantially lower than for other fuels though.

# 6 Sensitivity analysis

The results of this study are very sensitive to the values of the input parameters as fuel prices and emission factors. Therefore a sensitivity analysis has been conducted. Five cases (including the base case) with different fuel prices and emission factors are presented in the result chapter. The differences between the cases are presented below:

- The base case is calculated with fuel prices with taxes but without VAT and with emission factors that are based on LCA from literature sources (for example the $CO_2$-efficiency is

85% for ethanol). The aim with this case is to represent the companies' situation when making the decision about implementing measures.

- Case 1 is calculated with fuel prices without taxes and without VAT. The emission factors are the same as for the base case. Excluding taxes is a way of trying to exemplify the society cost for the measures. However, to calculate the true society cost a much more thoroughly investigation is needed.

- Case 2 is calculated with the same fuel prices as in the base case with the exception that the bio fuels are 30% cheaper. The same emission factors as in the base case are used. This case represents an optimistic technical future for bio fuels where the production cost falls and the bio fuels would be substantially cheaper compared to fossil fuels.

- Case 3 is calculated with the same fuel prices as in the base case. However, the emission factors only include direct emissions and bio fuels have zero emissions in this case. This represents the way emissions are calculated in the European Emission Trading Scheme (EU ETS).

- Case 4 is calculated with the same fuel prices as in the base case. However, the emission factors represent a LCA case where the bio fuels only have 50% $CO_2$ efficiency[57]. Indirect emissions from bio fuels vary substantially depending on how and where they have been produced. This case represents a scenario where the bio fuels have larger indirect emissions than assumed in the base case.

All fuel prices and emission factors can be found in the assumption chapter above.

# 7 Results

In table 9-15 below the results are divided according to the different categories. A table with the results listed according to cost level can be found in the appendix. The result tables include the base case and the four sensitivity cases.

[57] The use of bio fuels only reduces the $CO_2$ emissions by 50% compared to fossil fuels.

## 7.1 Bio fuels

### 7.1.1 Low blending of bio fuels (5%)

Table 10: See chapter “Description of measures” and the assumption chapter for more information about the measures. Be aware that the results are very dependent on the input parameters and the assumptions made for each measure. See the column “Scope of measure” to understand the size of the measure.

| Low blending | | Scope of the measure | Base case Abatement cost (SEK / ton $CO_2$ equ) | Case 1 Abatement cost (SEK / ton $CO_2$ equ) | Case 2 Abatement cost (SEK / ton $CO_2$ equ) | Case 3 Abatement cost (SEK / ton CO2 equ) | Case 4 Abatement cost (SEK / ton $CO_2$ equ) | Base case, case 1 & case 2 Reduction ton / year | Case 3 Reduction ton / year | Case 4 Reduction ton / year |
|---|---|---|---|---|---|---|---|---|---|---|
| Fuel supplier | 5% ethanol mixed with the petrol | The consumption in Sweden | -1 473 | 803 | -1 473 | -1 368 | -1 881 | 603 740 | 650 170 | 472 945 |
| Fuel supplier | 5% RME / FAME mixed with diesel | The consumption in Sweden | -1 821 | 340 | -1 821 | -1 253 | -2 223 | 334 453 | 486 281 | 274 008 |

### 7.1.2 High blending of bio fuels

Table 11: See chapter “Description of measures” and the assumption chapter for more information about the measures. Be aware that the results are very dependent on the input parameters and the assumptions made for each measure. See the column “Scope of measure” to understand the size of the measure.

| High blending of bio fuels | | Scope of the measure | Base case Abatement cost (SEK / ton $CO_2$ equ) | Case 1 Abatement cost (SEK / ton $CO_2$ equ) | Case 2 Abatement cost (SEK / ton $CO_2$ equ) | Case 3 Abatement cost (SEK / ton $CO_2$ equ) | Case 4 Abatement cost (SEK / ton $CO_2$ equ) | Base case, case 1 & case 2 Reduction ton / year | Case 3 Reduction ton / year | Case 4 Reduction ton / year |
|---|---|---|---|---|---|---|---|---|---|---|
| Fuel supplier | Use E85 instead of petrol in the flexifuel car | One taxi car, Saab 9-5 petrol/ethanol | 472 | 2 954 | -1 541 | 402 | 728 | 17 | 20 | 11 |
| Fuel supplier | Use biogas instead of petrol in the flexifuel car | One taxi car, Volvo V70 petrol/biogas | 1 578 | 4 204 | -740 | 893 | 4 249 | 13 | 22 | 5 |

## 7.2 Investment in new vehicles

Table 12: See chapter “Description of measures” and the assumption chapter for more information about the measures. Be aware that the results are very dependent on the input parameters and the assumptions made for each measure. See the column “Scope of measure” to understand the size of the measure.

| Investment in new vehicle | | Scope of the measure | Base case Abatement cost (SEK / ton $CO_2$ equ) | Case 1 Abatement cost (SEK / ton $CO_2$ equ) | Case 2 Abatement cost (SEK / ton $CO_2$ equ) | Case 3 Abatement cost (SEK / ton $CO_2$ equ) | Case 4 Abatement cost (SEK / ton $CO_2$ equ) | Base case, case 1 & case 2 Reduction ton / year | Case 3 Reduction ton / year | Case 4 Reduction ton / year |
|---|---|---|---|---|---|---|---|---|---|---|
| Taxi | Volvo V70 gas instead of a Volvo V70 diesel | One taxi car | 1 917 | 4 544 | -401 | 1 085 | 5 163 | 13 | 22 | 5 |
| Taxi | Saab 9-5 biopower (ethanol) instead of a Saab 9-5 diesel | One taxi car | 3 436 | 4 969 | 546 | 2 627 | 7 112 | 12 | 16 | 6 |
| Taxi | Toyota prius (electrical hybrid with petrol) instead of a Volvo V70 diesel | One taxi car | -2 746 | -2 524 | -2 746 | -2 919 | -2 750 | 8 | 7 | 8 |
| Taxi | Volvo V70 diesel instead of Volvo V70 petrol | One taxi car | -3 976 | -431 | -3 976 | -4 484 | -3 897 | 8 | 7 | 9 |
| Taxi | Saab 9-5 diesel instead of a Saab 9-5 petrol | One taxi car | -5 087 | -424 | -5 087 | -5 857 | -4 951 | 5 | 5 | 5 |
| Private car | Volvo V70 gas instead of a Volvo V70 diesel | One private car | 563 | 5 084 | -5 211 | 963 | 546 | 0,5 | 0,3 | 0,6 |
| Private car | Saab 9-5 biopower (ethanol) instead of a Saab 9-5 petrol | One private car | 202 | 1 669 | -1 533 | 175 | 291 | 2 | 3 | 2 |
| Private car | Toyota prius (electrical hybrid with petrol) instead of a Volvo V70 diesel | One private car | -7 420 | -7 198 | -7 420 | -7 887 | -7 430 | 0,9 | 0,9 | 0,9 |
| Private car | Volvo V70 diesel instead of Volvo V70 petrol | One private car | -844 | 2 700 | -844 | -952 | -828 | 1,0 | 0,9 | 1,0 |
| Bus | Ethanolbus instead of a diesel bus | One bus | 4 449 | 5 969 | 1 779 | 3 480 | 8 504 | 43 | 55 | 23 |

| Investment in new vehicle | | Scope of the measure | Base case Abatement cost (SEK / ton $CO_2$ equ) | Case 1 Abatement cost (SEK / ton $CO_2$ equ) | Case 2 Abatement cost (SEK / ton $CO_2$ equ) | Case 3 Abatement cost (SEK / ton $CO_2$ equ) | Case 4 Abatement cost (SEK / ton $CO_2$ equ) | Base case, case 1 & case 2 Reduction ton / year | Case 3 Reduction ton / year | Case 4 Reduction ton / year |
|---|---|---|---|---|---|---|---|---|---|---|
| Bus | Converting a diesel bus to a ethanol bus | One bus | 4 732 | 6 252 | 2 063 | 3 701 | 9 045 | 43 | 55 | 23 |
| Private car | Smaller and more fuel efficient engine for a Saab 9-3 sportcombi (150 hk instead of 175 hk) | One private car | -7 853 | -5 923 | -7 853 | -8 601 | -7 777 | 0,2 | 0,2 | 0,2 |
| Lorry | Biogas lorry | One lorry (35000 km / year) | 8 264 | 11 125 | 5 513 | 4 294 | 32 683 | 18 | 35 | 5 |
| Lorry (van) | Biogas van | One van (35000 km / year) | 5 437 | 8 342 | 2 606 | 2 783 | 23 559 | 7 | 13 | 2 |

## 7.3 Ecodriving

Table 13: See chapter “Description of measures” and the assumption chapter for more information about the measures. Be aware that the results are very dependent on the input parameters and the assumptions made for each measure. See the column “Scope of measure” to understand the size of the measure.

| Ecodriving | Scope of the measure | Base case Abatement cost (SEK / ton $CO_2$ equ) | Case 1 Abatement cost (SEK / ton $CO_2$ equ) | Case 2 Abatement cost (SEK / ton $CO_2$ equ) | Case 3 Abatement cost (SEK / ton $CO_2$ equ) | Case 4 Abatement cost (SEK / ton $CO_2$ equ) | Base case, case 1 & case 2 Reduction ton / year | Case 3 Reduction ton / year | Case 4 Reduction ton / year |
|---|---|---|---|---|---|---|---|---|---|
| Taxi | One taxi driver | -1 709 | -339 | -1 709 | -1 854 | -1 699 | 2 | 2 | 2 |
| Private car | One car, assumption that the number of cars and drivers are equal | 1 299 | 2 670 | 1 299 | 1 409 | 1 292 | 0,3 | 0,3 | 0,3 |
| Lorry | One lorry driver, assume one driver per lorry | -2 717 | -1 346 | -2 717 | -2 947 | -2 701 | 11 | 10 | 11 |
| Bus | One bus driver, assume two drivers per bus in average | -1 532 | -161 | -1 532 | -1 661 | -1 523 | 3 | 3 | 3 |
| Aircraft | The whole airline including all aircrafts in that company | -1 563 | -1 563 | -1 563 | -1 563 | -1 563 | 160 000 | 160 000 | 160 000 |

## 7.4 Tyre pressure

Table 14: See chapter “Description of measures” and the assumption chapter for more information about the measures. Be aware that the results are very dependent on the input parameters and the assumptions made for each measure. See the column “Scope of measure” to understand the size of the measure.

| Tyre pressure | | Scope of the measure | Base case Abatement cost (SEK / ton $CO_2$ equ) | Case 1 Abatement cost (SEK / ton $CO_2$ equ) | Case 2 Abatement cost (SEK / ton $CO_2$ equ) | 0 Abatement cost (SEK / ton $CO_2$ equ) | 0 Abatement cost (SEK / ton $CO_2$ equ) | Base case, case 1 & case 2 Reduction ton / year | Case 3 Reduction ton / year | Case 4 Reduction ton / year |
|---|---|---|---|---|---|---|---|---|---|---|
| Bus | 1.5% fuel efficiency improvement for a bus | One bus | -1 644 | -273 | -1 644 | -1 783 | -1 634 | 1,3 | 1,2 | 1,3 |

## 7.5 Efficient logistics

Table 15: See chapter “Description of measures” and the assumption chapter for more information about the measures. Be aware that the results are very dependent on the input parameters and the assumptions made for each measure. See the column “Scope of measure” to understand the size of the measure.

| Efficient logistics | | Scope of the measure | Base case Abatement cost (SEK / ton $CO_2$ equ) | Case 1 Abatement cost (SEK / ton $CO_2$ equ) | Case 2 Abatement cost (SEK / ton $CO_2$ equ) | Case 3 Abatement cost (SEK / ton $CO_2$ equ) | Case 4 Abatement cost (SEK / ton $CO_2$ equ) | Base case, case 1 & case 2 Reduction ton / year | Case 3 Reduction ton / year | Case 4 Reduction ton / year |
|---|---|---|---|---|---|---|---|---|---|---|
| Lorry | Optimization of traffic | Optimization of distribution traffic (total about 1400 vehicles) | -1 393 | -22 | -1 393 | -1 510 | -1 384 | 618 | 570 | 622 |

## 7.6 Various efficiency improvements

Table 16: See chapter “Description of measures” and the assumption chapter for more information about the measures. Be aware that the results are very dependent on the input parameters and the assumptions made for each measure. See the column “Scope of measure” to understand the size of the measure.

| Varrious efficiency measures | | Scope of the measure | Base case Abatement cost (SEK / ton $CO_2$ equ) | Case 1 Abatement cost (SEK / ton $CO_2$ equ) | Case 2 Abatement cost (SEK / ton $CO_2$ equ) | Case 3 Abatement cost (SEK / ton $CO_2$ equ) | Case 4 Abatement cost (SEK / ton $CO_2$ equ) | Base case, case 1 & case 2 Reduction ton / year | Case 3 Reduction ton / year | Case 4 Reduction ton / year |
|---|---|---|---|---|---|---|---|---|---|---|
| Ships | Change of propellers that were optimized for 21 knots instead of 18 knots. | One ship | -887 | -887 | -887 | -945 | -887 | 3 532 | 3 317 | 3 532 |

# 8 Discussion / Conclusions

The main conclusion that can be drawn from the calculations are that, regardless the large differences in input parameters, efficiency measures generally are much cheaper than measures including bio fuels. Even when fuel taxes were included, and the prices of bio fuels was assumed to be 30% lower compared to the end of 2006, many of the measures including bio fuels were still expensive.

This study only includes *examples* of measures for the transport sector and has not examined all possible options for reducing fossil carbon dioxide emissions in the transport sector. The focus of the report has been to examine which measures the interviewed companies have done to decrease their $CO_2$ emissions and which measures they plan to do and to calculate abatement costs for as many of these measures as possible.

The measures should be seen as illustrative examples. It is very difficult to assume the national potential for these measures based on the information in this study. The scopes of the measures differ a lot. Some include the national potential while other only include one vehicle. Estimating the national reduction potential for the measures is difficult and should be done with great care, especially if the reduction potential until a certain year should be estimated, as when a MAC[58]-curve is constructed. Further studies are needed to evaluate the national potential for each measure. In order to produce a MAC-curve for a specific year it is necessary to make an assumption about how many of these measures that are already included in the baseline and if the measure will be fully or partly implemented to the specific year[59]. At least some of the cheap measures will probably be implemented without any extra political incentives, and should then already be included in the baseline (of course it depends on what the baseline should represent).

The re-bound effect is not taken into account. Without including the re-bound effect the reduction potentials for the efficiency measures are overestimated because lower travel costs will probably result in increased travel distances. This increase in travel distance will increase the emissions and the reduction potential for the measures will decrease. Measures that increase the cost decrease the travel distances and the reduction potential is therefore larger for these measures if the re-bound effect is taken into account.

Abatement costs are very sensitive to the selected input parameters, especially fuel prices, taxes and emission factors for bio fuels. The sensitivity analysis shows how different selections of input parameters affect the results.

Many $CO_2$ –reducing measures have been identified in this project. However, the emissions from the transport sector will probably continue to rice. The “problem” for the transport sector is that the demand for transport increases faster than the corresponding emissions can be reduced. The emission reductions attained by efficiency measures are not enough and a fuel shift to bio fuels is, according to the results above, very expensive.

[58] Marginal abatement cost.
[59] E. g. it is very difficult to know how many people that could decrease the fuel consumption with 12% after attending an ecodriving course until a specific year.

When comparing the results in this report with results from other sectors and studies it is necessary that the results really are comparable. For example it is very important that the assumptions are comparable and that fuel prices and emission factors rely on the same basis. A study that is similar to this one has been made about the energy sector (Särnholm, 2005), but a direct comparison will not provide an accurate result. This report includes both efficiency measures and fuel-shift measures. The report about the energy sector (Särnholm, 2005) only includes fuel-shift measures and do not include any of the energy efficiency measures that could be done by the energy consumer. A comparison between the fuel-shift measures in these reports can be done though, if case 1 "without taxes" in the sensitivity analysis in this study is used. The cheapest fuel-shift measures in the transport sector in this case costs 340 SEK / ton $CO_2$ equ and the others are much more expensive. This should be compared to the fuel-shift measures in the energy sector that in average have an abatement cost of 228 SEK / ton $CO_2$ with a range of -800 to 2800 SEK / ton $CO_2$. To make a full assessment between the sectors a MAC-curve has to be constructed for the transport sector (that only includes fuel-shift measures). However, the preliminary conclusion is that abatement costs for reducing fossil $CO_2$ is more expensive in the transport sector than in the energy sector.

Bio fuels have some benefits that are not included in this report. The process of introducing bio fuels has a large learning cost before it might get profitable. This learning cost has to be paid by someone. A large part of the learning cost for bio fuels has been paid by Sweden. This is a great benefit on a global level. Other countries are now using this knowledge and Sweden could benefit from this through increased export.

It has been difficult to obtain reliable data from the transport companies. That depends partly on the short time frame of the project (most companies had very little time to provide information before Christmas) and in some cases the companies did not want to provide sensitive business information. However, the major problem for obtaining data of acceptable quality is that it does not exist. Each emitting source (each vehicle) is moving and is a relatively small emitter. Therefore statistic for a certain vehicle does not, in most cases, exist. It has also been difficult to separate an investment in fuel savings from other activities at company level. For further discussion about the difficulty of obtaining data, see the chapter "Description of measures".

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# Appendix A

Table 1: The abatement costs for the base case sorted according to the marginal abatement cost. Be aware that the results are very dependent on the input parameters and the assumptions made for each measure. See the column "Scope of measure" to understand the size of the measure.

| | | | | Base case | Base case |
|---|---|---|---|---|---|
| Measure category | Transport category | Description of measure | Scope of the measure | Abatement cost (SEK / ton $CO_2$ equ) | Reduction ton $CO_2$ equ / year |
| Investment in new vehicle | Private car | Smaller and more fuel efficient engine for a Saab 9-3 sportcombi (150 hk instead of 175 hk) | One private car | -7 853 | 0,2 |
| Investment in new vehicle | Private car | Toyota prius (electrical hybrid with petrol) instead of a Volvo V70 diesel | One private car | -7 420 | 0,9 |
| Investment in new vehicle | Taxi | Saab 9-5 diesel instead of a Saab 9-5 petrol | One taxi car | -5 087 | 5 |
| Investment in new vehicle | Taxi | Volvo V70 diesel instead of Volvo V70 petrol | One taxi car | -3 976 | 8 |
| Investment in new vehicle | Taxi | Toyota prius (electrical hybrid with petrol) instead of a Volvo V70 diesel | One taxi car | -2 746 | 8 |
| Ecodriving | Lorry | | One lorry driver, assume one driver per lorry | -2 717 | 11 |
| Low blending | Fuel supplier | 5% RME / FAME mixed with diesel | The consumption in Sweden | -1 821 | 334 453 |
| Ecodriving | Taxi | | One taxi driver | -1 709 | 2 |
| Tyre pressure | Bus | 1.5% fuel efficiency improvement for a bus | One bus | -1 644 | 1,3 |
| Ecodriving | Aircraft | | The whole airline including all aircrafts in that company | -1 563 | 160 000 |
| Ecodriving | Bus | | One bus driver, assume two drivers per bus in average | -1 532 | 3 |
| Low blending | Fuel supplier | 5% ethanol mixed with the petrol | The consumption in Sweden | -1 473 | 603 740 |
| Efficient logistics | Lorry | Optimzation of traffic | Optimization of distribution traffic (total about 1400 vehicles) | -1 393 | 618 |
| Change of propellers | Ships | Change of propellers that were optimized for 21 knots instead of 18 knots. | One ship | -887 | 3 532 |
| Investment in new vehicle | Private car | Volvo V70 diesel instead of Volvo V70 petrol | One private car | -844 | 1,0 |
| Investment in new vehicle | Private car | Saab 9-5 biopower (ethanol) instead of a Saab 9-5 petrol | One private car | 202 | 2 |
| High blending of bio fuels | Fuel supplier | Use E85 instead of petrol in the flexifuel car | One taxi car, Saab 9-5 petrol/ethanol | 472 | 17 |

| | | | | Base case | Base case |
|---|---|---|---|---|---|
| Measure category | Transport category | Description of measure | Scope of the measure | Abatement cost (SEK / ton $CO_2$ equ) | Reduction ton $CO_2$ equ / year |
| Investment in new vehicle | Private car | Volvo V70 gas instead of a Volvo V70 diesel | One private car | 563 | 0,5 |

| | | | | Base case | Base case |
|---|---|---|---|---|---|
| Measure category | Transport category | Description of measure | Scope of the measure | Abatement cost (SEK / ton $CO_2$ equ) | Reduction ton $CO_2$ equ / year |
| Ecodriving | Private car | | One car, assumption that number of cars and drivers are equal | 1 299 | 0,3 |
| High blending of bio fuels | Fuel supplier | Use biogas instead of petrol in the flexifuel car | One taxi car, Volvo V70 petrol/biogas | 1 578 | 13 |
| Investment in new vehicle | Taxi | Volvo V70 gas instead of a Volvo V70 diesel | One taxi car | 1 917 | 13 |
| Investment in new vehicle | Taxi | Saab 9-5 biopower (ethanol) instead of a Saab 9-5 diesel | One taxi car | 3 436 | 12 |
| Investment in new vehicle | Bus | Ethanolbus instead of a diesel bus | One bus | 4 449 | 43 |
| Conversion of vehicle | Bus | Converting a diesel bus to a ethanol bus | One bus | 4 732 | 43 |
| Investment in new vehicle | Lorry (van) | Biogas van | One van (35000 km / year) | 5 437 | 7 |
| Investment in new vehicle | Lorry | Biogas lorry | One lorry (35000 km / year) | 8 264 | 18 |