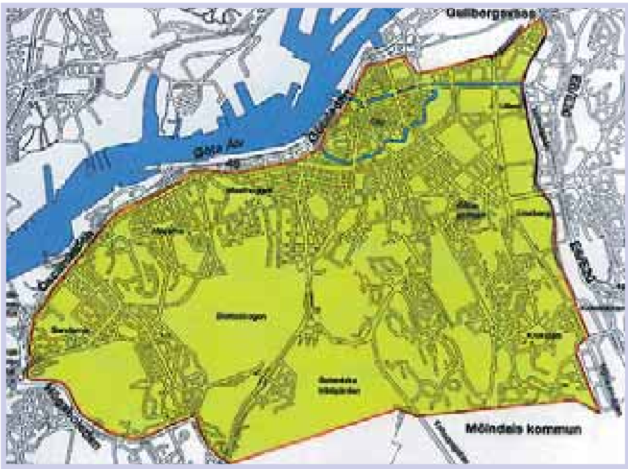
Assessment of environmental zone in Göteborg



A report for the Traffic & Public Transport Authority of the City of Göteborg

Revised report, May 2006

Göteborgs Stad
Trafikkontoret

At the request of the Traffic & Public Transport Authority of the City of Göteborg, Ecotraffic ERD3 AB has calculated and evaluated how the environmental zone rules (the difference with and without environmental zone rules) in Göteborg have affected emissions of hydrocarbons (HC), carbon monoxide (CO), nitrous oxide (NO_X) and particles (PM) into the air. The study relates to 2004.

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ABBREVIATIONS AND GLOSSARY

Abbreviations

ARTEMIS — Emission model for calculation of traffic emissions. Developed by a partnership in an EU project between organisations and companies in a number of different EU countries.

CBG — Compressed biogas. A fuel primarily for Otto engines (engines with spark plugs). The fuel is stored in the vehicle in high-pressure tanks (approx. 200 bar).

CH4 — Methane. The main component in natural gas and biogas.

CNG — Compressed natural gas. A fuel primarily for Otto engines (engines with spark plugs). The fuel is stored in the vehicle in high-pressure tanks (approx. 200 bar).

CO — Carbon monoxide. An odourless poisonous gas that is primarily formed during combustion due to a shortage of air.

COPERT — Emission model for calculation of traffic emissions. Developed by Thessaloniki Technical College, Greece.

ECE R49 — An older 13-stage stationary operating cycle used by ECE countries (incl. the EU) for engine testing in engine test benches.

EEV — Environmentally Enhanced Vehicles. A voluntary emission level in the EU for heavy-duty engines with particularly low emissions. There is currently no equivalent for light vehicles.

EGR — Exhaust Gas Recirculation. (e.g. from exhaust pipe to inlet pipe). A method of reducing NO_X emissions. When exhaust gases are recirculated in this way, the local combustion temperature and oxygen concentration drop, thus reducing formation of NO.

EMV — Emission model for calculation of traffic emissions. Developed by VTI.

ESC — The latest European 13-stage stationary operating cycle for engine testing in engine test benches.

ETC — The transient European operating cycle for engine testing in engine test benches. The engine load and speed varies second by second.

Euro 1 — A type of popular name for the EU's different levels for emissions in the exhaust gas directive. Euro 1 was introduced in 1992/1993. Subsequent levels have been called Euro 2, Euro 3, etc. For light vehicles, Euro 4 has been applicable since 1 January 2006, while the equivalent level was introduced on 1 October 2006 for engines for heavy-duty vehicles. The introduction period is normally 1 year, which means that new, so-called "engine families" must comply with the limits one year earlier than the date mentioned (which applies to all engine families).

FC — Fuel consumption. Usually specified in the following units litres/100 km, litres/Swedish mile (10 KM), g/kWh and g/km.

HC — Hydrocarbons. In principle, unburnt fuel, but also hydrocarbon com-pounds other than those present in the fuel are found in the exhaust gases.

KWh — Kilowatt hours. The normal unit for the performance achieved by an engine during engine testing. Emissions are often specified as grams per kilowatt hour (g/kWh).

MK1 — Environmental class 1, e.g. diesel oil or petrol of environmental class 1. Environmental class 2 and 3 are designated in the same way: MK2 and MK3. Environmental class 1, 2 and 3 have previously also existed as the designation for environmentally-classified cars and engines for heavy-duty vehicles. Now used for vehicle designations with year of introduction of the environmental class, e.g. Environmental class 2000, etc.

MKN — Environmental quality norms. MKN indicates "required" levels for various pollutants. The levels for MKN are lower than the relevant limits for the same components.

NMHC — Non-methane hydrocarbons, i.e. all hydrocarbons (HC) except methane (see abbreviation HC). Methane is harmless from a health perspective and therefore hydrocarbon emissions for vehicles and engines operating with gas are often specified both as total HC (often designated THC) and NMHC.

NO_X — Overall designation for the nitrous oxides: nitrogen oxide (NO) and nitrogen dioxide (NO_2). NO_2 is the more toxic component of the two. NO_2 contributes to formation of tropospheric ozone, irritates the mucous membrane of people with respiratory problems and causes damage to growing crops. NO oxidises fairly rapidly (depending on atmospheric conditions)

	in the surrounding air to form NO_2. When calculating total NO_X emissions, therefore, the molecular weight of NO_2 is also used for NO in the calculations.
PM	Particle emissions. The weight of all the material that can be collected on a sampling filter. Measurement requirements differ depending on whether the measurement is taken in vehicle exhaust gases or in the surrounding air. PM is usually specified as concentration (e.g. mg/m^3) or as specific emissions (g/km).
PM10	Particle emissions for particles less than 10 micrometres (10 mm).
RME	Rape methyl ester. Rapeseed oil that has been re-esterified using methanol. Fuel for diesel engines.
SAE	Society of Automotive Engineers. An American association for engineers operating within the field of transport. SAE has members across the world, but also “sister organisations”. Its sister organisation in Sweden is SVEA (Swedish Vehicular Engineering Association).
SCB	Statistiska centralbyrån - Statistics Sweden
SIKA	The Swedish Institute for Transport and Communications Analysis
VTI	The Swedish National Road and Transport Research Institute

Glossary

Energy content	This usually refers to the lower thermal value for fuel (see also “lower thermal value”).
Chassis dynamometer	A type of “rolling road” that is used for exhaust gas testing of vehicles, etc. The vehicle is loaded on the chassis dynamometer in relation to rolling resistance, air resistance, and the inertia (mass) of the vehicle, and driving conditions identical to those for actual driving can be simulated in this way. Emissions from chassis dynamometers are often specified as grams per kilowatt hour (g/kWh).
Retro-fitted exhaust gas purification equipmen	This usually refers to retro-fitted catalytic converters or particle filters for heavy-duty vehicles. Other equipment for reducing emissions is also available (see EGR in the list of abbreviations).
Emission factor	Specific emissions expressed as grams per km driven (g/km).
Driving cycle	The agreed test cycle used for engine testing or testing on chassis dynamometers. Driving cycles may be stationary or transient (variation second by second).
Lean-burn	Lean burn, i.e. combustion during huge excess air, often designated as an air-fuel ratio (lambda) over 1 ($\lambda>1$). Used, for example, for gas-powered engines to reduce NO_X emissions.
Engine test bench	An engine is tested in an engine test cell by connecting it to a dynamometer that loads the engine in the manner required. Load and speed can, in the most advanced case, be controlled second by second and the driving cycle is then called “transient”. Emissions from an engine test bench are often specified as grams per kilowatt hour (g/kWh).
Stoichiometric combustion	Combustion with a ratio between air and fuel where the oxygen in air is just enough for the fuel to burn completely. Also designated lambda 1 ($\lambda=1$). See also lean burn.
Traffic volume	Traffic volume achieved is specified for goods traffic as tons kilometres (tkm) and for passenger transport as passenger kilometres (pkm). The unit of vehicle kilometres is also used (vkm).

SUMMARY AND CONCLUSIONS

On 1 July 1996, environmental zone rules for heavy-duty vehicles were introduced in Göteborg. These rules prescribe that diesel-powered vehicles older than 8 years and with a total weight over 3.5 tons may not travel within the limits of the zone. Exceptions to the rules are granted for vehicles equipped with retro-fitted exhaust gas purification equipment or judged to have low exhaust gas emissions (e.g. gas-powered buses) for other reasons.

In this project, the environmental benefit of the environmental zone has been calculated with respect to exhaust gas emissions. Calculations have been undertaken by VTI using a database simulation program called the EMV model. Two calculations have been performed, one with the environmental zone and one without. In the case with the environmental zone, the calculations were based on the vehicle fleet currently travelling in the zone. In the comparison case, a fictitious fleet of heavy-duty vehicles was used. The composition of this fictitious fleet, as it would have looked if no environmental zone rules existed, was developed based on knowledge of the entire country's fleet of heavy-duty vehicles. The fleet in Göteborg, Stockholm and Malmö has then been removed, as these cities have environmental zone rules. All the information has been obtained from the motor-vehicle register and supplemented by data from SIKA and SCB. Input data for the calculations in terms of emission factors has been obtained from the EMV model and compiled by Ecotraffic. The year selected for calculations was 2004. The reason why 2005 could not be selected was that no statistics for the year were available when the input data was compiled.

The environmental zone rules have the greatest impact on particle emissions, if you look at the percentage reduction. This is of huge importance, as the health effects of particles are probably the major significant health effect if all emission components are taken into consideration. A reduction in emissions of small particles within the zone also contributes to reducing the PM10 emissions in Göteborg, something that is important in light of the applicable environmental quality norms (MKN).

Nitrous oxides (NO_X) are the emission component that has been reduced most on a weight basis. The total reduction in emissions of NO_X within the zone is over 13 tons per year – which is a direct result of the environmental zone. Relatively speaking, this is a lot compared with the measures discussed to further reduce NO_X emissions.

	percentage	**kg/year**
Reduced emissions of carbon monoxide within the zone (CO)	3.6	286
Reduced emissions of hydrocarbons within the zone (HC)	6.1	6,652
Reduced emissions of nitrous oxide within the zone (NO_X)	7.8	13,229
Reduced particle emissions within the zone (PM)	33.2	2,767

The effects of the environmental zone according to the calculations carried out previously (1996) were greater than in this study. This is not surprising, as the ongoing technical trend yielded reduced emissions for new vehicles and, in combination with the scrapping of older vehicles with higher emissions, a 'natural' reduction in emissions would have been achieved even without the environmental zone having been introduced.

The environmental zone rules seem to have had the greatest effect, relatively speaking, on heavy-duty lorries with a total weight of under 16 tons. Thanks to the environmental zone rules, particle emissions from these lorries have been reduced by as much as 67 %.

Emissions are only increasing from one vehicle type and one exhaust gas component as a result of the environmental zone rules, and that is HC for buses. This increase is due to the fact that gas buses discharge, relatively, more HC than an equivalent diesel-powered bus. There are quite a lot of gas-powered buses within the environmental zone, which explains the increase. In the case of gas buses, HC is virtually synonymous with CH_4 (methane), as the gas fuel largely consists of methane. As methane is significantly less harmful to health than hydrocarbons from conventional fuels such as petrol and diesel oil, it can be confirmed that the health effects from hydrocarbons were significantly reduced in total, even though the total emissions increased slightly.

Among the health effects from exhaust gases discussed among the researchers within this field, the particle emissions are thought to be responsible for most deaths and daily illness. The mechanisms behind these effects are still not entirely clear, but definite links have nonetheless been found between particle contents and effects on people with heart and vascular disorders. Recent research has also shown that tropospheric ozone causes a dramatic increase in daily mortality and illness. A number of substances, such as various hydrocarbon compounds, aldehydes, polycyclic aromatic compounds (PAC), light aromatic hydrocarbons and particles, cause cancer. The group of emission components which, according to calculations, are responsible for most cancer cases are PAC. These constitute a small sub-set of the hydrocarbons (HC) but still indicate that a reduction in HC is desirable. Hydrocarbons (HC) and nitrogen dioxide (NO_2) contribute, along with sunlight, to the formation of tropospheric ozone. Normally, the content of HC controls the speed of ozone formation in Sweden. This is also a reason for reducing HC emissions. The complex chemistry that governs ozone formation and breakdown is the reason for the ozone contents often being higher outside built-up areas than within built-up areas. Nitrogen dioxide (NO_2) is highly irritating for people with respiratory problems and in high concentrations (normally much higher than those that occur in outside air) degrades lung tissue. It has proven to be difficult to meet the requirements and objectives set for both NO_2 and particles.

Calculations of emissions based on statistics and emission factors contain, by definition, a number of uncertain factors. The results from this type of calculation must, therefore, be regarded as indicators and provide an idea of the magnitude. However, it is quite clear that the introduction of the environmental zone in Göteborg is very positive for the local environment within the zone – and, of course, outside (as many vehicles also remain outside the zone).

1 INTRODUCTION AND BACKGROUND

Sweden currently has environmental zones in four cities: Stockholm, Göteborg, Malmö and Lund. The rules as to what vehicles are permitted within the limits of the zones only cover, for the moment, heavy-duty vehicles with a total weight of over 3.5 tons.

The first version of the environmental zone rules was introduced in Göteborg on 1 July 1996. The reason for these zones being introduced was to improve the environment locally with regard to air pollution, noise and congestion. Subsequently, the environmental zone rules have been updated on a number of occasions.

In Göteborg, the environmental zone covers an area of around 15 km^2. Around 100,000 inhabitants live within the area, and the number of workplaces within the zone limits is also around 100,000. In addition, the number of visits to the area is huge.

The main rule for being allowed to drive into the environmental zone is that heavy-duty diesel engine-powered vehicles must be no older than 8 years. The age is calculated from the date when the vehicle was registered for the first time. Exceptions to this age requirement may be permitted for vehicles with particularly low emissions or if vehicles are equipped with approved exhaust gas purification equipment. Vehicles that are permitted to drive in the zone must have a badge stating that the vehicle may drive within the zone clearly displayed on the vehicle. No survey of the development of these rules has been carried out here. For detailed rules regarding the exception procedure, etc., refer to reference 1 in the reference list.

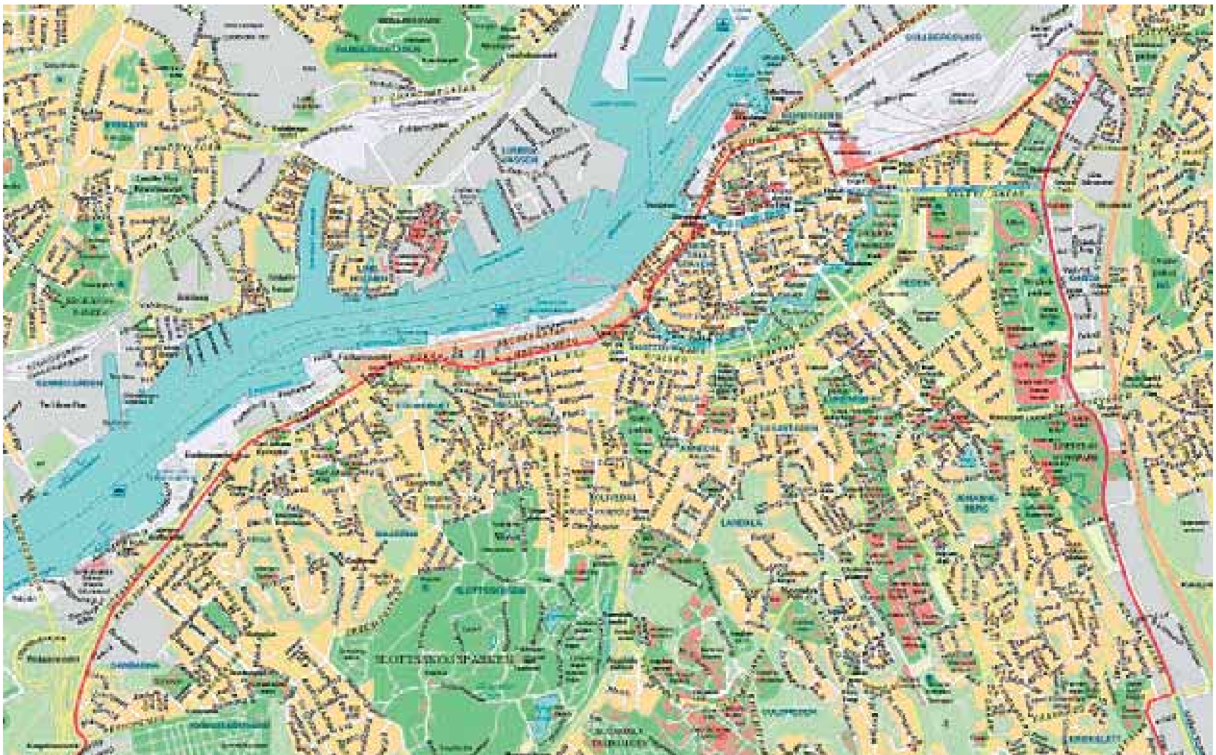

Figure 1. The environmental zone in Göteborg

2 METHODOLOGY

2.1 Limits and assumptions

In order to be able to calculate the environmental benefit of the environmental zone in Göteborg, some delimitations have been set. Calculations relate to 2004. The reason for 2005 not being used as the calculation year is that reasonably established vehicle statistics often have a lag of approximately one year. Furthermore, the calculations have been limited to cover emissions into the air from vehicles within the zone. As the rules only cover heavy-duty traffic, no calculations have been performed for emissions from private car traffic. Calcula-tions have been performed based on calculations of how the vehicle fleet (distribution of vehicles) of heavy-duty vehicles looks within the zone. This has then been compared with a fictitious vehicle fleet that corresponds to how the fleet would have looked in the zone if no environmental zone rules were in place. In order to determine the vehicle distribution of the fictitious vehicle fleet, the composition of “the entire country’s fleet” minus those vehicles found in the environmental zone cities (Göteborg, Stockholm, Malmö and Lund) has been used. This has been done based on extracts from the motor-vehicle register and from statistics from SCB and SIKA.

2.2 Choice of database calculation model

There are a number of different calculation models to choose from for calculating emissions from vehicular traffic. The various methods have their respective advantages and disadvantages. The method for this project has been chosen in consultation with VTI. In practice, there were two calculation models to choose from for this project: EMV and COPERT III .

The EMV model has been used in Sweden for many years, for tasks such as reporting national emissions to the EU . The COPERT model has been used by around half of the EU member countries in order to report national emissions. A comparison between the two models has been carried out by VTI (reference 2). It is also worth mentioning that Germany has used a self-developed “Handbook, Emission Factors” model for calculating emissions in Germany.

A new calculation model has been developed within the ARTEMIS project in the EU based on COPERT and HANDBOOK and this will probably be used in the future by the majority of EU countries , replacing the above models. Several partners from Sweden have participated in the ARTEMIS project. As the ARTEMIS model was still not officially available when this project was carried out, this model was not regarded as useable for calculation of emissions in the environmental zone. Consequently, the remaining potential emission models were EMV and COPERT.

This probably also applies to Sweden, where the Swedish National Road Administration now has responsibility for compiling road traffic emissions.

After discussions between Ecotraffic and VTI, the EMV model was chosen for the following reasons:

- EMV employs annual models, while COPERT uses requirement levels (Euro I, II, III, etc…). EMV provides significantly better definition than COPERT to describe the 8-year limit in the zone.
- EMV works with Swedish vehicle descriptions and the corresponding emission factors, while COPERT relates to the rest of Europe and, therefore, does not always provide the best compatibility with the vehicle types used here.
- COPERT does not include emission factors for gas-powered buses. Although such an addition would theoretically be possible, it would probably be relatively demanding in terms of resources.

2.3 Calculations

In this project, all the computerised calculations using the EMV model have been carried out by VTI. Input data for emission factors for the calculations has been compiled by Ecotraffic. In order to check the reasonableness and magnitude of the results calculated using the EMV model to a certain extent, simpler calculations have been carried out by Ecotraffic based on data from COPERT. This check came out positive.

Official website for COPERT: http://vergina.eng.auth.gr/mech0/lat/copert/copert.htm.

The Swedish National Environmental Protection Agency coordinates this reporting, which, among other things, involves all traffic authorities. VTI performs the calculations of the transport sector’s emissions.

3 INPUT DATA

Input data is required in order to perform emission calculations. This section describes how the values were produced.

3.1 Traffic volume within the zone

Data for traffic volume was produced for a number of different categories of vehicle, including light vehicles, should that be of interest in the future. With regard to emission data, a definition for input data has been set for the category of heavy-duty vehicles. Heavy-duty vehicles are divided up into the following categories in the EMV model (Table 1):

Table 1 Vehicle categories in the EMV model

Vehicle category	Total weight / no. pass.	Comment
Heavy-duty vehicles (Hdv)	< 16 tons	
Heavy-duty vehicles (Hdv)	> 16 tons	
Bus	< 29 passengers	Not used
Bus	30 – 59 passengers	Not used
Bus	> 60 passengers	

The dominant type of buses in the environmental zone is city buses. Therefore, it is assumed that all the traffic volume in the zone for buses relates to the category with room for at least 60 passengers, i.e. what is presumed to correspond to a bus that operates between bus stops in urban areas, with the associated emission factors. The two other bus types in EMV have not been used in the calculations.

The total traffic volume with heavy-duty vehicles in the zone in 1996 was 30,000 vkm/d year (vehicle kilometres per day). When the traffic volume for the vehicle category of heavy-duty vehicles within the zone was not measured in Göteborg, the traffic volume has been calculated using data from SCB and SIKA. Between 1996 and 2004, the traffic volume for heavy-duty vehicles has increased by 30 % in the Västra Götaland area. It can be noted that for private cars, the corresponding figure was 11 %. Traffic volume within the zone is judged to have developed in the same way as for the whole of Västra Götaland. This means that the traffic volume is adjusted upward by 30 % from 1996. The traffic volume used in these calculations is thus 39 000 vkm/d. The "national distribution" has been used for distribution within the group of heavy-duty vehicles in urban areas in 2004. The load factors used have been obtained from the EMV model for short trips. Proportions and load factors are shown in Table 2.

Table 2. Load factors and proportions in the EMV model

Vehicle type	Proportion [%]	Load factor [%]
Bus > 60 passengers	38.2	14
Heavy-duty vehicle (Hdv) < 16 tons (med)	9.0	32
Heavy-duty vehicle (Hdv) < 16 tons (med)	1.0	37
Heavy-duty vehicle (Hdv) > 16 tons (med)	25.3	39
Heavy-duty vehicle (Hdv) > 16 tons (med)	26.5	45

The proportion of heavy-duty buses in the heavy-duty vehicles group is greater within the zone than for the City of Göteborg as a whole (reference 4). In this study, the same proportion has been used within and outside the zone. When Trivector evaluated the environmental zone in Stockholm, Göteborg and Malmö in 1997, the following was determined:

- 5 % of vehicles in the zone were not entitled to be there,
- the proportion of foreign vehicles in the zone was 1-2 %

The Traffic & Public Transport Authority has produced statistics for 2004, when the corresponding results were as follows:

- 3 % of vehicles in the zone were not entitled to be there,
- the proportion of foreign vehicles in the zone was 1 %

The percentages for lorries were slightly worse than for buses in the Traffic & Public Transport Authority's statistics.

The information above has not been used in the calculations. The judgement is that any correction for these factors would have very little effect on the end results. New input data for such a calculation is also unavailable, which for practical reasons made this calculation impossible.

3.2 The number of vehicles and distribution between vehicles

In order to calculate the environmental benefit of the environmental zone rules, information on the number and distribution of vehicles with and without environmental zone rules is required, i.e. how the heavy-duty fleet operating in the zone looks (with rules) – and how it would have looked without rules. It is, of course, a difficult task to make such an assessment without extensive collection of input data, and certain simplifications have therefore been applied to facilitate this work. The following principles have been used:

With environmental zone rules – it is assumed the fleet of heavy-duty vehicles looks as follows:
- Based on the average fleet for Göteborg as a whole (the motor-vehicle register)
- All heavy-duty vehicles 1996 model or later may travel in the zone
- 7.5 % of cars, 1992-1995 model, have been equipped with exhaust gas purification equipment so that they meet the requirements and thus may travel in the zone (this figure comes from the Traffic & Public Transport Committee in Göteborg)

Without environmental zone rules – it is assumed that the fleet of heavy-duty vehicles looks as follows:
- The composition of the fictitious fleet (as it would have looked if no environmental zone rules were in place) has been developed based on knowledge of the entire country's fleet of heavy-duty vehicles. The fleet in Göteborg, Stockholm and Malmö has been discounted, as these cities have environmental zone rules. All information has been obtained from the motor-vehicle register

Appendix 2 contains the following comparisons by vehicle type:
- Göteborg's fleet of heavy-duty vehicles compared with the national fleet of heavy-duty vehicles excluding Göteborg, Stockholm and Malmö
- Göteborg's fleet of heavy-duty vehicles compared with partially estimated distribution within the environmental zone.

The calculations also include distribution of fuel by vehicle type as follows (Table 3):

Table 3. Distribution of fuel and vehicle types.

	Buses		Heavy-duty Vehicles	
	Diesel [%]	Gas [%]	Diesel [%]	Gas [%]
Without environmental zone	95.7	4.3	100	0
With environmental zone	71.5	28.5	100	0

It should be noted that a number of factors in addition to the introduction of the environmental zone have probably affected the proportion of gas-powered city buses. One example is the procurement rules for public transport used by the city. Lastly, it is, of course, more or less impossible to know what the results would have been without the environmental zone in this case. If the environmental zone had not existed, other control measures might have been used to a greater extent to increase the proportion of gas-powered buses. In summary, it can be confirmed that the effect of the environmental zone is probably overestimated using the input data for gas buses as per Table 3.

3.3 Vehicle use

Information on vehicles' annual mileage as a function of vehicle age is required in order to calculate vehicle emissions. In terms of diesel and gas-powered buses, the same annual mileage is assumed, i.e. that the mileage for diesel and gas buses does not differ. There are currently no substantial statistics within this field. However, it is probable that the distance is roughly the same, as the city's purchases are made for specific transport performance.

Mileage by model have been produced as follows:
- Mileages at national level for 2004 in according to SCB
- The same data used for ARTEMIS, (the EU's and probably also the National Swedish Road Administration's new model for emission estimates regarding road traffic)

3.4 Requirement levels

In the EMV model, each year model is divided into requirement levels (emission levels). Information on this has been obtained from the motor-vehicle register.

The designations in the vehicle register are inadequate in the following ways:
- Incidence of conversion to other requirement levels is not shown
- Official designations (such as Euro I, Euro II, etc.) are not used. Instead, the following is used: MK0, MK1, MK2, MK3, MK4, etc.
- Certain designations as above can mean different things for different year models

New requirement levels (emission levels) have been defined for vehicles equipped with exhaust gas purification equipment and thus required exemption for travelling in the zone. For 2001-2003 models, up to 50 % of the diesel-powered vehicles may be classified as MK0. All gas buses are classified as MK0. For this reason, it has been vital to produce new emission factors for these buses.

Assignment of official requirement levels has been implemented as follows:

- MK3 93-96: A30
- MK1-2 93-96: A31
- All 97-01: A31
- All 02 and later: Euro III

It is probable that a number of diesel-powered heavy-duty vehicles that comply with Euro IV or have the equivalent emission level without being certified as Euro IV were put into service back in 2004. However, the proportion of these vehicles has been estimated to be so small that it has not been necessary to take this into consideration. Emission factors for Euro IV vehicles have been produced, but not used in the calculations.

3.5 Description of vehicles

3.5.1 Emission measurements and emission factors

Emission limits for heavy-duty vehicles are expressed as g/kWh and tests are carried out in a vehicle test bench. In order to calculate emissions from vehicles in traffic, input data expressed as g/km is generally used. It is certainly possible to convert from one unit to the other, but it is then necessary to know the kWh, i.e. performance accomplished by the engine, which is consumed per km driven. Such data is very difficult to produce and there is very little information on this in the available literature. Another option would be to calculate the performance, but for this it is necessary to know the fuel consumption and the engine's average efficiency. Although the first is easy to obtain, the latter is as difficult to obtain as the performance accomplished by the engine. For light vehicles, emission limits are expressed as g/km, and emission data can, therefore, be used directly (or with the necessary corrections for different parameters). This emission data is produced using tests on a chassis dynamometer. The options available for generating emission factors for heavy-duty vehicles are to use data from chassis dynamometer measurements or converting data from engine test benches. Most emission models use the former, as we have done in this case.

3.5.2 Developing emission models

Vehicles have mainly been assigned emission factors developed in the EMV model. However, additions have been required, as there are no emission factors for Euro 3 or later. Although emission factors for Euro 4 have not been used in the calculations, an addition has been made for this category of vehicle. Ecotraffic has previously produced emission factors for heavy-duty vehicles. One such example is emissions for city buses powered by different fuels, where tests carried out in Sweden have been compiled and evaluated. Some of this documentation has been produced using joint funding from the Traffic & Public Transport Authority. A publication with results from this project was issued in 2000 at the SAE F&L conference in Paris. Later updates have been made in presentations at the DEER conference in the USA (most recently 2003). This documentation also includes estimates of the emission levels for Euro 3 and 4. The emission levels for city buses that comply with Euro 2 or earlier are similar to those contained in the EMV model, which is not surprising as the basic material is largely the same. One option would be to use the above estimates for Euro 3 and 4. We have, however, chosen not to do this. One reason is that this particular part of the material has not been published and, therefore, the methodology has not been described in detail. The method that has been chosen instead was to convert data for 1996 bus models (Euro 2) in proportion to how much the emission limits for Euro 3 and 4 have been changed in relation to Euro 2. Although this may seem to be a 'poorer' method than using the aforementioned material, there are fewer objections. The material produced for SAE/DEER for Euro 3 and 4 is, of course, largely based on predictions of the technology engine manufacturers have chosen or will choose, and that, of course, is a subjective assessment.

The EMV model does not include emission factors for converted diesel vehicles (old vehicles retro-fitted with exhaust gas purification equipment) and for gas buses. This work includes an assessment that vehicles from the period prior to 1993 have not been equipped with exhaust gas purification equipment. The vehicles that have been converted and travel in the zone with exemption are, therefore, vehicles model 1993 – 1996. The measures carried out for converted vehicles have been judged to be:

- 1993-1995 – the vehicles have been equipped with catalytic converters only
- 1996 – 90 % of vehicles have been equipped with catalytic converters and 10 % with filters
- 2000 – no catalytic converters, therefore 100 % filters

At the start of the 1990s, oxidizing catalytic converters for retro-fitting on heavy-duty vehicles were introduced, followed a few years later by particle filters. Today, particle filters are dominant among retro-fitted equipment. It has not been possible to differentiate by year model for the distribution of these for the vehicles travelling in the environmental zone. We have instead chosen to assume linear distribution between 1995 and 2000, when the propor-tion of particle filters went from zero (1995) to 100 % (2000). As a result, the distribution is 90 %

catalytic converters and 10 % filters in 1996, as shown by the bulletin-point list above.

Over the years, Ecotraffic has worked a great deal on emissions and exhaust gas purification on vehicles converted (equipped with exhaust gas purification) from diesel-powered heavy-duty vehicles and from gas-powered vehicles. Based on this knowledge/databank (primarily SAE/DEER as above), emission factors for the exempt vehicles from 1993 to 2000 have been produced. In purely practical terms, it is a matter of a degree of purification (in percent) for each type of retro-fitted emission equipment (particle filters, catalytic converters) being applied to the emission factors contained in the EMV model. The degrees of purification for different emission components and the effect on fuel consumption (FC) used are shown in Table 4. Please note that a reduction in emission is expressed as a positive figure in this table. A negative figure, therefore, indicates an increase in emissions.

Table 4. Reduction in emissions with exhaust gas treatment

Emission	Catalytic converter	Particle filter
HC	88.0 %	92.0 %
CO	90.0 %	92.0 %
NO_x	1.0 %	4.0 %
FC	-1.4 %	-1.7 %
PM	15.0 %	90.0 %

The degrees of purification specified in Table 4 are mainly applicable for the driving conditions and driving patterns that apply to buses in city traffic, but have still been used for other heavy-duty vehicles when they are also used in this case within the environmental zone. As shown by the data in Table 4 the particle filter provides a slightly higher degree of purification than an oxidizing catalytic converter with regard to HC and CO. The effect on NO_X and fuel consumption is minimal. The degree of purification for the particle filter is, understandably, much higher than for the oxidizing catalytic converter. Data in Table 4 assumes ageing and a certain frequency of error for the exhaust gas purification equipment, i.e. the degree of purifica-tion which (on average) can be expected during the service life of the vehicle has been approxi-mated. It explains, for example, that the degree of purification of the particle filter is as 'low' as 90 %, while measurements for efficient filters often result in a significantly higher figure (>98 %).

The EMV model does not include emissions for gas buses. It may, therefore, be interesting to discuss the emission data used for gas buses in slightly more detail. For older city buses (1996 and older), the figures are based on the above documentation for SAE/DEER. In order to estimate the emissions for newer gas buses, an assessment of the technology used by the manufacturers must be carried out, as no new emission data is available. In principal, three different options are possible:

- Lean-burn (with $\lambda>1$)
- Stoichiometric combustion ($\lambda=1$)

A combination of the two, i.e. stoichiometric combustion under certain operating conditions and lean burn in other operating conditions

For example, older gas buses use lean-burn, i.e. a high level of excess air ($\lambda>1$), while newer buses (Euro 3, 4, 5 and EEV) are powered entirely or partially using stoichiometric combus-tion, i.e. a perfect balance between air and fuel $\lambda=1$). With lean burn, you have a high level of excess air, which reduces the combustion temperature and thus NO_X emissions. A catalytic converter, on the other hand, due to the excess oxygen, has no effect on NO_X emissions (but does affect other emission components). With stoichiometric combustion, you get relatively high NO_X emissions from the engine, but these can be reduced in a catalytic converter in the same way as in petrol cars, for instance, and the NO_X emissions after the catalytic converter will thus be lower than in the previous case. One benefit of the more recent technology with stoichiometric combustion is (probably) better durability of catalytic converters and improved regulation of the fuel/air ratio, which also leads to smaller variations in the emission level. Exhaust gas tests carried out by Ecotraffic for the Traffic & Public Transport Authority have, in any case, shown significantly better results for catalytic converters on new buses in terms of conversion of hydrocarbons (HC). The disadvantage of stoichiometric combustion is higher fuel consumption than with lean burn. It is possible to compensate for this, to a certain extent, by employing Exhaust Gas Recirculation (EGR). With total stoichiometric combustion, EGR is also required to keep the engine's thermal load under control. For instance, Volvo employs stoichiometric combustion and EGR in its latest gas engine for buses. The previous gas engine used a combination of both methods, while older engines used lean burn.

As an example of emission data used in the calculations, (the emission factors for diesel-powered buses) are shown in Figure 2 and the same for the gas-powered buses in Figure 3. Complete tables of emission factors can be found in appendix 3.

As shown in Figure 2, emissions have been continuously reduced over time for diesel-powered buses, with an exception for 1996. One possible explanation for this

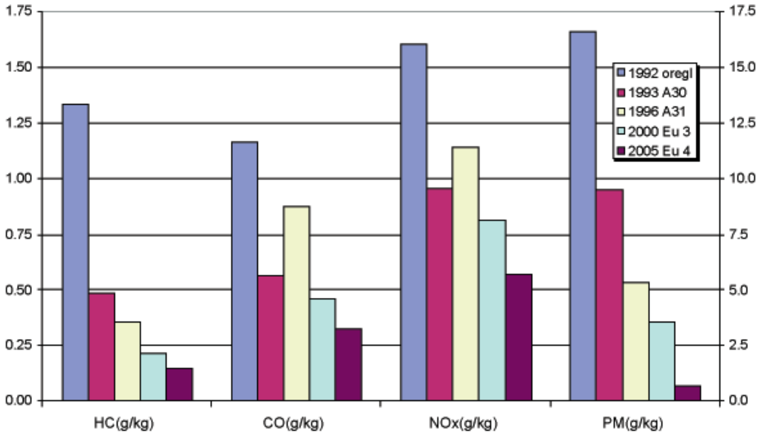

Figure 2. Emissions for diesel-powered buses without aftertreatment

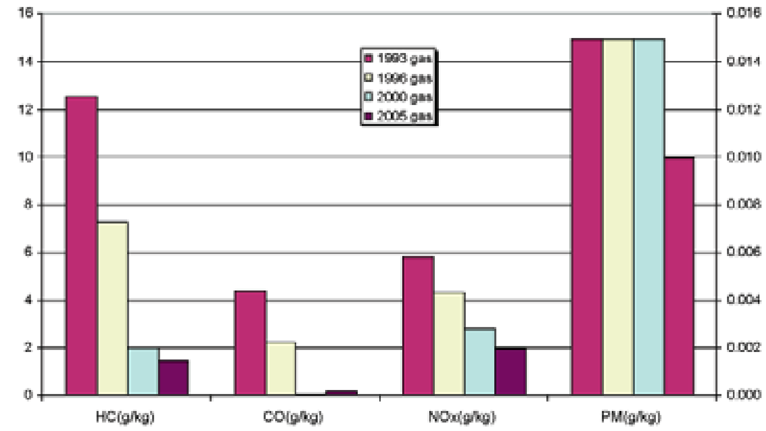

Figure 3. Emissions for gas-powered buses with catalytic converters

discrepancy for NO_X emissions is that data for the EMV model takes account of the 'optimisation' implemented by certain manufacturers during the period in order to reduce fuel consumption during normal driving. This optimisation relates to complying with the emission limits in the operating cycle prescribed at the time (ECE R49) but can cause elevated emissions for other operating patterns. The higher level seen for CO emissions for 1996/Euro 2 cannot be explained in a simple manner. A covariance between CO and particles is normal for diesel engines, but what is seen here is the complete opposite trend. One possible explanation could be that data in the model comes from different types of vehicle or that the conditions during testing varied. In other respects, all the other changes as a function of time were more or less as expected. It can be noted that a dramatic reduction in particle emissions is expected for Euro 4. In some cases, this will involve some manufacturers fitting particle filters while other manufacturers meet the levels without filters. It is also very probable that manufacturers will supply vehicles with particle filters for use in particularly sensitive environments (e.g. city buses) more than they do today, even in those instances where the particle limit value can be met without particle filters.

In the same way as for the diesel-powered buses, the emissions from gas-powered buses have also reduced (Figure 3). Please note that the scales are different than in the previous case and the location of each emission component on the different Y axes differs. Previous generations of gas buses have had problems with high HC and methane emissions and dramatic variation in NO_X levels (from very low to very high values). In the case of HC, this is not only due to problems with the catalytic converter, but is also affected to a large degree by engine control. The problem with control is also one reason for the variation in NO_X emissions. We assume here that the problems mentioned would be solved with gas buses complying with Euro 3 and later emission levels. This should also be positive for CO emissions, although this emission component is of less importance to health and the environment than the other emissions. Data for year model 2005 (which has not been used in the calculations) requires the EEV emission limits to be met. The particle emissions for gas buses are normally low (note the scale), even with problems with motor control and catalytic converters. Some improvement in stoichiometric engines can be expected due to a higher degree of oxidization in the catalytic converter than for engines with lean burn, but it is difficult to precisely quantify this potential improvement.

RESULTS & DISCUSSION

Based on the input data, delimitations, assessments and assumptions described in the previous section, data simulations have been carried out. All computer-based calculations have been carried out by VTI using the EMV model.

Separate calculations have been performed for the two situations: with and without an environmental zone. The results of the calculations are available at drive system (fuel) level and requirement level (emission levels). The following table shows total emissions by vehicle type and emission component. The case with the environmental zone includes the vehicles permitted to drive into and travel in the zone as per the relevant rules. The case without an environmental zone refers to a fictitious (assumed) vehicle fleet based on an assessment of how the fleet would have looked if there had been no environmental zone rules. Table 5 below shows the data obtained from the calculations.

Table 5. Summary of results

	HC kg/year	CO kg/year	NO_X kg/year	PM kg/year
With environmental zone – Bus	4245	39018	55712	2070
Without environmental zone – Bus	3643	42619	60830	3239
With environmental zone – Heavy-duty vehicle < 16 tons	311	3458	7420	187
Without environmental zone – Heavy-duty vehicle < 16 tons	577	4715	9362	566
With environmental zone – Heavy-duty vehicle > 16 tons	3166	59465	92299	3312
Without environmental zone – Heavy-duty vehicle > 16 tons	3788	61259	98468	4531
With environmental zone - Total	7722	101941	155431	5569
Without environmental zone - Total	8008	108593	168660	8336
Environmental gain with environmental zone	**286**	**6652**	**13229**	**2767**

The environmental zone rules have the greatest impact on particle emissions, if you look at the percentage reduction. This is of huge importance, as particles probably have the greatest impact on health, if all emission components are taken into consideration. A reduction in particle emissions of small particles within the zone is very positive in efforts to reduce PM10 emissions in Göteborg (reducing the content of NO_X and particles is important with respect to the relevant environmental quality norms MKN).

Nitrous oxides (NO_X) are the emission component that has reduced most by weight. The total reduction in emissions of NO_X within the zone is over 13 tons per year – which is a direct result of the environmental zone. Relatively speaking, this is a lot compared with the measures discussed to further reduce NO_X emissions.

It is, of course, – despite the fact that HC and CO are not regulated as per MKN – satisfying that these emissions are also reducing – despite everything they are especially unwanted substances in city air. The different components classed among HC emissions include substances that cause cancer.

The environmental zone rules seem to have had the greatest effect, relatively speaking, on heavy-duty vehicles with a total weight of under 16 tons. Thanks to the environmental zone rules, particle emissions have reduced by 67 % from these lorries. However, this vehicle group is small and does not contribute as much to the total particle emissions. The documentation for calculations here is also less and the results are, therefore, more uncertain than for the other vehicle groups.

Emissions are only increasing from one vehicle type and one component as a result of the environmental zone rules, and that is HC for buses. The fact that this emission component is increasing is due to the fact that gas buses discharge relatively more HC than an equivalent diesel-powered bus. There are quite a lot of gas-powered buses within the environmental zone, which explains the increase. In the case of gas buses, HC is more or less synonymous with CH_4 (methane), as the gas fuel largely (90 % or more) consists of methane. Methane has (per mass unit) much less of an impact on health and the environment (apart from climate effects) than hydrocarbons from vehicles powered by conventional fuel such as petrol and diesel oil. The improvement in health effects due to the environmental zone, therefore, is greater than for the results HC would suggest. The emissions for methane-powered vehicles are often reported as both 'total' HC (often designated THC in these contexts) and non-methane hydrocarbons (NMHC). There is no division between THC and NMHC in the EMV model, but with the large proportion of gas vehicles used in Göteborg there is good reason to do this in future assessments. If this evaluation had been done for NMHC instead of HC, the results would have been very positive and also more relevant to the impact on health effects.

A summary of the relative reduction in emissions with the environmental zone is shown in Table 6. Figure 4 - Figure 7 also show the results in graph form.

Reduced quantity of HC thanks to the Environmental Zone (3.6% or 286 kg per year)

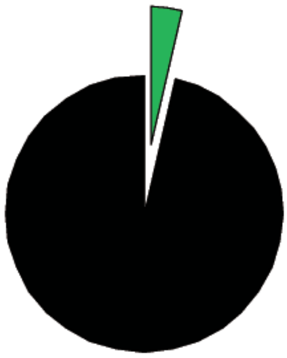

Figure 4. Reduced emissions of HC with environmental zone

Reduced quantity of CO thanks to the Environmental Zone (6.1% or 6,652 kg per year)

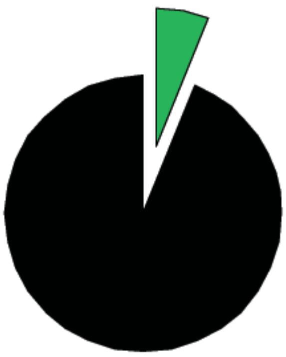

Figure 5. Reduced emissions of CO with environmental zone

Reduced quantity of NO_X thanks to the Environmental Zone (7.8% or 13,229 kg per year)

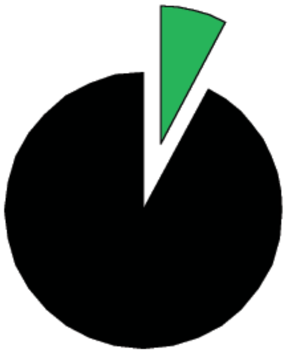

Figure 6. Reduced emissions of NO_X with environmental zone

Reduced quantity of CO thanks to the Environmental Zone (33% or 2,767 kg per year)

Figure 7. Reduced particle emissions with environmental zone

Table 6. Distribution of fuel and vehicle types

	HC %	CO %	NOx %	PM %
Environmental gain with environmental zone – Bus	16,5	-8,4	-8,4	-36,1
Environmental gain with environmental zone – Heavy-duty vehicle < 16 tons	-46,1	-26,7	-20,7	-67,0
Environmental gain with environmental zone – Heavy-duty vehicle > 16 tons	-16,4	-2,9	-6,3	-26,9
Environmental gain with environmental zone – Total	**-3,6**	**-6,1**	**-7,8**	**-33,2**

Among the health effects from exhaust gases discussed among researchers within this field, particle emissions seem to be responsible for most deaths and daily illness. The mechanisms behind these effects are still not entirely clear, but definite links have nonetheless been found between particle contents and the effect on people with heart and vascular disorders. Recent research has also shown that tropospheric ozone causes a dramatic increase in daily mortality and illness. A number of substances, such as various hydrocarbon compounds, aldehydes, polycyclic aromatic carbohydrates (PAC), light aromatic hydrocarbons and particles cause cancer. The group of emission components which, according to calculations, are responsible for most cancer cases are PAC. These constitute a small sub-set of hydrocarbons (HC) but still indicate that a reduction in HC is desirable. Hydrocarbons (HC) and nitrogen dioxide (NO_2) contribute, along with sunlight, to the formation of tropospheric ozone. Normally, the content of HC governs the speed of ozone formation in Sweden. This is also a reason for reducing HC emissions. The complex chemistry that controls ozone formation and break-down is reason for ozone contents often being higher outside built-up areas than within built-up areas. Nitrogen dioxide (NO_2) is highly irritating for people with respiratory problems and in high concentra-tions (normally much higher than those that occur in outside air) degrades lung tissue. It has proven to be difficult to meet the requirements and objectives set for both NO_2 and particles.

Calculations of emissions based on statistics and emission factors include, by definition, a number of uncertain factors. The results from this type of calculation must, therefore, be regarded as indicators and provide an idea of magnitude. However, it is quite clear that the introduction of the environmental zone in Göteborg is very positive for the local environment within the zone – and, of course, outside (as many vehicles also remain outside the zone).

For future evaluations of the zone, a number of activities are suggested that will refine the calculation results and increase precision and accuracy:

- Measure the traffic volume with the aim of establishing the traffic volume of heavy-duty vehicles within the zone
- Collect data on the number of converted vehicles and what each conversion relates to
- Collect data on the number of foreign vehicles within the zone
- Collect data on breaches (the number of vehicles within the zone without permission)

There are plans in Göteborg to expand the zone to cover a larger geographical area. This is positive for the environment because the greater the area, the greater the proportion of traffic operation that will be carried out using vehicles that meet the environmental zone rules (and thus discharge, in relative terms, fewer undesirable exhaust gas components).

Ecotraffic supports the idea of expanding the zone's geographical area. For this purpose, it is suggested that you work on removing old diesel-powered vehicles, diesel cars and working machines without particle filters from the zone. Mopeds and motorbikes without catalytic filtering contribute a relatively large amount to the emission of HC and CO. Levels at 100 – 10,000 times that of a modern car are not unusual. The sound level is also much too high in relation to the traffic volume they achieve. Improving emissions from or removing (the models with catalytic converters should be allowed) the groups mentioned from the urban environment should markedly improve the environment in and around the zone.

4 REFERENCES

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4 Effects of the environmental zone in Göteborg, The Traffic & Public Transport Authority Report no. 2:1996

5 Ahlvik P. and Brandberg Å. (Ecotraffic): "Relative Impact on Environment and Health from the Introduction of Low Emission City Buses in Sweden." SAE Paper 2000-01-1882, 2000.

6 Ahlvik P. (Ecotraffic): "Summary of Swedish Experiences on CNG and "Clean" Diesel Buses." DEER Conference, Newport, Rhode Island, USA, August 24-28, 2003.

Appendix 1 - Correction of EMV calculations obtained with reference to speed

The emission factors in the EMV model for built-up areas correspond to the following average speeds:

	Speed km/h
Bus	22.8
<16t without trailer	27.6
<16t with trailer	24.4
>16t without trailer	38.5
>16t with trailer	36

Average speeds in the environmental zone have been estimated based on driving sequence measurements in Stockholm. These streets are within Stockholm's environmental zone. Traffic speeds are also regarded as applicable to built-up area traffic in Göteborg. Travel speeds for different times during the day are:

	Times	Travel speed min
Morning	07:30 - 08:30	19.9
Day	10:15 - 12:15	24.9
Afternoon	16:00 - 17:00	19.2
Night	00:00 - 03:30	41.1

The stretches selected are:

H1. R1 & R2. Norrtull – Roslagstull – Valhallavägen – Lidingövägen
H2. R1 & R2. R1 & R2. R1 & R2. Norrtull – St. R1 & R2. R1 & R2. R1 & R2. Eriksgatan – Fridhemsplan
H3. R1 & R2. R1 & R2. R1 & R2. Sveaplan – Sergelstorg
H5. R2. Tegelbacken – Solnabron
H6. R1 & R2. Hornstull – Hornsgatan – Ringvägen – Folkungagatan – Stadsgården – Södermälarstrand
H7. R1 & R2. Lindhagensplan – Tegelbacken

Based on correlation between emissions and speed in COPERT III, correction factors have been calculated for daytime and rush-hour traffic.

Correction for EMV base to average speeds according to Stockholm measurements.

Daytime traffic correction factor

	CO	NO_x	VOC	PM	Fuel consuption
Bus	**1**	**1**	**1**	**1**	1
<16t without trailer	1.074115	1.079081	1.094532	1.077593	1.051793
<16t with trailer	1.074115	1.079081	1.094532	1.077593	1.051793
>16t without trailer	1.353449	1.302301	1.465743	1.36292	1.229662
>16t with trailer	1.291789	1.228439	1.381893	1.292504	1.174673

Peak-hour traffic correction factor

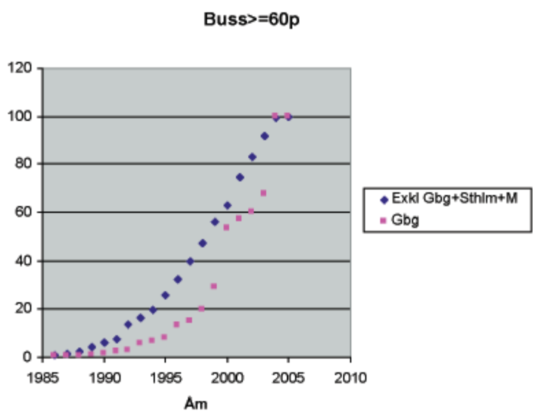
	CO	NO_x	VOC	PM	Fuel consuption
Bus	1.180833	1.156112	1.233672	1.185364	1.120239
<16t without trailer	1.268351	1.28795	1.350293	1.282057	1.182808
<16t with trailer	1.268351	1.28795	1.350293	1.282057	1.182808
>16t without trailer	1.598198	1.505606	1.808247	1.615556	1.377515
>16t with trailer	1.525388	1.403991	1.704804	1.526779	1.304095

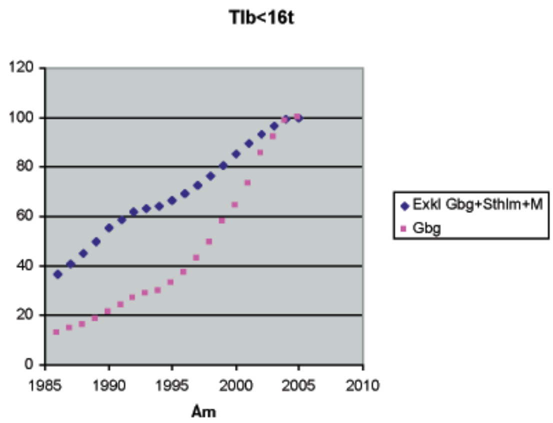
COPERT III uses the same correlation, regardless of requirement level. Information on gas buses is lacking in COPERT. III

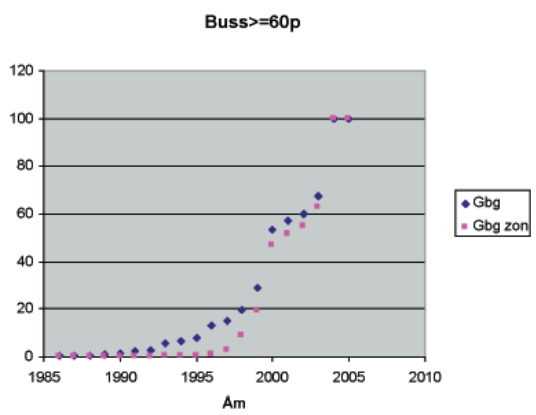
Appendix 2 – Comparison between vehicle fleets

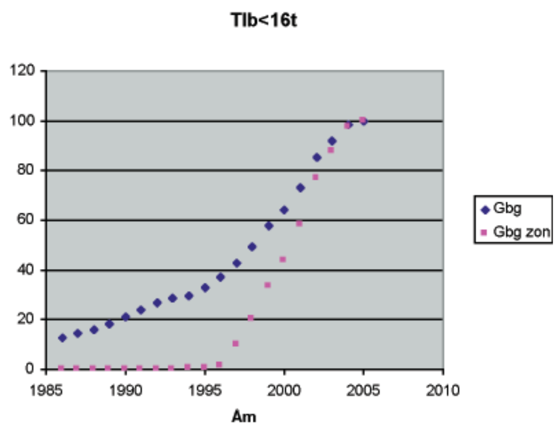
This appendix contains the following comparisons by vehicle type:

- Göteborg's fleet of heavy-duty vehicles compared with the national fleet of heavy-duty vehicles excluding Göteborg, Stockholm and Malmö
- Göteborg's fleet of heavy-duty vehicles compared with partially estimated distribution within the environmental zone.









Appendix 3 – Emission factors

The tables below list emission factors (g/km) and fuel consumption (FC, in litres per km) for the different categories of heavy-duty vehicle.

Emission factors for city buses

	Without conversion	With catalytic converter	With particle filter	Gas buses with cat
	1992 unregulated			
HC(g/km)	1.339			
CO(g/km)	11.69			
NO_x(g/km)	16.05			
FC(l/km)	0.377			
PM(g/km)	1.661			
	1993 A30			
HC(g/km)	0.487	0.058	0.039	12.573
CO(g/km)	5.662	0.566	0.453	4.398
NO_x(g/km)	9.599	9.503	9.215	5.84
FC(l/km)	0.379	0.384	0.385	0.521
PM(g/km)	0.955	0.812	0.096	0.015
	1996 A31			
HC(g/km)	0.361	0.043	0.029	7.306
CO(g/km)	8.759	0.876	0.701	2.245
NO_x(g/km)	11.432	11.318	10.975	4.343
FC(l/km)	0.369	0.374	0.375	0.508
PM(g/km)	0.533	0.453	0.053	0.015
	2000 Eu 3			
HC(g/km)	0.217	0.026	0.017	2.040
CO(g/km)	4.598	0.460	0.368	0.093
NO_x(g/km)	8.166	8.084	7.839	2.840
FC(l/km)	0.369	0.374	0.375	0.496
PM(g/km)	0.355	0.302	0.036	0.015
	2005 Eu 4			**2005 EEV**
HC(g/km)	0.151	0.018	0.012	1.500
CO(g/km)	3.285	0.328	0.263	0.200
NO_x(g/km)	5.716	5.659	5.487	2.000
FC(l/km)	0.369	0.374	0.375	0.500
PM(g/km)	0.071	0.060	0.007	0.010

Emission factors for lorries <16 ton

	Without conversion		With catalytic converter		With particle filter	
	Without trailer	With trailer	Without trailer	With trailer	Without trailer	With trailer
	1992 unregulated					
HC(g/km)	0.705	0.716				
CO(g/km)	4.279	5.475				
NO_x(g/km)	8.029	10.595				
FC(l/km)	0.171	0.223				
PM(g/km)	0.827	1.153				
	1993 A30					
HC(g/km)	0.286	0.295	0.034	0.035	0.023	0.035
CO(g/km)	1.1	1.125	0.110	0.113	0.088	0.113
NO_x(g/km)	3.464	3.715	3.429	3.678	3.325	3.678
FC(l/km)	0.195	0.208	0.198	0.211	0.198	0.211
PM(g/km)	0.403	0.437	0.343	0.371	0.040	0.371
	1996 A31					
HC(g/km)	0.205	0.213	0.025	0.026	0.016	0.026
CO(g/km)	2.627	4.236	0.263	0.424	0.210	0.424
NO_x(g/km)	5.21	6.694	5.158	6.627	5.002	6.627
FC(l/km)	0.183	0.248	0.186	0.251	0.186	0.251
PM(g/km)	0.147	0.209	0.125	0.178	0.015	0.178
	2000 Eu 3					
HC(g/km)	0.123	0.128	0.015	0.015	0.010	0.015
CO(g/km)	1.379	2.224	0.138	0.222	0.110	0.222
NO_x(g/km)	3.721	4.781	3.684	4.734	3.573	4.734
FC(l/km)	0.183	0.248	0.186	0.251	0.186	0.251
PM(g/km)	0.098	0.139	0.083	0.118	0.010	0.118
	2000 Eu 4					
HC(g/km)	0.086	0.089	0.010	0.011	0.007	0.011
CO(g/km)	0.985	1.589	0.099	0.159	0.079	0.159
NO_x(g/km)	2.605	3.347	2.579	3.314	2.501	3.314
FC(l/km)	0.183	0.248	0.186	0.251	0.186	0.251
PM(g/km)	0.020	0.028	0.017	0.024	0.002	0.024

Emission factors for lorries > 16 ton

	Without conversion		With catalytic converter		With particle filter	
	Without trailer	With trailer	Without trailer	With trailer	Without trailer	With trailer
	1992 unregulated					
HC(g/km)	1.213	1.397				
CO(g/km)	9.532	15.723				
NO_x(g/km)	15.725	24.045				
FC(l/km)	0.363	0.534				
PM(g/km)	1.117	1.641				
	1993 A30					
HC(g/km)	0.523	0.693	0.063	0.083	0.042	0.083
CO(g/km)	3.32	5.338	0.332	0.534	0.266	0.534
NO_x(g/km)	7.982	12.408	7.902	12.284	7.663	12.284
FC(l/km)	0.365	0.551	0.370	0.559	0.371	0.559
PM(g/km)	0.604	1.069	0.513	0.909	0.060	0.909
	1996 A31					
HC(g/km)	0.356	0.396	0.043	0.048	0.028	0.048
CO(g/km)	4.984	8.928	0.498	0.893	0.399	0.893
NO_x(g/km)	9.417	14.112	9.323	13.971	9.040	13.971
FC(l/km)	0.323	0.527	0.328	0.534	0.328	0.534
PM(g/km)	0.329	0.57	0.280	0.485	0.033	0.485
	2000 Eu 3					
HC(g/km)	0.214	0.238	0.026	0.029	0.017	0.029
CO(g/km)	2.617	4.687	0.262	0.469	0.209	0.469
NO_x(g/km)	6.726	10.080	6.659	9.979	6.457	9.979
FC(l/km)	0.323	0.527	0.328	0.534	0.328	0.534
PM(g/km)	0.219	0.380	0.186	0.323	0.022	0.323
	2000 Eu 4					
HC(g/km)	0.089	0.099	0.011	0.012	0.007	0.012
CO(g/km)	0.981	1.758	0.098	0.176	0.078	0.176
NO_x(g/km)	3.363	5.040	3.330	4.990	3.229	4.990
FC(l/km)	0.323	0.527	0.328	0.534	0.328	0.534
PM(g/km)	0.029	0.051	0.025	0.043	0.003	0.043

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