CLEVER
Clean Vehicle Research

WP1

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Overview of vehicle technologies
Task 1.1

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Table of contents

1. Introduction

In this report, the different currently available transport-based technologies and those expected in the mid and long term will be described and compared from a technical point of view. They will be compared with each other in terms of their availability on the market, any special infrastructure needed, filling and charging stations, vehicle equipment, safety aspects, driving ranges and energy consumption and emissions (well-to-wheel approach).

2. Technologies for transport

2.1 Conventional fuels: Petrol and diesel vehicles

In this case spark-ignition engines are normally used refering to internal combustion engines where the fuel-air mixture is ignited with a spark. This contrasts with compression-ignition engines, where the heat from compression alone ignites the mixture. Spark-ignition engines can be either two-stroke or four-stroke, and are commonly referred to as "gasoline engines" in America and "petrol engines" in Britain. A four-stroke spark-ignition engine is an Otto cycle engine.

Until recently, a major distinction between spark-ignition and compression-ignition engines has been where the fuel is mixed - spark-ignition engines mix fuel outside the cylinders and compression-ignition engines mix fuel inside the cylinders. However, both two-stroke and four-stroke spark-ignition engines are increasingly being designed with gasoline direct injection, eliminating this distinction between the two systems.

Small petrol vehicles consume around 7 litre per 100 km, while the average consumption of the bigger family cars equals around 9 litre per 100 km. On the other hand, small diesel vehicles consume approximately 5 litre per 100 km, whereas the consumption of diesel family cars results in an average of 7 litre per 100 km. These are theoretical values, the actual consumption could increase, depending on the driving behaviour and traffic situation (i.e. congestion traffic).

Taking into consideration the energy content of a fuel (expressed in MJ/km or kWh/km), the primary consumption level of petrol vehicles exceeds the one of similar diesel vehicles. Primary energy includes the energy consumption of the vehicle (direct energy consumption) as well as the energy necessary for the production of the fuel (indirect energy consumption).

Various technical developments of conventional vehicles have been elaborated in the last couple of years. One of the first steps, was the improved management of the ignition moment, the injected fuel quantity and the injection moment. These processes are controlled by the engine management system. Hereto, dedicated sensors are built into the newly developed engine devices to measure and control the air inlet, temperatures of cooling liquid, outside environment, driving speed, revolutions per minute and residual oxygen in the outlet gas (lambda sensor). As such, it is possible to fine-tune and control the engine behaviour depending on environmental events (e.g. cold start) or the composition of tailpipe gases, in order to optimise the process of catalysts and to reduce the overall emissions (Buning L. *et al*., 2005).

To improve the low efficiency rate of petrol engines at reduced load (closed gas valve, increasing loading losses), various technological solutions have been developed or are in the development stage: Second generation direct ignition, full variable valve timing and valve lift, Miller cycle, downsizing, Homogeneous Charge Compression Ignition (HCCI), etc.

At present, diesel cars emit substantially more small soot particles and nitrogen oxides than similar petrol vehicles. In spite of the generally lower CO_2-emissions, the environmental impact tends to be mostly unfavourable as a result of the negative impact of soot particles on the human health. The installation of catalysts and soot filters can diminish these defects.

Catalysts process tailpipe gases and have to be seen as an after_treatment step, in order to reduce nitrogen oxide (NO_X) and carbon monoxide (CO) and hydrocarbon (HC) emissions. Other similar aftertreatment processes are the recirculation of outlet gases (Exhaust gas recirculation or EGR) and the selective catalytic reduction (SCR). The EGR process (the recirculation of outlet gases in the cylinder) results in extra heat capacity in the combustion chamber at the expense of power, whereby the combustion temperature decreases and as a result also the NO_X-emissions. SCR includes the injection of a small amount of harmless urea that decomposes in ammonia, which reacts and the further conversion with NOx into nitrogen and oxygen. More expensive models of specific car brands already apply sSoot filters are used to reduce emissions of soot particles. Starting from emission standard Euro V (2008, guideline in process), all diesel cars will probably need to be equipped with a soot filter to comply with these strict limits.

2.2 Alternative Fuels

2.2.1 LPG Vehicles

LPG (liquefied petroleum gas) mainly consists of propane (C_3H_8) and butane (C_4H_{10}) and is a by-product of the oil refinery process. At ambient conditions (approximately 1 bar), LPG is a gaseous mixture, but it can be liquefied at a pressure of 4 bar. Hence its name "*liquefied petroleum gas*".

At normal temperatures and pressures, LPG will evaporate. Because of this, LPG is supplied in pressurised steel bottles. In order to allow for thermal expansion of the contained liquid, these bottles are not filled completely; typically, they are filled to between 80% and 85% of their capacity. The ratio between the volumes of the vaporised gas and the liquefied gas varies depending on composition, pressure and temperature, but is typically around 250:1. The pressure at which LPG becomes liquid, called its vapor pressure, likewise varies depending on composition and temperature; for example, it is approximately 220 kilopascals (2.2 bar) for pure butane at 20 °C (68 °F), and approximately 2.2 megapascals (22 bar) for pure propane at 55 °C (131 °F). LPG is heavier than air, and thus will flow along floors and tend to settle in low spots, such as basements. This can cause ignition or suffocation hazards if not dealt with.

Presently, most of the LPG vehicles originate from adapted ('retrofit') petrol cars. Actually, car manufacturing companies tend to produce more LPG-dedicated vehicles, although its present share of the car market is still limited. The ratio of composing LPG compounds differs significantly depending on the originating country and the period of the year. For example, in the United Kingdom, LPG consists for 90 % out of propane, while Italy only handles LPG with 20 % of propane. Belgium has a 60/40 LPG ratio of propane/butane. Originally this lead to some problems while travelling through the European Union, but nowadays this variability in composition will not cause adverse effects on the engine.

In order to achieve the same autonomy as conventional petrol vehicles, the LPG reservoir should be 1.4 times larger than a petrol tank. This is due to the lower volumetric energy content of LPG as referred to petrol, as well as by the tank volume limitations of 80 % for safety reasons.

Small LPG vehicles, type city car, consume 9 to 10 litre LPG per 100 km. Larger LPG vehicles, type family car, on the other hand, consume about 11 tot 12 litre per 100 km. Expressed in litre per 100 km, the consumption of LPG vehicles exceeds the one of petrol cars and certainly scores higher than diesel vehicles, which is mainly caused by the previously mentioned lower energy content of LPG. The weight of LPG is around 0.54 kg/l, compared to ± 0.78 kg/l for petrol and ± 0.86 kg/l for diesel fuel. This is the reason for the higher consumption (at the pump) for an LPG engine.

However, in energy terms the mass of the fuel (kg) is used for calculations. The efficiency results of the LPG engine are comparable with the achievements of a petrol engine, and consequently slightly lower than the diesel engine. The production of LPG necessitates less energy compared to petrol (resulting in a lower indirect energetic consumption).

Taking into account the direct and indirect energy consumption, LPG vehicles generate higher CO_2 emissions than diesel vehicles but slightly lower than petrol vehicles.

In case LPG cars are adequately adjusted, all harmful emissions (NO_x, SO_2, CO, HC or hydrocarbons) are usually lower compared to the emissions of petrol cars. Nevertheless, this outcome necessitates a correct maintenance and a continuous adjustment. If not, some emissions (i.e. NO_x en HC) will increase. The emission reduction of converting a petrol vehicle to an LPG vehicle is variable and depends strongly on the quality of the installation. Only by the use of high-tech LPG installations, LPG can result in an effective reduction of these emissions.

LPG is available throughout the European Union, with a significant concentration of gas stations in the Netherlands, Belgium (about 550 filling stations), France, Italy and UK.

2.2.2 Natural gas vehicles

Natural gas is an odourless product found in nature and mainly consists of methane. The ratio of the different components depends strongly on the source location. The methane content varies between 80 and 99 %. This variation could result in engine problems, since the engine has initially not been developed to operate major changes in gas composition. Natural gas vehicles can also use biogas, generated from anaerobic fermentation of manure and/or vegetable (waste) materials.

Natural gas engines are spark ignition engines, comparable with petrol or LPG engines. The natural gas is filled into the vehicle under high pressure conditions (up to 200 bar). Besides the compression process of the natural gas, it is also possible to store it in liquid form. Then it is called ‘Liquefied Natural Gas’ (LNG), in stead of ‘Compressed Natural Gas’ (CNG). The difficulty of this technology is the fact that the liquefied natural gas has to be stored at rather low temperatures of -160 °C. Worldwide, the majority of natural gas vehicles use CNG.

As for the LPG vehicles, most of the CNG vehicles are adapted petrol cars, but presently there is a tendency to develop dedicated engines for CNG. Like this, the CNG technology can be optimized to operate natural gas as a fuel. This technology is also applied for buses and trucks (heavy duty vehicles). The heavy duty vehicles use modified diesel engines, since there are no large petrol engines available for heavy duty. The main owners of CNG vehicles in Belgium are Electrabel and MIVB/STIB. The use of natural gas for heavy duty is mainly from an environmental point of view: better air quality and less noise production in the cities (city buses run on natural gas (eg MIVB, garbage trucks (Antwerp).

The energy consumption of private cars, operating on natural gas, depends on the engine technology. ‘Bifuel’ vehicles (natural gas - petrol) cannot be easily fine-tuned for both natural gas and petrol, which creates a surplus of 10 % of energy consumption, as compared to a petrol vehicle. For vehicles with dedicated engines for natural gas, up to 80 % in energy consumption could be saved compared to petrol cars. Nevertheless, the compression of the natural gas requires an extra energy consumption of 10 to 20 % of the direct energy consumption of the natural gas car.

Taking into account the direct and indirect energy consumption, natural gas vehicles have a comparable or slightly lower emissions of CO_2 versus diesel cars and 20 % lower versus petrol cars. Since natural gas mainly contains methane, natural gas cars emit 2 to 3 times more hydrocarbons than petrol vehicles. Moreover, methane itself is a strong greenhouse gas. Nevertheless, the emissions of all other pollutants is generally lower for CNG vehicles (see section 3).

A great advantage of natural gas is the fact that it is lighter than air, which makes that it will be immediately dispersed into the atmosphere and no inflammable mixtures can be developed. In enclosed spaces this might still be possible though.

Natural gas vehicles are significantly more silent than conventional ones and the engine vibration is also less. A disadvantage of natural gas vehicles is the smaller trunk space, since they need extra space for a special gas tank, taking a part of the useful place.

The autonomy of CNG passenger cars is 200 to 250 km. To achieve equal autonomy results as conventional petrol vehicles, the CNG reservoir should be 5 times larger than a petrol tank.

There are two different methods to supply fuel into a natural gas vehicle, namely ‘quick fill’ and ‘slow fill’. A ‘quick fill’ handles a buffer storage at a pressure of about 250 bar and the filling process needs only a few minutes. In countries where CNG is applied on a large scale, public CNG filling stations are mostly equipped with a ‘quick fill’ system. In case of the ‘slow fill’ method, the reservoir is filled directly by a compressor device. This filling activity takes around 5 hours. This method is operational for natural gas buses, like the ones used by MIVB/STIB.

Currently, the number of filling stations for natural gas in Belgium is limited. The main advantage compared with other alternatives, is that, as for electricity, there is already an existing natural gas distribution network; in particular, the infrastructure for household heating can be used. The possibility of home filling stations can be easily connected to the grid, but lot of time is needed to fill and it has a high private investment cost (+- 4000 €).

In 1998, the number of natural gas vehicles in Belgium was 243, of which 202 cars and utility vehicles, 27 buses and 14 trucks. These numbers hardly changed in 2007. Worldwide, more than 4 million natural gas vehicles are driven. Argentina scores the best in this market share with an amount of 1,5 million vehicles.

2.2.3 Hydrogen

Hydrogen can be used in a combustion engine as well as in a fuel cell (see further).

The conversion of a petrol engine to hydrogen is comparable with the change of a petrol to an LPG car. For the hydrogen conversion, the ignition and injection timing (and injection duration) need to be reprogrammed. For safety reasons, the cater ventilation eventually needs to be improved and knock sensors are essential.

The hydrogen combustion engine has many important advantages compared to other fuels, such as very fast combustion (higher thermal efficiency), power controlled by the richness of the fuel-air mixture in stead of gas valve controlling (no obstruction caused by the gas valve, no loading losses and higher efficiency), higher possible compression ratio (higher theoretical efficiency). This yields a higher global efficiency of the hydrogen combustion engine compared with the petrol combustion engine (Sierens & Rosseel, 2000; Sierens & Verhelst, 2000; Verhelst, 2006; Ciatti *et al*, 2006).

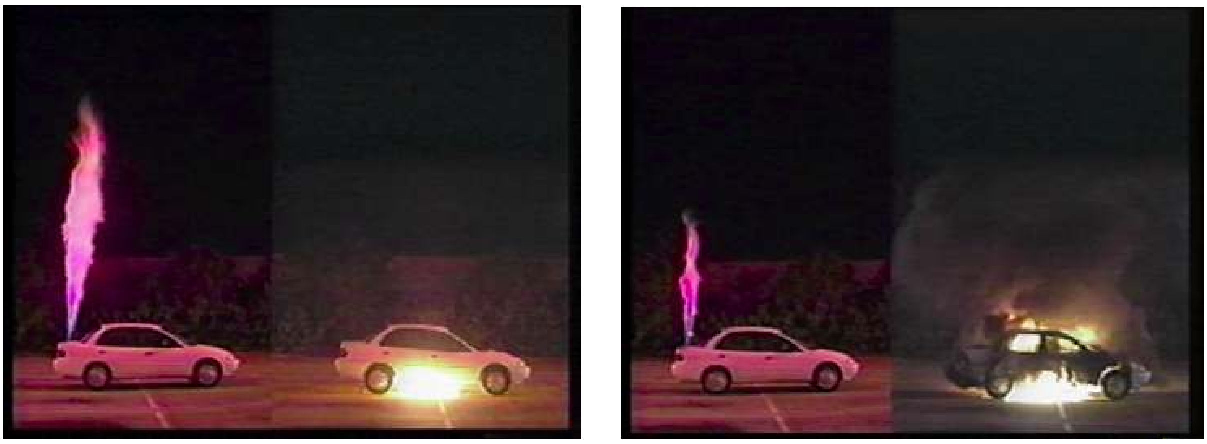
Hydrogen as such, is only in limited quantities present in nature, but the hydrogen atom is plentifully present in the water of lakes, rivers and oceans and of course also in fossil fuels as well as in fuels derived from biological processes (methanol, ethanol, biomass, ...). Four production systems are possible and mutually combinable: oxidation of gas originated from organic or fossil fuels, electrolysis of water and the direct production from biomass or from the use of bacteria. Presently, 96 % of the consumed hydrogen (mainly in the chemical industry) is produced from a fossil fuel, i.e. natural gas (CH_4).

On the one hand, the production of hydrogen gas can take place on-board of the car by converting petrol, ammonia, methanol or natural gas into hydrogen by means of a "*reformer*". The disadvantage of this "reformer method" however, is that the vehicle is not entirely emission-free. On the other hand, hydrogen can also be filled directly (in liquefied or gas phase). The liquefied storage requires lower temperatures (20 K of -253 °C) and results in losses in the storage tank. The storage under high pressure (700 bar) creates significant losses due to the compression of the gas. A mass-ratio of 5 % (ratio of the weight of the stored hydrogen versus weight of the storage tank) is feasible. An alternative solution is the storage of hydrogen in metal hydrid structures or absorption in carbon nanotubes .

Hydrogen has the image of being dangerous (as result of the Hindenburg accident and the Challenger crash event), but crash tests have proven that this fuel can be safely used in vehicles. Picture 1 shows a comparison of a fire in a car filled with hydrogen (left car) and with petrol (right car). The petrol car completely burnt out. The hydrogen car however, shows a short-lived blow-pipe flame, hardly heating the interior of the car.

Picture 1: Comparison of a fire with hydrogen (left car) and petrol (right car).

Left side: start of the ignition; right side: after one minute.



Source: Swain, 2001

In comparison with petrol, hydrogen has a higher specific energy content, namely 120 MJ/kg versus 45 MJ/kg, but it is characterized by a smaller energy density: 4,6 litre of hydrogen at 700 bar equals 1 litre of petrol.

There are also combustion engines operating on a mixture of natural gas and hydrogen. Hythane, for example is a fuel mixture of natural gas and hydrogen, usually with a hydrogen content of 20 % in volume.

In contrast to the fuel cell technology, the hydrogen combustion engine has the ability to make the shift towards a hydrogen economy more gradually. Bi-fuel (hydrogen - petrol) combustion engines have been declared operational by BMW (Rottengrubber *et al*, 2004) and Ford (Stockhausen *et al*.,2002). They will allow the hydrogen network to be built gradually and to collect the necessary experience with the handling of hydrogen. The 'topping' or the electricity generation of alternating wind power (otherwise not usable), will enable to gain very cheap hydrogen (Allaert *et al*, 2004).

There are many prototypes and demonstration projects e.g. GM – Opel testing the Zafira Fuel cell with Ikea in Berlin, Honda FCX being tested in the US, many other studies in the US, Japan and Germany (http://www.premia-eu.org/reports.htm).

2.2.4 Bio-fuels

As opposed to petrol and diesel, generated from mineral oil, bio-fuels are renewable fuels. They are produced from agricultural crops, wood or organic waste. Consequently, various types of bio-fuels exist. They have the advantage of being compatible to a certain extent with conventional vehicle technologies, such as petrol and diesel engines.

The European Commission has set the objective by the end of 2005 to achieve a share of 2 % bio-fuels in the global quantity of consumed transport fuels. Up to the end of 2010, this objective should reach a share of 5,75 %. On the short term, they count mainly on bio-diesel, bio-ethanol and to a lesser extent also on bio-gas and pure plant oil (PPO). On medium term, they count on production processes of the second generation. These processes originate from biomass, initially gasified and then converted to liquefied fuels. Examples of such processes are: Fisher-Tropsch bio-fuels, bio-DME (Dimethyl ether) and bio-methanol. There are two main types of second generation bio-fuels: (i) initially gasified and then converted to liquefied fuels (mainly FT-diesel) and (ii) the other is bio-ethanol from cellulosic biomas. This requires an additional production step, but is much more efficient then nowadays starting from sugar or starch crops.

Theoretically, bio-fuels are CO_2-neutral: CO_2 is taken up by plants and converted via photosynthesis in energy-rich biomass. Afterwards, this biomass will be reconverted to CO_2 by combustion in the vehicle engines. However, during the agricultural process and the processing of the plants to bio-fuels, harmful pollutants are emitted, such as greenhouse gases, so that this process cannot be called CO_2-neutral .

Bio-diesel can be made from vegetable oil, such as rapeseed, sunflower, palm or soy oil, eventually even from used alimentary oil or animal fats. In order to achieve a high fuel quality, these oils undergo a chemical reaction (esterification) with methanol. The outcome is a methylester, such as rapeseed methylester (RME). This product has characteristics comparable with those of conventional diesel oil.

Provided some small adaptations (such as adequate seals and fuel piping in suitable materials, to avoid corrosion of rubber), pure bio-diesel could be used in a conventional diesel engine. Bio-diesel is also perfectly mixable with fossil diesel fuel. All diesel engines from after 1980, could operate without any problems on mixtures containing up to 5 % bio-diesel. This ratio could even increase up to 20 or 30 %. For the time being, car manufacturers accept mixtures up to 5 % for use in the current fleet of cars. A number of car models is standard equipped with bio-diesel compatible materials and can thus run on pure bio-diesel.

Like diesel cars, bio-diesel vehicles emit more NO_x and PM than petrol cars. A diesel engine operating on pure bio-diesel, will emit a little more NO_x (about 10 %) than running on conventional diesel, whereas, the emissions of PM, CO and hydrocarbons usually decrease with 50 % using bio-diesel. A disadvantage of bio-diesel is the possible generation of smell overload ("deep-fried oil smell"), but this could be neutralized to a large extent by using an oxidation catalyst (standard equipment for new passenger cars). Most net greenhouse gas emissions are due to the agriculture phase (most N_2O emissions), the oil extraction and the esterification. Generally it is stated that bio-diesel leads to a global reduction of 40 tot 60 % in greenhouse gas emissions versus fossil diesel (IEA, 2004). Bio-diesel is biologically degraded for 98 % within a period of 21 days. This means that a leak does not result in permanent soil or water pollution.

Pure plant oil (PPO) can also be used in diesel engines, but for this purpose, the engine needs to be specifically converted (mainly for the preheating and the filtration of the fuel, also eventually for the adaptation of the injectors). Thus far, most applications have been carried out on older diesel engine models. The experience of new diesel technologies (e.g. common-rail) is rather limited. Even so, not all brands of diesel pumps are suitable. The costs for such kind of conversion lies between 2000 en 3000 Euro for passenger cars.

The advantage of pure rapeseed oil versus bio-diesel (RME) can be found in the more simplified production process (cancelling the esterification step). As a result, the fuel becomes cheaper, the production process requires less fossil energy and the greenhouse gas emissions are also lower. Regarding other harmful emissions, the effects are less unambiguous. Engine constructors react rather reluctant against the use of pure rapeseed oil (or other oils), since it could have an adverse impact on the engine operation (and as such it could potentially increase the emissions) and also because there is less control on the quality of the fuel, which may cause possible engine damage on the long term.

A third type of bio-fuel is *Bio-ethanol.* Bio-ethanol is alcohol generated by fermentation of sugar containing plants (such as sugar beet or sugar cane) or of starchy plants (such as wheat, maize or potatoes). On the long term, also celluloid materials (straw, grasses, wood) could be used for the production of ethanol.

Due to the high octane number of ethanol, it is excellent for use in spark ignition engines. Adding ethanol into petrol up to 20 % hardly results in operational problems for modern petrol cars. In case of high ethanol concentrations (such as E85 = 85 % ethanol, 15 % petrol) or use of pure ethanol, some materials in the fuel system should be adapted and the injection quantity increased, due to the lower combustion value ethanol. So-called Flexible Fuel vehicles (FFV) can operate on any mixture of petrol and ethanol. Various car constructors already developed FFV models, but these are mostly destined for the American or Brazilian market.

Currently in Europe, there are several vehicles suitable for ethanol on the market. They are so-called Flexible Fuel Vehicles (FFV): the Koenigsegg CCXR, the Peugeot 307, the Citroen C4, the Ford Focus/C-MAX FFV, the Volvo C30, S40, V50, V70 and S80 FFV and the Saab 9-3 and 9-5 FFV. Those vehicles run both on petrol and ethanol. The engine management system reacts on the fuel composition (Buning *et al*., 2005).

The production of ethanol needs a lot of energy. The exact energy amount depends on the used raw material. Even the global reduction of greenhouse gas missions is strongly dependent on the raw material and on the production process. The IEA (International Energy Agency) states that ethanol, taken into account the current generation technologies from corn or maize, is scoring globally only 30 to 40 % lower on greenhouse gas emissions in comparison with petrol. In the case that ethanol is produced from sugar containing plants, such as sugar beet and especially sugar cane, the reduction yields are higher (IEA, 2004).

Ethanol is less toxic than petrol and above all than methanol, which was mainly used in the US during the nineties. Mostly, methanol was generated from natural gas, which globally did not improve the level of greenhouse gas emissions. Moreover, methanol is more volatile than ethanol and is strongly corrosive.

In the case that ethanol is mixed in limited quantities (typically 5 %) with petrol, the volatility of the fuel increases (and consequently also the evaporation emissions). In order to solve this problem, especially in Europe ETBE (ethyl tertiary butyl ether) is introduced. *Bio-ETBE* is an octane enlarger generated from bio-ethanol and fossil iso-butylene. ETBE may be mixed up to 15 % with petrol without increasing its volatility. Provisionally, bio-ETBE is used mostly in France and Spain.

The first generation bio-fuels can be especially seen as a first step towards reducing the dominating dependence on fossil oil products in the transportation sector. In the framework of the Kyoto protocol, also their lower impact on the greenhouse effect is important. However, the ecological friendliness of first generation bio-fuels often needs to be put into perspective. The used plants require artificial fertilizer and pesticides. Moreover, agricultural and production processes require lots of energy and cause many additional emissions. In addition, more agricultural area is occupied, about one hectare is necessary to produce adequate fuel for one car operating for one year. Bio-fuels from tropical plants also need to be handled with some precaution, since they can lead to deforestation of tropical forests or jeopardizing the local food supply.

2.3 Alternative drive trains

Besides vehicles driven by a conventional drive train with combustion engine, cars with "alternative" drive trains are operational, such as battery electric vehicles, hybrid and fuel cell vehicles.

2.3.1 Battery electric vehicles

Electrically driven vehicles exist since the end of the 19^{th} century, but have been pushed aside by the combustion engine. During the eighties and nineties, electric vehicles drew more attention again thanks to their ecologically sound characteristics. Moreover, after the oil crisis in the mid seventies, it became clear that our oil dependence becomes too high and needs to be limited. After all, electric vehicles are less dependent for their power supply on oil producing countries.

An electric vehicle is driven by an electric motor and takes its power from a rechargeable battery. Due to the characteristics of the electric motor, a gearbox device is mostly not necessary. Moreover, a part of the brake energy is recovered to load the battery again. There is even a possibility to integrate the motor into the wheels (for two-wheel and four-wheel drive). Starting from standstill, the electric motor can develop its maximum torque, resulting in a quite large acceleration power. Another fundamental difference with traditional vehicles is that the engine does not operate when the car is standing still and consequently does not consume any energy.

An important asset of electric vehicles is the absence of exhaust fumes during operation. Because of their positive impact on the environment, electric vehicles contribute considerably to the improvement of traffic and especially to a more healthy city environment. The generation of electricity can however also generate emissions. In case the consumed electricity would be generated using renewable energy sources, such as wind and solar energy or hydro-electric power stations, emissions should be negligible. Thus, the composition of the electricity generation park determines the emissions associated with these vehicles.

An electric motor has a much higher efficiency (80 to 90 %) than his thermal counterparts (10 to 40 %). Even in case the efficiency for the generation of electricity will be taken into account, as well the charging and discharging losses of the battery, an electric vehicle consumes constantly less energy. The regenerative braking and the zero-consumption at standstill result in up to 40 % more energy efficiency of electric vehicles compared to petrol vehicles (see further).

There are three types of charging infrastructures for electric vehicles, namely the "regular", the "semi-fast" and the "fast" charging infrastructures. For the regular type a usual plug socket is used (230 V, 16 A, 3.5 kW) and a full charge lasts 5 to 8 hours. For the semi-fast type (7 kW), it takes half the time and for the fast type (20 kW and more) only some ten minutes. Besides the private plug sockets, largely present in houses and garages, also public charge stations could be used. However, relevant electric points are not yet available in our country, but require only limited adaptations or extensions of the existing electricity network.

More than 95 % of the materials of the batteries could be recycled. A network for collection and recycling of batteries is already present and runs very efficiently (Van den Bossche, 2005; Matheys. *et al.,* 2005).

The current battery electric vehicles have limited autonomy and could cover on average 80 to 120 km with a fully charged battery. Consequently, they are only very suitable for use in the city or for short distance applications. In the future, it is expected that this radius of action will increase to 300 km by using new battery technologies (such as lithium batteries).

In 2000, Belgium operated some 1053 registered electric vehicles, of which 30 passenger vehicles, 6 motorcycles, 2 buses, 78 trucks, 5 tractors and 932 special vehicles (mainly fork lift trucks).

A major financial obstacle for a market breakthrough for electric vehicles is the operating cost of the battery, since it needs to be replaced every couple of years (depending on the battery type and the number of charge-discharge cycles). It is expected that the cost of the battery will decrease, thanks to mass production and future technological developments. On the other hand, electricity is by far the cheapest energy source in comparison with diesel, petrol, LPG and bio-diesel. Given a price tag of 0,08 Euro per kWh, the electricity cost per 100 km fluctuates between 1,6 and 1,7 Euro for small and family cars. The fuel cost of diesel vehicles per 100 km is 3 to 5 times higher than what should be paid for the charging of electric vehicles (fuel costs dd. 2001).

2.3.2 Fuel cell electric vehicles

Electric vehicles could also be equipped with a fuel cell instead of a battery. To generate electricity, fuel cells use oxygen (from the air) and hydrogen (from a gas tank).

The fuel cell technology is still under development and currently, no commercial fuel cell vehicles are available. Only a few prototypes have been developed yet. Probably within 10 to 20 years, the consumer will be able to purchase such a type of vehicle.

As a result of the higher efficiency of fuel cells, combined with the electric drive train, the energy consumption of a fuel cell vehicle is lower than for conventional vehicles with a combustion engine (see further).

The current prototypes of fuel cell vehicles (FCEV) have an autonomy of around 300 km, but the aim is to increase this up to 600 km. The high production costs of fuel cells (3000 €/kW to 8000 €/kW) are partially due to the use of expensive materials, such as platinum for the separators. Switching to mass production and using cheaper materials, can lower the cost to 200 €/kW (Zegers, 2005). This price needs to be compared with the lower costs and the cancelled external costs as a result of the lower air pollution compared to conventional vehicles.

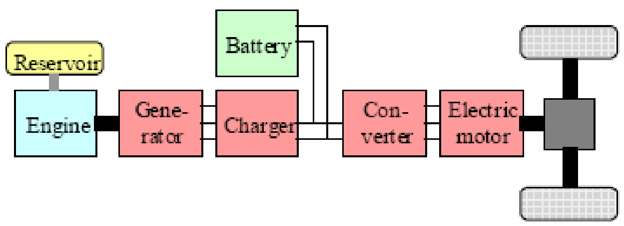
2.3.3 Hybrid vehicles

The term "hybrid vehicles" covers a compilation of vehicle technologies using two (or more) drive trains or energy sources. Often, they include a combustion and an electric engine/motor.

Two important categories can be distinguished: the *parallel hybrid* and the *series hybrid* vehicles. In the first category, the electric and the thermal motor/engine are mechanically linked and can both drive the wheels. With the second category, the wheels are only driven by an electric motor, sourcing its energy from a battery or from a generator driven by a thermal engine.

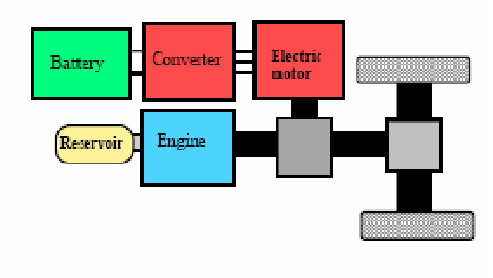
The *series hybrid* structure (see figure 2 can optimize the operation of the combustion engine by supplying the peak capacities for acceleration to the battery (e.g. Irisbus, Renault Kangoo RE). The battery can also recuperate the braking energy . In case there is no battery, when only a generator group is present, the 'diesel-electric' drive train is obtained, which is in fact no typical hybrid drive concept (e.g. Mercedes Cito bus). The family of *hybrid fuel cell drives* belongs to the series hybrid category. Actually, the division of the power occurs between the fuel cell and the battery (e.g. Mercedes Citaro bus).

In the *parallel hybrid* category (see figure 3, a combustion engine is assisted by an electric motor. Both engines are mechanically coupled to the wheels (e.g.Honda Civic).



Bron: Van Mierlo (2000)

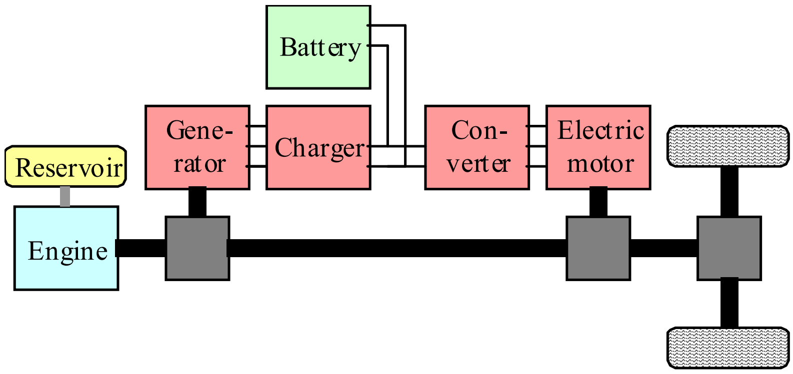
Figure 2: Series hybrid drive train



Bron: Van Mierlo (2000)

Figure 3: Parallel hybrid drive train

The combination of a series hybrid and a parallel hybrid structure ( ) is called 'combined' or series–parallel hybrid structure (e.g. Toyota Prius).



Source: Van Mierlo (2000)

Figure 4: Combined hybrid drive train

As such, several combinations are possible and used in practice. Obviously, these different options do not all have the same value in the field of energy efficiency, neither ecologically nor economically. The evaluation of to be considered criteria have been integrated in a computer behavioural model, within the framework of a PhD at the Vrije Universiteit Brussel (Van Mierlo, 2000).

The choice of the structure depends on the envisaged market segment. For instance, the series hybrid structure will be preferred for city buses. On the other hand, the parallel drive train is recommended for (family) cars, particularly driving on highways. The combined structure is more appropriate for mixed use (urban-rural).

The combustion engine of hybrid vehicles mostly uses petrol (passenger cars), but also fuels such as (bio)diesel, LPG, CNG, etc. are possible.

The battery of some hybrid vehicles could be charged via the electricity grid ("*Plug-in-hybrid*"), other hybrid vehicles are operational with an automatic charging device through a generator unit on board of the car.

Hybrid vehicles could strongly reduce emissions and fuel consumption because:

- The combustion engine can be stopped when no power is required (for instance in a traffic jam or standing still at traffic lights). As a result, the fuel consumption, and the associated CO_2-emissions, could be reduced with 8 to15 %.
- While braking, the braking energy can be stored and reloaded to the battery, saving energy up to 15 % for passenger cars.
- The combustion engine could be utilized within a field of activity consistent with low emissions and low fuel consumption.

That's why hybrid vehicles can consume 15 to 30 % less primary energy compared with conventional vehicles; for city traffic, the reduction can be even up to 50 % less. Some even have the possibility to drive entirely electric and consequently are capable of making locally emission-free displacements.

Presently, only a few hybrid cars are available on the Belgian market (Toyota Prius, Honda Civic IMA, Renault Kangoo Elect'Road, Lexus RX400h, Lexus GS450h). The purchase price of these vehicles is a little bit higher than the price for a conventional car of the same class. On the other hand, due to the lower fuel consumption and potential fiscal benefits, they are cheaper in use

3. Energetic comparison of vehicle technologies

Even today, little attention is paid to the fact that the energy efficiency of conventional vehicles scores less then 15% in municipal areas (80 % of the vehicles mainly move in the city). Nonetheless, this means that when starting with 50 litre fuel in an average fuel reservoir, less than 7,5 litre is fully used to drive, while the remaining 42,5 litre is converted into unused heat. Diesel motors yield the best results regarding energy efficiency, followed by petrol engines and engines using gaseous fuels (natural gas and LPG).

Moreover, fuel consumption is also defined by driving behaviour. Fuel can be saved by lowering the rotational speed of the engines (<2500 revolutions per minute (r.p.m.) for petrol and <2000 r.p.m. for diesel). Outside the built-up area, fuel saving of 25 % can be obtained by keeping the number of revolutions per minute of the engines low. The city traffic strongly depends on external factors such as traffic flux, traffic lights control, etc., through which fuel saving by driving behaviour is rather limited (about 5 %) (Van Mierlo *et al*. 2004, Van Mierlo *et al*. 2002). In order to focus on the global impact of vehicle emissions, the crucial point is the motivation of the individual driver to use a sparing driving style. Based on corporate communication (mass media, and similar), it is stated that 18% of the drivers do apply the most important elements of ecologically sound driving in practice. Referring to the Flemish fleet of cars and in case of proper driving behaviour, the potential fuel saving will be 1,8 %. (Van Mierlo *et al*., 2002).

Both, the weight of the vehicle and the power of the engines (number of kilowatt), determine the fuel consumption of the vehicle. Research studies (Van Mierlo J., 2002) stipulate that an increase in mass of the vehicle by 200 kg, will rise the fuel consumption with 8 to 13 % for lighter vehicles (< 1 ton) and with 3 to 5 % for more heavy vehicles (1.7 ton). Ecodrive (2002) also states an increase of the fuel consumption by 6.7 % for a medium-sized vehicle of 1500kg, transporting an extra load of 100 kg. In case of the same date of construction and fuel type, it appeared that the smaller the engine power, the sparing the car will be (Van Mierlo J., 2002).

The increasing safety- and comfort measures of the vehicles, but also the larger volumes of the vehicles resulted in a weight gain of almost 30 % between 1993 and 2004 (De Mol J., 2006). Also the size of the engine power increased by 51 % between 1983 en 2004 (De Mol J., 2005). Febiac (2006) outlines a mean weight increase of 24 % and an increase of the engine power by 22 % (period 1995-2005). In the same period, the official fuel consumption decreased by 15 %. Higher fuel reduction would be possible, if more smaller cars with smaller engines were constructed and purchased.

Besides, the load on the car will increase in fuel consumption due to aerodynamics. According to Vito (2002), a luggage rack on the roof of the car results in a fuel consumption increase of 7.5% at 120km per hour speed; a fully loaded luggage rack 38.7% and a ski box 16.1%. Generally, Vito (2002) states an additional fuel consumption of 10% for a ski box and 20 to 30 % for a bicycle rack on the roof of the car.

Above-mentioned analysis mainly relates to conventional vehicles. What would be the actual relation of vehicles with alternative fuels and power systems versus conventional fuels? Hereto we should use the "*Well-to-Wheel*" (WTW) approach. Table 1 shows the fuel characteristics, the direct energy consumption ("*Tank-to-Wheel*", or TTW, according to the energy consumption in the vehicle itself), the indirect energy consumption ("*Well-to-Tank*" (WTT), according to the energy consumption for the production of the fuel) and the primary (WTW) energy consumption. The vehicles from Table 1 meet EURO IV and have a engine with a cylinder volume of about 1600 cc. All vehicles were compared based on an equal driving cycle (NEDC).

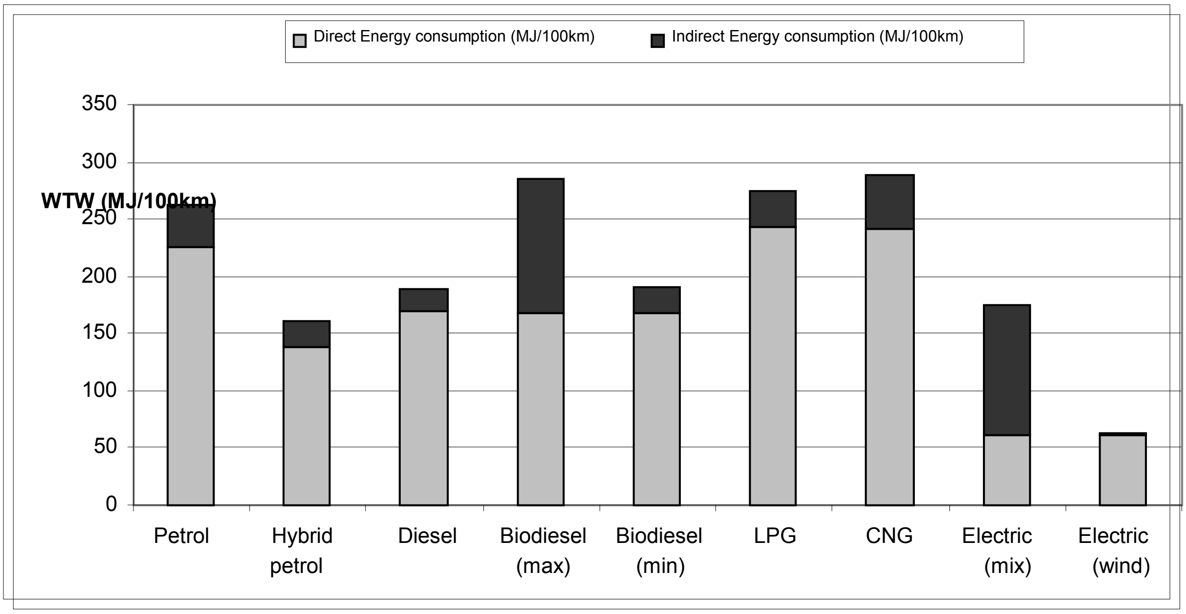
Table 1: 'Well-to-Wheel, energy consumption of passenger cars

	Consumption		Density	LHV		TTW	Energy input	WTT	WTW	
			kg/m^3.	MJ/kg	kg/100km	MJ/100km	MJ/MJ	MJ/100km	MJ/km	
Petrol	7	L/100 km	755	42.715	*5.29*	*226*	0.16	*36*	2.62	100%
Hybrid petrol	4.3	L/100 km	755	42.715	*3.25*	*139*	0.16	*22*	1.61	61%
Diesel	4.6	L/100 km	850	43.274	*3.91*	*169*	0.12	*20*	1.90	72%
Biodiesel (min)	5.06	L/100 km	880	37.700	*4.45*	*168*	0.70	*118*	2.85	109%
Biodiesel (max)	5.06	L/100 km	880	37.700	*4.45*	*168*	0.14	*24*	1.91	73%
LPG	9.8	L/100 km	550	45.114	*5.39*	*243*	0.13	*32*	2.75	105%
CNG (min)	6.42	M3/100 km	717	52.367	*4.60*	*241*	0.20	*48*	2.89	110%
Electric (mixture)	0.17	kWh/km				*61*	1.87	*114*	1.76	67%
Electric (wind)	0.17	kWh/km				*61*	0.03	*2*	0.63	24%

Source: Timmermans *et al.* (2005)

Figure 5 shows these values graphically. It demonstrates the important advantage of the hybrid drive system and the influence of the production of bio-fuel and electricity on the primary energy consumption of bio-fuel vehicles, respectively battery electric vehicles. The vehicles with LPG and natural gas yield a higher energy consumption than the petrol vehicle. The diesel vehicle has a more favourable energy consumption than the petrol vehicle. The hybrid vehicle has the best score regarding energy consumption.

Figure 5: Well-to-Wheel, energy consumption of passenger vehicles, in 2005.



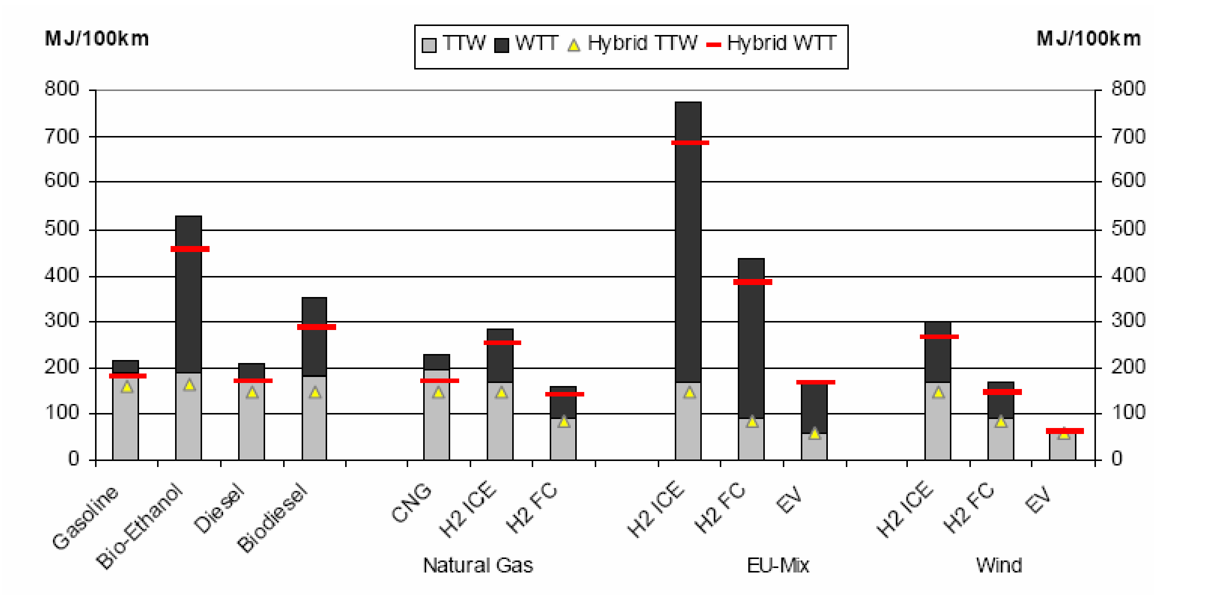
Source: based on MIRA-T (2005)

Below mentioned analysis, carried out by EUCAR (R&D network of European automobile sector), outlines a projection of the primary energy consumption up to 2010 and this for different fuels and production technologies (EUCAR, 2004). The results are shown in Figure 6. Because the different alternative and conventional vehicles could be produced with or without a hybrid drive system, the result after hybridisation is also given with a horizontal stripe.

Hydrogen can be generated from different energy sources, such as natural gas, nuclear energy, alternative energy sources (wind, hydropower, solar cells, etc.) (Brinkman N. *et al*. 2005; Choudhury R. *et al.* 2002; R. Edwards et al. 2004; Bogart S.L., 2002). Which production paths finally will be chosen for large scale production, is currently not yet clear. In most cases, electric energy will be used to produce hydrogen gas via electrolysis of water.

Alternative ways of energy supply will be discussed in function of the expected situation in 2010. For diesel and petrol an extrapolation is made to the expected technology in 2010. Comparison is made with bio ethanol and bio diesel (*RME*). To this end, diesel vehicles are provided with soot filters. In addition, attention is paid to the use of natural gas in the combustion engine *(CNG)*. Hydrogen is marked by *H2* (compressed). Distinction is made between the use of hydrogen in a combustion engine *(ICE)* or in a fuel cell *(FC)*. Hydrogen can be generated based on natural gas *(Natural gas)*, electricity according to the European mix *(EU-mix)* or electricity sourced from windmill energy *(Wind)*. The electricity could also be used directly in the battery electric vehicle (*EV*).

Figure 6: Well-to-Wheel, energy consumption of passenger vehicles, in 2010.



Source: based on EUCAR (2004)

These graphs demonstrate that the advantage of hydrogen is the lowering of the *Tank-to-Wheel* energy consumption if the fuel cell is used, but this is going to the prejudice of the *Well-to-Tank* energy, necessary for the generation of hydrogen gas. Up to 2010, the combination of hydrogen and the combustion engine shows to be no alternative for petrol and diesel, regarding energy consumption (EUCAR, 2004).

This analysis shows that almost three times more power stations should be built (for instance windmills) in case hydrogen gas is used as energy source for the fuel cell electric vehicle, than when the produced electricity would be used directly in the battery electric vehicle.

On the other hand, hydrogen gas can be seen as possible energy buffer. The electricity production of windmills is dependent on wind circumstances. However, electricity has to be generated on the moment of consumption. Therefore, power stations should be adjacent to windmills and should be switched on during the time of wind absence. Another solution is to store the electricity produced by windmills as hydrogen gas; consequently, this gas could be used in periods of less (or too much) wind. Also, one should question the economical efficiency of the use of hydrogen compared to pump stations as energy buffer, such as in Coo.

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Clean **Ve**hicle **R**esearch: LCA and Policy Measures
(CLEVER)

Report Task 1.2
Overview of environmental vehicle assessments

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Table of contents

Table of figures

Table of tables

Introduction

Between 1990 and 2004, Greenhouse Gas emissions from transport increased by 32.2%, or 2 per cent per year on average [1] in the EU25. In spite of the technological improvements of new vehicles, the total environmental impacts are not diminishing because these improvements have been outbalanced by the increasing number and size of the vehicles on the road. As a consequence a shift towards greener vehicles is still needed [2].

Several environmental vehicle rating tools have been developed in order to promote the purchase and the use of greener cars. They also a function as a sensitisation tool of the general public. Life Cycle Assessment (LCA) is indisputably the most developed and the worldwide accepted tool for environmental comparison of products and services. Besides LCA, some web based and/or methodological public or policy support tools have been developed at regional (e.g. Ecosore), national (e.g. EPA green vehicle guide) and European Union levels (e.g. Cleaner Drive). These last years, a big number of environmental vehicle assessments have been performed. LCAs of specific vehicles, average vehicles, and Comparative LCAs of different vehicle fuels and technologies have been performed.

This document provides answers to questions such as: “What are the main features of those tools? Which ones take into account all the requirements of a complete environmental vehicle assessment? What are the main conclusions?”

I. Existing Vehicle Eco-rating system

I.1 Life cycle assessment

Environmental Life Cycle Assessments study the environmental aspects and potential impacts of a product/service from ‘cradle-to-grave’ i.e. from raw material acquisition through production, use to disposal. It is the only environmental assessment methodology which has been standardised.

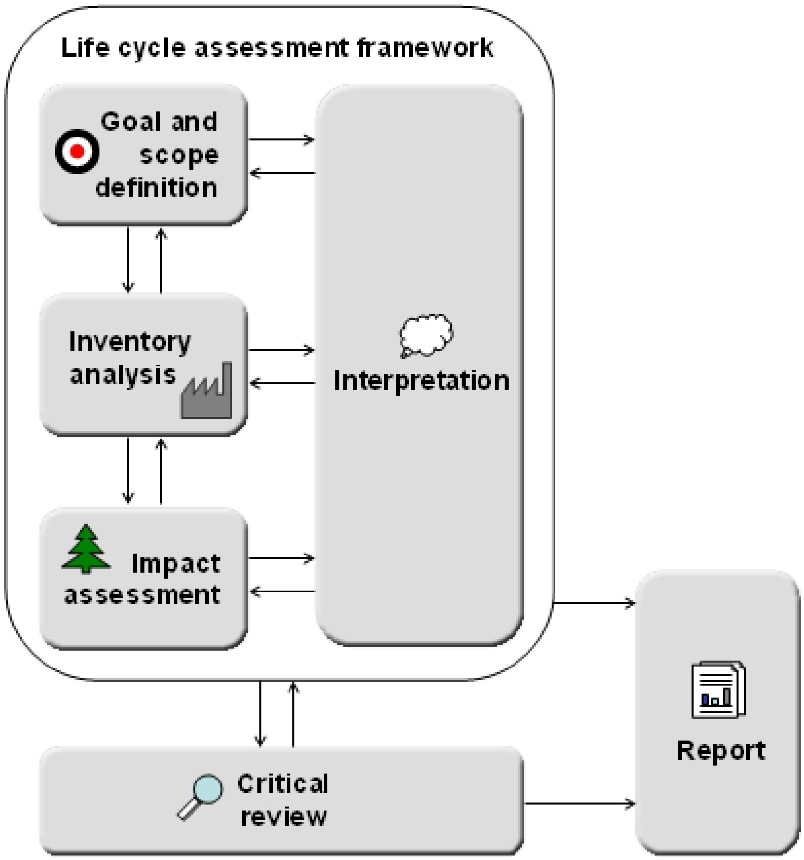

Figure 1: Life Cycle Assessment framework **Source: [3]**

The ISO (International Organization for Standardisation) 14040 standards series describes the method presenting the different options for the development of Life Cycle Assessment (the following descriptions are the ISO ones):

ISO 14040 This document is intended to provide a clear overview of the practice, applications and limitations of LCA to a broad range of potential users and stakeholders, including those with a limited knowledge of life cycle assessment.

ISO 14041 This document is intended to provide special requirements and guidelines for the preparation of, conduct of, and critical review of life cycle inventory analysis (the phase of LCA that involves the compilation and quantification of environmental relevant inputs and outputs of a product system).

ISO 14042 This document is intended to provide guidance on the impact assessment phase of LCA (that phase of LCA aimed at evaluating the significance of potential environmental impacts using the results of the life cycle inventory analysis).

ISO 14043 This document is intended to provide guidance on the interpretation of LCA results in relation to the goal definition phase of the LCA study, involving review of the scope of the LCA, as well as the nature and quality of the data collected.

I.1.1 Life Cycle Assessment history

In the aftermath of the first oil crisis, industries had begun doing the inventory of their energy consumptions per activity. But very rapidly they noticed that they needed a common framework to be able to compare their results within a company and between different companies. The following dates have marked the Life Cycle Assessment history [4]:

- **1984** Publication by the EMPA of the « Ecological report of packaging material »
- **1991** First works at SETAC (Society of Environmental Toxicology And Chemistry)
- **1992** First European scheme on Eco-labels
- **1992** Creation of SPOLD, creation of a data exchange standard between 1995 and 1996
- **1997-2000** ISO 14040,41,42,43, international series of standard defining the different stages of the LCA methodology
- **1999-2001** ISO 14020, 25 , 48, 49, series of standard and technical documents concerning communication, environmental declaration directions and working methods

I.1.2 The different steps of a Life Cycle assessment

The different steps of an LCA are the following:

- **Goal and scope definition**

The Goal and scope definition step determines the outcome of the assessment. One should define clear and comprehensive objectives for the study. The purpose of the study and the intended use of the results should be specified.
The ISO 14041 standard provides the guidance on the elements to be covered in the scope definition:

- The **functional unit** is the quantified performance or service of a product system that is used as a reference unit in the study. It allows the comparison of the different product systems that are studied on a common a basis.

- The definition of the **system boundaries** which enables to include the relevant activities, life cycle phases and processes to be studied. The LCA practitioner can choose to exclude the operations or the life cycle phases which will not modify the results of the study.
- The checking of **data quality** because the data are from several sources (industry, estimations, measurements…) and some of them need to be updated.
- The definition of Cut-off rules to decide the threshold values (mass, energy or environmental significance) at which an input or output is taken into account.

- **Life cycle Inventory Analysis**

Life Cycle Inventory Analysis step is the most developed from a methodological point of view. According to the ISO 14041 standard, the life cycle inventory is the compiling and the quantification of all the inputs and outputs of the product system through out its life cycle.

A first limited data collection (literature research) is undertaken to compile all the operations and processes included in the product system. The identification of all the processes will lead to the construction of the 'life cycle tree' of the product.

The second step of the inventory will be the collection of all the input data (materials and energy consumption) and output data (solid, liquid and gaseous emissions). Those data will be quantified for every phase of the product life cycle. Some allocation rules will be defined to take into account all the co-products of the system.

Finally, the inventory will be computed and the most representative stages will be identified.

- **Impact assessment**

The aim of the impact assessment is the quantification of all damages on human health and ecosystems. Three main impact categories are considered by Life Cycle Assessment practitioners:

- The depletion of resources (energy, materials, water and soil)
- The impacts on human health
- The impacts on ecosystems.

The LCA practitioners don't have a common point of view of impact assessment studies. Some think that this step should be abandoned because of the uncertainties inhere in environmental studies. According to them, LCA studies should be stopped at the inventory stage. Others esteem that environmental evaluation needs further works in order to reduce the uncertainties [5].

An agreement is obtained, in the LCA community, on the components (see figure 2) of the impact assessment step:

- the **classification** which is the determination of the flows that are taken into account for the impact assessment and per impact category.

- the **characterization** which is the determination of the contribution of each flow to a given impact category e.g. on a scale of 100 years, the contribution to the global warming of 1 kg of methane (CH_4) rates 21 times the one of 1 kg of CO_2. So the characterization factor of CO_2 will be 1 and the one of CH_4 21.

Two optional steps exist in LCA. These steps are **normalisation** and **weighting**. According to the ISO 14042 standard, normalisation and weighting are not mandatory. However, those two steps are defined in the standard:

- **Normalisation**: calculating the magnitude of the category indicator results relative to reference values where the different impact potentials and consumption of resources are expressed on a common scale through relating them to a common reference, in order to facilitate comparisons across impact categories

- During the **Weighting** step and taking the goal of the study into account, weights are assigned to the different impact categories and resources reflecting the relative importance they are assigned in the study.

In other words, the Normalisation step is the quantification of the relative burden of an impact category with respect to a reference value. The Weighting step is the aggregation of the different damage categories in order to obtain a unique score which is the total impact of the product. The weighting method takes the policy priorities and decision maker's opinions into account as the weighting factors are determined by all the stakeholders (government, political parties, environmental NGO's, consumer organization, the automotive sector, etc…).

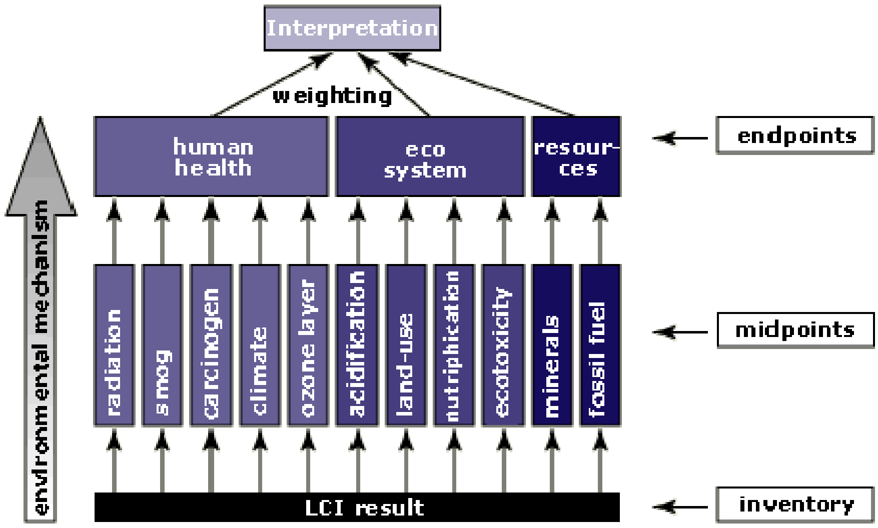

Figure 2: Life Cycle Impact Assessment **Source: [6]**

- **Interpretation of results**

The aim of the interpretation of results is the identification of the strong and weak points of the studied cases. The opportunities of environmental impact reduction will be identified and evaluated. It will be checked whether the goals set during the "goal and scope definition" are met.

I.2 Eco-Efficiency

The Eco-Efficiency analysis was developed in 1996 by BASF. It is a proprietary tool for analysing products and their production processes from an economical and the ecological perspective (see figure 3).

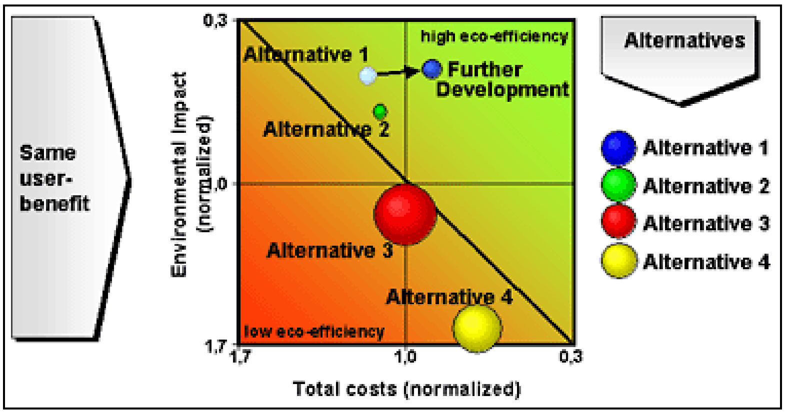

Figure 3: The Eco-Efficiency Portfolio **Source: [7]**

Economic and ecological data are plotted on an x/y graph (see figure 3). The costs are shown on the horizontal axis and the environmental impact is shown on the vertical axis. The graph reveals the eco-efficiency of a product or process compared to other products or processes.

The eco-efficiency is based on assessing environmental impacts, possible impacts on human health, and ecosystems and the costs of products and processes within given system boundaries. It includes the following working steps [7]:

- Life cycle analysis for all investigated products or processes according to the rules of ISO 14040
- Determination of impacts on human health and ecosystems
- Determination of risk potentials
- Calculation of total cost from a consumer point of view
- Normalisation and weighting of Life Cycle Analysis
- Determination of relation between ecology and economy.
- Analysis and interpretation of results.

The total environmental impact includes the following impact categories:

- Consumption of raw materials,
- Land use
- Consumption of energy
- Emissions into air, water and soil (waste)
- Toxicity potential of the used substances and released,
- Hazard potential for human beings and material

The eco-efficiency analysis has a weighting scheme made up of two factors:

-**Societal factors** give the contribution of the above categories, sub-categories and sub-sub-categories (see figure 4) to the total impact. Those factors are determined by a group of with some knowledge concerning to the current situation in the addressed community.

-**Normalisation** of the results with respect to a reference value (national, European or worldwide). The total environmental impact of the product system will be divided by the total environmental impact in western Europe (see equation 1).

$$\frac{Maximal.Environmental.impact.of.options}{Total.Environmental.impact.in.W-Europe} = \text{Relevance}_{\text{environment}} \qquad (1)$$

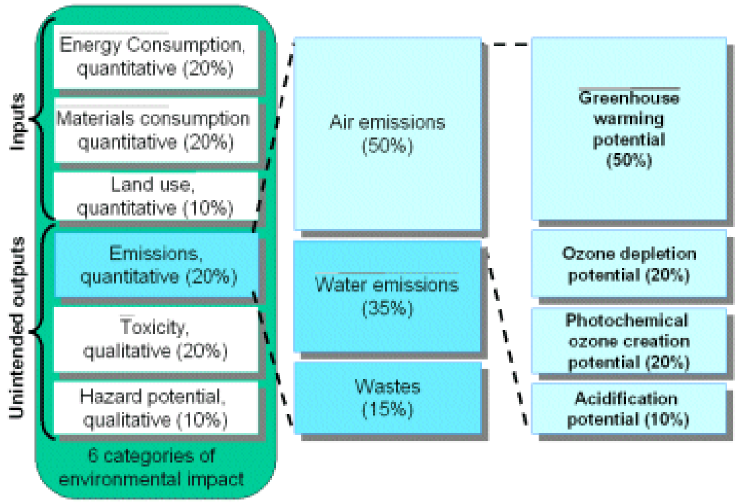

Figure 4: The Weighting system of the Eco-Efficiency analysis **Source: [7]**

In conjunction with the LCA, a Life Cycle Cost analysis has to be performed. The costs determination is performed through the following framework:
-Actual costs/prices of vehicles
-Estimation of costs for single operation units/processes by standard figures (e.g. transport, assembly)
-Prospective cost analysis (e.g. recycling)
-Prospective cost estimation on the basis of expert judgment (e.g. dismantling)

The economical weighting scheme is similar to the ecological one. The total cost of the product system will be divided by a reference value (see equation 2) e.g. the sales of the total manufacturing industry in western Europe.

$$\frac{Maximal.\cos t.of.options}{Sales.of.total.manufacturing.Industry.in.W-Europe} = \mathrm{Re}levance_{\cos ts} \qquad (2)$$

And finally, ecology and economy will be weighted by dividing the Relevance $_{Environment}$ by the Relevance $_{\cos ts}$:

$$\frac{\frac{Max.environ.impact}{total.environ.impact}}{\frac{Max.\cos t}{total.\cos t}} = \frac{\mathrm{Re}levance_{environment}}{\mathrm{Re}levance_{cocts}} = \frac{E}{C} \qquad (3)$$

A $\frac{E}{C}$ ratio higher than 1 indicates that the product system is causing a higher environmental impact than the average product system with respect to costs.

A $\frac{E}{C}$ ratio lower than 1 indicates that the product system creates a lower environmental impact with respect to costs. The cost indicator has a higher ‘weight’.

I.3 Ecoscore

The Ecoscore methodology is an environmental vehicle rating tool developed by a consortium of three partners:
- The Department of Electrotechnical Engineering and Energy Technology of the Vrije Universiteit Brussel
- The Flemish Institute of Technological Research (VITO)
- The Centre of Economical and Social Studies of the Environment (CESSE) of the Université Libre de Bruxelles.

This tool allows evaluating the environmental impact of road vehicles with different fuels and drive trains on a well-to-wheel basis, i.e. direct tailpipe (tank-to-wheel) and the indirect emissions (well-to-tank) due to the fuel production and distribution are taken into account. The vehicle assembly and its material production are not included because of a lack of coherent data. Neither are the maintenance phase and recycling phase of end of life vehicles. The Ecoscore methodology is a pragmatic assessment methodology for policy support and is built on a Life Cycle Assessment framework through a sequence of five steps [8]: inventory, classification, characterization, normalization and weighting (see the figures 5 and 6).

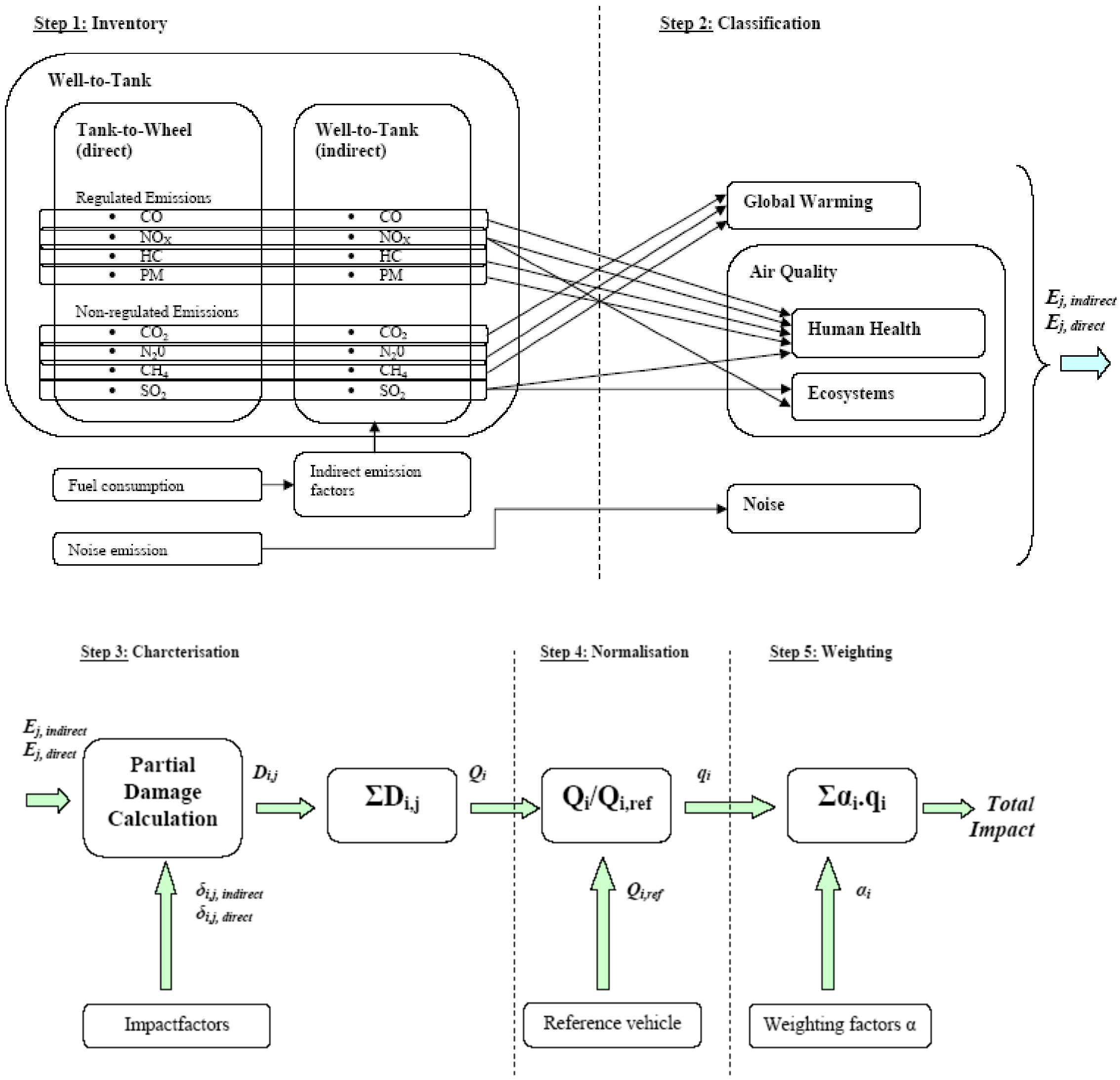

Figure 5 : Overview of the Ecoscore methododology **Source: [6]**

The emission values used in the Ecoscore methodology during the inventory phase are from different sources. Regulated emissions are CO, NOx, HC and PM. They are type approval'emissions collected by the Belgian federal ministry for mobility and transport. The vehicle database (Technicar) of the Belgian federation of the automotive industry, Febiac, was also used for this purpose. Besides the regulated emissions, unregulated emissions (CO_2, SO_2, N_2O, and CH_4) are considered as well. CO_2 and SO_2 emissions can be calculated on the basis of the vehicle fuel consumption and emission factors [2] developed by the Conservation of Clean Air and Water in Europe (CONCAWE). The N_2O emissions for vehicle complying with the different "euro emission standards" [2] come from the Cleaner Drive project estimations. For the older vehicles (pre-euro), no emissions data are available, so estimations of the emissions and of the fuel consumption were made based on the COPERT III methodology [8]. Direct CH_4 emissions values are the ones of the well-to wheel study of General Motors [8].

It is important to mention that the Ecoscore methodology can be used to rate two-wheelers, light and heavy duty vehicles.

The indirect emissions are calculated through a formula (see equation 4) [8] (in the case of light duty vehicles and Two-wheelers) using indirect emissions factors developed by the Methodologies for Estimating Air Pollutant Emissions for Transport [MEET] Project [8], VITO and Electrabel.

$$E_{i,j\ indirect} = \frac{1}{3{,}6.10^{11}} F_j\, \rho.EC.FC[g/km] \qquad (4)$$

Where:

F_j Indirect emissions factor for pollutant j, expressed in milligram per kilowatt hour

ρ Fuel density expressed in gram per litre

EC Energy content of the fuel, expressed in kilojoules per kilogram

FC Fuel consumption of the vehicle, expressed in litre per 100 kilometres (in case of light duty vehicles or two-wheelers)

The factor 1/3, 6.10^{11} in this formula is a conversion factor.

The Ecoscore methodology takes into account three main damage categories: global warming, air quality and noise. The air quality category is subdivided into human health effects and effects on ecosystem.

Different impact factors are defined to calculate the contribution of the emissions (both 0.direct and indirect) to the different damage categories in the **Characterization** step:

-The calculation of the contribution of greenhouses gases to global warming is based on the global warming potentials (GWP) as defined by the IPCC.

-The contribution of airborne emissions to the air quality depletion and their effects on human health and ecosystems are weighted on the basis of their external costs. The external cost factors used for the human health damage are based on the European Union ExternE project [8].

During the calculation of damage factors, the average mileage distribution (between urban and extra-urban) estimated by the Belgian National Institute of Statistics (NIS) is taken into account. The weight factors (see table 1) for each category are defined according to that mileage distribution

-The damage calculation for noise takes into account the sensitivity of human hearing. In that methodology, the noise level is decreased with 40 dB corresponding to a 'non-disturbing background sound level [8].

Table 1: Overview of mileage distribution fro different vehicles categories

Mileage distribution (δ)	urban	rural
Light duty	25%	75%
Heavy duty	10%	90%
Two-wheelers	40%	60%

Source: [8]

A reference car is used as a baseline and its associated damage was taken as a reference point It is a vehicle with the Euro IV emission limits for passenger cars and a vehicle with the Euro III EEV (Enhanced Environmental Vehicle) emissions limits for heavy duty vehicles. A vehicle complying with the directive 2002/51/EC emission limits is taken as a reference for two-wheelers. The reference vehicle corresponds to an Ecoscore of 70[2].

$$q_i = \frac{Q_i}{Q_{i,ref}} \qquad (5)$$

Where:

q_i normalised damage on category i

Q_i total damage of the assessed vehicle on category i

$Q_{i,ref}$ total damage of the reference vehicle on category i

In the end, the different normalised damage categories will be weighted and aggregated to obtain the total impact (see equation 6) of the vehicle. The weighting factors were determined by consensus between different stakeholders (Government, the automotive sector, environmental NGO's, consumer organizations and others).The list of the weighting factors is the following:

- Global Warming 50%
- Human Health 20%
- Ecosystems 20%
- Noise 10%.

$$TI = \sum_i \alpha_i . q_i \quad \text{with} \quad \sum_i \alpha_i = 1 \qquad (6)$$

Where:

TI total impact of the assessed vehicle

α_i weighting factor of damage category i

q_i normalised damage of category i.

The total impact of the vehicle will be the 'Ecoscore' of the vehicle defined on a 0 to 100 scale. This score definition was chosen to facilitate the communication towards a broad public. The transformation is based on an exponential function, so it can not deliver negative scores [2].The higher the Ecoscore is, the lower the environmental impact of the vehicle is.

I.4 ACEEE's green Book

The American Council for an Energy-Efficient Economy (ACEEE) is an independent, nonprofit research group dedicated to improving energy efficiency as a means of environmental protection and economic development [9].

The environmental rating methodology for ACEEE's green book is based on principles of life cycle assessment and environmental economics. It covers both the vehicle life cycle and the fuel cycle, using a mass-based characterization of vehicle manufacturing impacts. But only the use phase is well covered because of the data limitations encountered when attempting to develop vehicle model-specific assessments [9].

The ACEEE methodology includes different types of emissions from different sources. Tailpipe emissions (regulated and non-regulated), fuel supply cycle emissions and emissions embodied in the vehicle are taken into account.
As vehicle manufacturing emissions are not systematically available, the environmental impacts of the materials production and manufacturing phases are best estimated in proportion to vehicle mass (**0.056 g of CO_2-eq/mile per kg of vehicle**). This lack of data makes the manufacturing phase under-represented in the current methodology. The vehicles End-of-life is not included in the rating-system too.
For electric vehicles, the battery weight and replacement during all the vehicle lifetime are taken into account.

1.4.1 The calculation methodology

To calculate the life cycle impact of vehicles, and environmental damage index (EDX) is defined as a sum of damage functions (see equation 7), each based on attributes associated with the life cycle of the vehicle and its fuel [9]:

$$\text{EDX} = \Sigma_i \text{ Damage (Impact}_i) \quad (7)$$

Damage functions are monetized so that the EDX expresses an expected life-cycle environmental cost of the vehicle. The EDX index is defined on a 0 to infinity range and is not easily understandable for a non-expert. To facilitate communication and make it easier to compare vehicles, two indicators were derived from the EDX. One is a green score on a 'higher-is-better' scale of 0 to 100. The other is a set of class ranking symbols that compare vehicles within a given size class.
The definition of the green score is:

$$\text{Green score} = a \frac{e^{-EDX/c}}{(1 + EDX/c)^b} \quad (8)$$

With a = 100, b =3 and c = 5.76 cents/mile
The set of class ranking symbols is determined by some EDX cutpoints which are the class ranking upper limits.

Table 2: The ACEEE's set of class ranking symbols source: [9]

Percentile Guideline	Symbol	Appreciation
+ 95%	√	Superior
80%-95%	▲	Above average
35%-80%	○	Average
15%-35%	▼	Below average
0-15%	x	Inferior

I.5 EPA Green vehicle guide

The Environmental Protection Agency (EPA) is the US national office in charge of environmental science, research, education and assessments efforts.

The EPA Green vehicle guide uses emission levels and fuel economy values to determine the environmental scores for cars and trucks. Three pieces of information about a vehicle's environmental performance are presented:

- The air pollution score
- The greenhouse score
- The SmartWay or SmartWay Elite designation (if eligible).

The two (three for SmartWay certification eligible vehicles) scores give a complete picture of the relative environmental performance of the use phase of a vehicle. The air pollution and greenhouse scores are defined on a 0 to 10 range. They are added together to have the SmartWay score.

The air pollution score is based on the vehicle's officially certified exhaust emission standard as indicated on its US EPA certificate of conformity [10](See table 3).

Table 3: The EPA Air pollution score (ZEV= Zero Emission Vehicle, PZEV= Partial Zero Emission Vehicle, SULEV= Super Ultra Low Emission Vehicle, ULEV= Ultra Low Emission Vehicle)

US EPA Vehicle Information Program: Air Pollution Score		
Selected Emissions Standards	**Original Score**	**Updated Score**
Bin 1 and ZEV	10	10
PZEV	10	9.5
Bin 2 and SULEV II cars	10	9
Bin 3	9	8
Bin 4	9	7
Bin 5 and LEV II cars	8	6
Bin 6	8	5
Bin 7	7	4
Bin 8	7	3
Bin 9a and LEV I cars	6	2
Bin 9b	5	2
Bin 10a	4	1
Bin 10b and Tier 1 cars	3	1
Bin 11	2	0
Tier 1 diesel cars	1	0
Tier 1 large trucks	0	0

Source: [10]

The estimations of fuel economy provide the EPA with miles-per-gallon city and highway values for each car and light truck (see table 4).The greenhouse gas score is based on the combined adjusted fuel economy label value determined according to the code of the federal regulations and is assigned according to the table below. The lower the fuel economy, the more carbon dioxide is emitted as a by-product of combustion. The amount of fuel burned varies by fuel type, since each type of fuel contains a different amount of carbon per gallon.

Table 4: The EPA Greenhouse Gas score (MPG= Miles-per-Gallon, lb/mi= Pound-per mile)

Score	CO2 Emission (lb/mi)	Gasoline (MPG)	Diesel (MPG)	E85 (MPG)	LPG (MPG)	CNG (MPG)
10	Less than 0.45	44	50	31	28	33
9	0.45 to < 0.55	36	41	26	23	27
8	0.55 to < 0.65	30	35	22	20	23
7	0.65 to < 0.75	26	30	19	17	20
6	0.75 to < 0.85	23	27	17	15	18
5	0.85 to < 0.95	21	24	15	14	16
4	0.95 to < 1.05	19	22	14	13	14
3	1.05 to < 1.15	17	20	13	12	13
2	1.15 to < 1.25	16	18	12	11	12
1	1.25 to < 1.35	15	17	11	10	11
0	1.35 and more	14	16	10	9	10

Source: [10]

-SmartWay and SmartWay Elite

SmartWay is earned by those vehicles that score 6 or better on both air pollution and greenhouse gas score and achieve a combined score of at least 13 when added together.

I.6 The Cleaner Drive

The Cleaner Drive environmental rating system was developed by a European consortium of 17 partners coordinated by the 'Energy Saving Trust' of the United Kingdom. The project was financed by the European Commission. The tool considers tailpipe emissions and indirect emissions, and combines them to give each car a single environmental score defined on a 0 to 100 scale [11]. The higher this score is, the cleaner the car is.

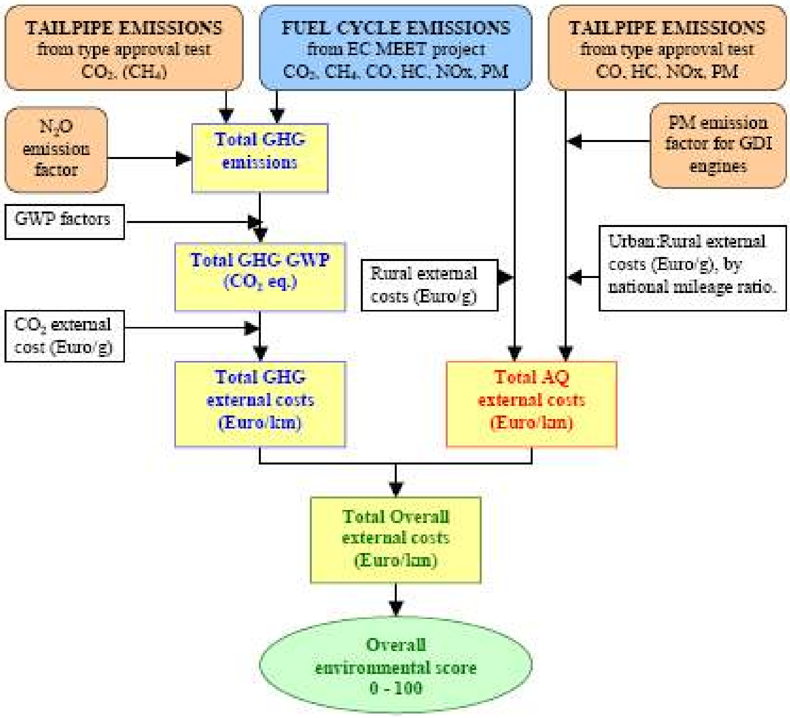

Figure 6 Overview of the cleaner methodology **Source: [12]**

The Cleaner-Drive rating system covers the following vehicle fuels and technologies:

- Hydrogen, Natural Gas, LPG and Bio fuels
- Electric and Hybrid Electric Vehicles
- Clean gasoline and Diesel Technologies

The Cleaner Drive considers greenhouse gas emissions and ‘air quality’ emissions and their contribution to three damage categories: greenhouse gases for global warming and ‘air quality’ emissions for human health and ecosystems quality. The Cleaner Drive uses the global warming potentials established by the IPCC.

The emissions weighting system is based on ‘external cost’ expressed on monetary terms (€/kg).It reflects the overall damage to the environment and to human health caused by emissions.

Tailpipe emissions are based on European type approval emissions (CO, HC, NOx and diesel PM emissions). The fuel cycle emissions expressed in grams per gigajoule (g/GJ), include emissions produced from feedstock production to fuel distribution. The rating system considers fuel cycle emissions of CO_2, NO_x, CH_4, NMHC, SO_2 and PM. Those data are collected from the European Commission MEET project [11].

I.7 The CAIR Environmental Rating system

The Centre for Automotive Industry Research (CAIR) is an academic center (University of Cardiff, UK) dedicated to the study of the economic and strategic aspects of the world motor industry. In 1998, CAIR proposed a Vehicle rating system which had to meet the following criteria:

- It must be based on sound environmental principles

- It must be based on easily available data
- That data must have an 'official' status
- It must have a clear methodology that results in a simple numerical score
- It must allow 'good' performance to be identified
- It must be applicable to cars on the market now [13].

The approach is based on two elements: performance and footprint.
The footprint is defined as the product of the length, the width and the weight of the car. That footprint is adjusted by a durability factor. Vehicle durability is measured by the median life of the model produced by a manufacturer. 'The median (following the approach used in Sweden) is the period of time that passes from the first registration of the population of vehicles to the point where 50% of them have been removed from circulation' [13]. The durability factor is obtained (in percentage) by making the difference between the real age of the vehicle and its medium life and dividing it by the latter. The footprint will be reduced or increased by that factor (in percentage) depending on whether the car lasted longer or shorter than the average. The footprint could be used to classify cars within a given size segment.
The performance is defined as the "better than standard" proportion of the car emissions. "So, if a car has CO emissions which are only 25% of those allowed under regulations, the 'better than standard' proportion would be 75%" [3]. The car emissions are those measured in the official test cycle. An average 'better than standard' is then calculated across all variables to give a single score. The performance is then calculated by dividing the CO_2 emissions of the car by the average 'better than standard' proportion. The final rate is obtained by multiplying the performance figure by the footprint figure.

Table 5: CAIR evaluation of the Volvo S70 **Source: [13]**

Model	CO (g/km)	HC+NOx (g/km)	CO_2 (g/km)	PM (g/km)	Length (m)	Width (m)	Weight (t)
Euro 4	1.81	0.23		/			
Volvo S70 2.0	0.78	0.22	206	0	4.66	1.76	1.37

Model	Performance	Footprint	Rating
Volvo S70 2.0	3.83	11.24	43.05

I.8 ETA Car Buyer's Guide

Founded in United Kingdom in 1990, the Environmental Transport Association (ETA) aims to raise awareness of the impact of excessive car use and help individuals and organizations to make positive changes in their travel habits [14].
The ETA environmental rating system relies on answers provided by car manufacturers i.e. the data applies to new cars only. Dangerous substances used during the production phase e.g. asbestos and recyclability are taken into account. It has the advantage of ranking the best cars in each category and has the added value of providing an

environmental ranking for each car category. The classification system used is the same as for EuroNCAP [15]. The points are relative, not absolute. The ETA system is based on a statistical combination of five factors (see the table 6): power (engine capacity), carbon dioxide emissions, fuel consumption (urban cold cycle), noise and safety (impact on pedestrians) [14].
The point scoring system excludes the Yes/no categories and the type approval based emissions data [14]

Table 6: ETA evaluation of the Volvo 850 **Source: [13]**

ETA Environmental Rating VOLVO 850	
Category	
Make	Volvo
Model	850
Type	GLT/SE
Transmission	M5
Fuel	Petrol
Cylinder containt	2400
Power kW	103
Consumption(l/100 km)	
urban	12.6
90 km/h	6.6
Top speed km/h	200
Noise dB(A)/50 km/h	12
Emissions	
soot	0
CO (g/km)	0.75
HC (g/km)	0.23
NOx (g/km)	0.1
HC+NOx (g/km)	0.33
Asbestos free?	
Cadmium free?	
Plastic parts labelled?	
Dismantling manual available?	
Points	43
Stars	**

-The star rating system has a maximum of 5 stars and a minimum of no stars, as follows:
The best 10%: 5*
The next best 10%: 4*
21%-50%: 3*
51%-80%: 2*
The next worst 10%: 1*
The worst 10%: no stars

I.9 The VCD's list of environmentally friendly vehicles

The Verkehrsclub Deutschland (VCD) is an association for sustainable mobility and a major German environmental organisation. They offer information for the public on sustainable means of transportation [16].
Like the ETA system, VCD's list of environmentally friendly vehicles relies on answers provided by manufacturers or importers. The drawback of the VCD system is the attribution of a 0 score to not-answered questions and which leads sometimes to some strange results. It has a point scoring system. The following parameters are scored (with ratings for Volvo 850):
The technical score starts with 100 basic points, to which are added or subtracted points from categories listed in the table 7. An environmental interest score, rated out of 50 (see below) is added to the technical score to provide an overall rating with a maximum of 335.

Table 7: VCD Environmental Rating of Volvo 850 **Source: [13]**

VCD Environmental Rating VOLVO 850		
Category		
Model		850 2.0-10V
Body type		L/K (Salon/estate)
Price		46,400 DM
Kerb weight		1370
Power(kW/PS)		93/126
Cylinder containt		1984
Top speed		195
Fuel type		S(Euro 95)
Fuel consumption(l/100km)		
	town	11.9
	mixed	8.9
CO_2 equivalent (g/km)		276
Noise (dB(A))		73
CO (g/km)		0.81
HC+NOx (g/km)		0.32
Particualtes(g/km)		0
Technical score		30
Environmental interest		0
Total points		30

The VCD also includes a manufacturing score, which takes into account the following categories: "paint sludge processing, water-based paint, high solid content paint, catalyst recycling, CFC-free production processes, formaldehyde-free production, closed loop water system, suppliers supply more than 50% by rail or water, supply to dealers more than 50% by rail or water, avoidance/replacement of combined materials, use of renewable raw materials, fewer plastic variants than a year ago, use of plastics compared with 1 year ago, dealer training in environmental protection, cold start technology built into all/some models, heated lambda-sensor standard, alternative fuel versions (AFVs) available, same environmental standards in non-EU and in EU plants, environmental report published, EMAS in some plants, information policy, fuel consumption according to new EU standards available, emission values supplied on request, supportive of legal reduction of benzene to 1%" [13].

I.10 Ecotest

The Ecotest tool was jointly developed by the FIA foundation and ADAC. The FIA foundation has been established in the United Kingdom as an NGO with a donation of $300 million made by the Fédération Internationale de l'Automobile (FIA), the non-profit federation of motoring organisations and the governing body of world motor sport [17]. It manages and supports activities promoting car safety, environmental protection and sustainable mobility. ADAC automotive is an automotive equipment supplier dedicated to the production of door handles and components, cowl vent grilles, exterior trim, and marker lighting for worldwide automakers [18].Its headquarters are located in Grand Rapid, Michigan (USA).

Ecotest is an environmental vehicle rating tool which can assess cars with different drive-trains. It takes into account pollutant emissions (HC, CO, NO_x and PM), CO_2 emissions and fuel consumption (see figure 8). The CO_2 is measured per vehicle class and takes into account the influence of mobile air conditioner and the driving behavior. But the measurement of pollutant emissions is independent of vehicle class. Ecotest uses the new European Driving Cycles as well as its own measurement procedures to cover the aspects not included in the NEDC.

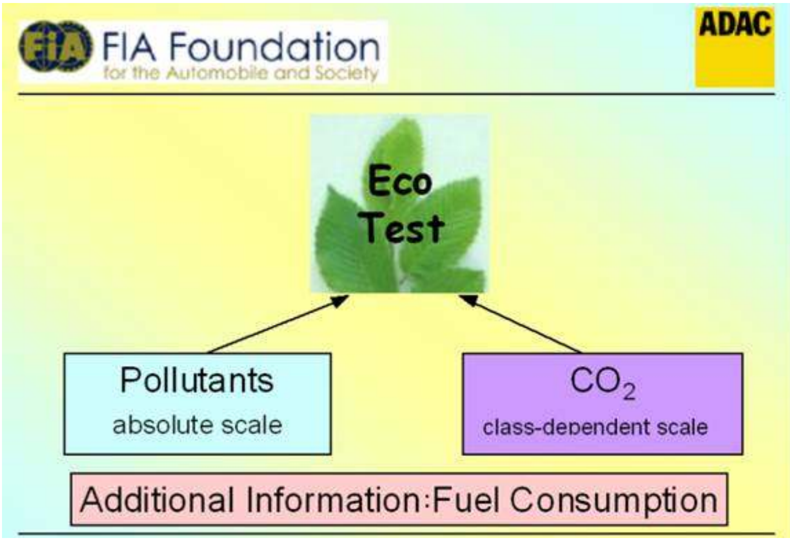

Figure 7: Influencing parameters of Ecotest **Source: [19]**

The Ecotest has a star scoring system defined by 1 to 5 stars range. The more stars a vehicle wins, the lower its environmental impact (see figure 9).

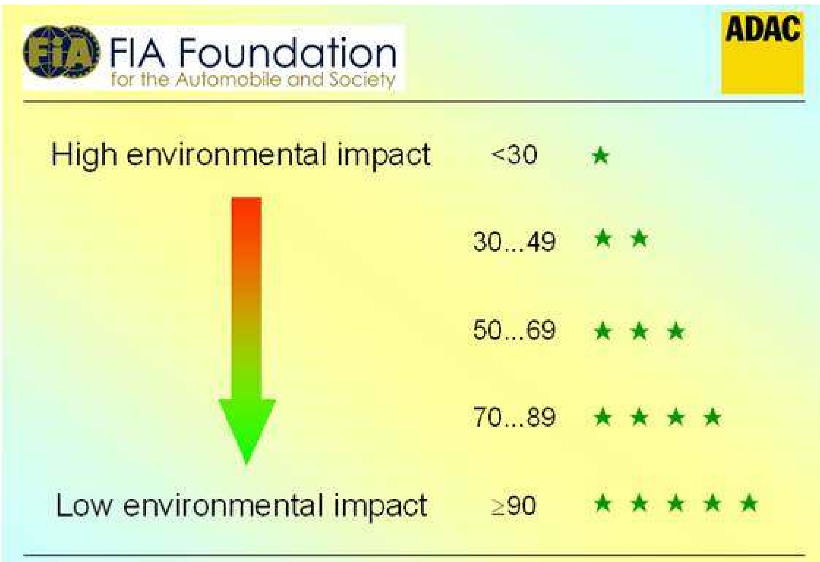

Figure 8: The Ecotest rating **Source: [19]**

The outcomes of Ecotest are individuals and are based on the measurements. The web based version of the tool gives a detailed assessment (see table 8) of the vehicles including the model, the engine type, the cylinder capacity and the fuel consumption.

Vehicle class	Model	Testdate	Emission standard	Engine	kW	ccm	l/100km	active	Grade pollution	Grade CO2	Rating EcoTest	EcoTest stars	
4	Toyota Prius 1.5 Hybrid Executive	17.02.2004	Euro4	Hybrid	82	1497	5,02	No	50	39	89	★★★★☆	Details

Table 8: The display form of the Ecostest outcomes Source: [19]

I.11 Others

The Swedish **Rototest** ranking system is the narrowest one. It is focused only on exhaust emissions. The scoring system is an Environmental Pollution Index (EPI). The EPI measures emissions of HC, CO, NOx and VOC. The lower the EPI, the better. The specificity of the Rototest system is that the measurement conditions are closer to the real vehicle use. Rototest is an independent exhaust emission laboratory established in 1988.

The **Auto Motor und Sport** (AMS) is a german independent, committed and critical magazine. It has introduced environmental categories to its comparative road test. The considered categories are the following: fuel consumption, CO_2 emissions, toxic emissions, footprint, noise and dismantling/recycling. The score calculation rules are not provided to the reader. The score is rated out of 100. According to the European Green Purchasing Network, this scoring cannot be considered as a rating scheme since only a limited amount of vehicles are compared.

II. Comparative assessment of vehicles Eco-rating systems

To compare the existing tools mentioned above, we have used the European Green Purchasing Network methodology [2]. The comparison takes into account the life cycle phases that are assessed by the Eco-rating systems.

	Fuel life cycle		**Vehicle life cycle**		
	Production Phase	**Use phase**	**Production Phase**	**Use phase**	**End-of-life Phase**
Eco-efficiency	x	x	x	x	x
Ecoscore	x	x			
ACEEE	x	x	x	x	
EPA		x		x	

Cleaner Drive	x	x		x	
CAIR		x		x	
ETA		x	x	x	x
VCD		x	x	x	x
Ecotest		x		x	

Table 9: Life Cycle phase addressed

Table 10: In use phase, pollutants addressed

	Regulated Emissions	Unregulated emissions	Fuel consumption	Noise
Eco-efficiency	x	x	x	
Ecoscore	x	x	x	x
ACEEE	x	x	x	
EPA	x	CO_2 only	x	
Cleaner Drive	x	x	x	
CAIR	x	CO_2 only	x	
ETA	x	x	x	x
VCD	x	x	x	x
Ecotest	x	CO_2 only	x	

Table 11: In End-of-life, items addressed

	Reduce Waste	Recyclability	Actual Recycling
Eco-efficiency			x
Ecoscore			
ACEEE			
EPA			
Cleaner Drive			
CAIR			
ETA	x	x	x
VCD	x	x	x
Ecotest			

Table 12: Weighted scoring system

	Yes	No
Eco-efficiency	x	
Ecoscore	x	
ACEEE	x	
EPA	x	
Cleaner Drive	x	

CAIR	x	
ETA	x	
VCD	x	
Ecotest	x	

III. Overview of vehicle LCA's

Nowadays, the interest of customers and policy makers towards green cars is growing. But the evaluation and the quantification of the environmental impact of a vehicle is not always easy to undertake: to assess a product system, one needs to know all the operations and processes included in its boundaries. A repeatable methodology (to allow comparison) and dedicated calculation tools are also necessary to conduct such kind of assessments. In all the vehicle environmental assessment tools mentioned above, only LCA reaches those requirements. Several types of vehicle LCA have been performed in the LCA scientist community. They can be classified into four main categories:

- LCA of a specific car
- LCA of an average vehicle
- Comparative LCA of different vehicle fuels and technologies
- LCA look of a future implementation of scenario

III.1 LCA of a specific car

Most of the time, specific cars LCAs are performed by manufacturers. Such a study requires detailed data which are most of time confidential. The outcomes are used for several purposes:

- Vehicle environmental certification
- Improvement of the ecological quality of vehicles
- Green marketing.

The LCA performed by Daimler Chrysler for the environmental certification of the Mercedes-Benz S-Class [20] is a good example. It compares the S-350 new model with the previous one (see the table below). The comparison basis is a driven distance of 300,000 km. The assessment includes manufacturing, use and end-of-life. The Gabi 4.0 database and Daimler Chrysler's own database were used. The life cycle modeling is made with the Daimler Chrysler Design for Environment software (DC DfE-Tool).
The main results of that LCA are the following:

- The Global Warming Potential of the new S-Class vehicle was reduced by 6%
- The acidification Potential was reduced by 2%
- The eutrophication potential by 13%

- The photochemical ozone creation potential by 9%

Table 13: Comparison of the new and the previous models of the Mercedes Class S

Parameter	S 350 new model	S 350 previous model	Unit
Power	200	180	kW
Fuel consumption NEDC	10.1	11.1	l/100km
Carbon dioxide	242	266	g/km
Carbon monoxide	0.21	0.185	g/km
Hydrocarbons	0.026	0.05	g/km
Nitrogen oxides	0.011	0.046	g/km

Source:20

The contribution of the life cycle phases of the new S-Class in selected pollution parameters are shown in the figure below.

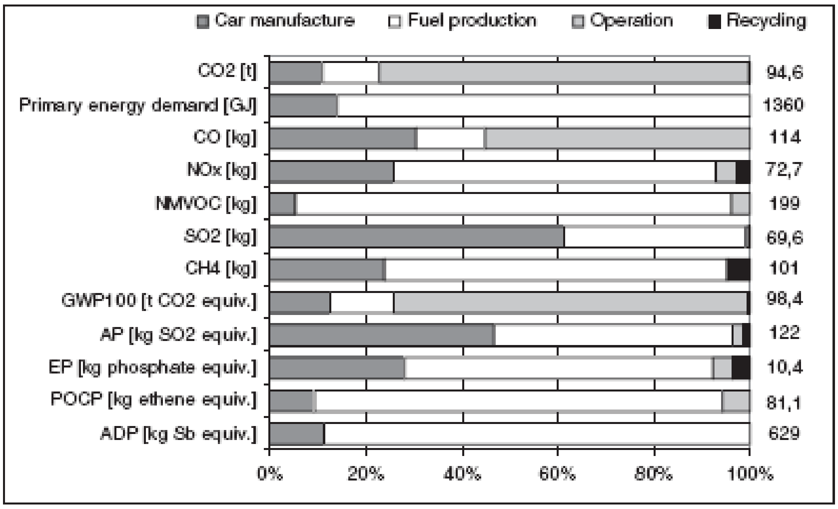

Figure 9: Share of life cycle stages in selected parameters of the new Mercedes S-Class
Source: [20]

III.2 LCA of an average vehicle

LCA of an average vehicle is generally sponsored by decision makers. The main objective is decision-making support. An average vehicle LCA gives an overview of the environmental impact of the average vehicle on a regional, national or community level. The assessed vehicle is a theoretical one. The used data are estimated or come from some databases (governments, customer's and professional associations, European Commission, independent laboratories or working groups…). Those studies provide the decision maker (policy makers, fleet managers) with the technical informations and recommendations which can improve the ecological quality of a fleet.
Since the last few years, several national and community LCAs of an average vehicles have been performed in the world e.g. the Life Cycle Impact Assessment of the Average

Passenger Vehicle in the Netherlands [21] performed by the Delft University of technology. An average vehicle with an empty eight of 900 kg was considered. A driven distance of 200,000 km and an average fuel consumption of 11.5 km/l were used as references. The fuel used in this study is the unleaded gasoline. The product system includes materials and fuel production, transport, vehicle manufacturing, the use of the vehicle, maintenance, and end-of-Life.
The Simapro software version 4 and the Idemat 2000 database were used. The main results of the study are the following:
- the largest environmental impact occurs in the use phase- over 90%-
- the use of the fossil fuels is the dominant impact, even for the production phase
- NOx emissions are one of the smallest emissions to air in quantity but are responsible for 36% of the impact of the life cycle
- CO_2 is the largest emission to air but caused only 6% of the environmental impact.

III.3 Comparative LCA of different vehicle fuels and technologies

LCA is an archetypal tool of comparison. The outcomes of a comparative LCA are more comprehensible than the ones of an absolute LCA. They are referred to each other (in percent) or expressed on the same scoring scale. Comparative LCA is the most appropriate one for decision making support both for governments as for industrial companies. It allows quantifying the ecological benefit of a policy measure or a product improvement.
The Camden LCA [11] performed by Ecolane Transport Consultancy compares different vehicle fuels and technologies in a Londoner context. The study includes petrol, diesel, bioethanol, biodiesel, natural gas, liquefied petroleum gas, battery electric and hybrid electric vehicles. It was focused on passenger cars and light duty vans, including car derived vans. The impact associated with the fuel production, the vehicle manufacturing, the use of the vehicle and the end-of-life were considered. A driven distance of 225,000 km is used as a comparison basis and a normalized weight of 1000 kg is given to all the vehicles. The vehicles are classified per category according to the International Federation of Automotive Engineering Societies (FISITA) classification. The Cleaner drive rating methodology was used to calculate the life cycle impacts of the vehicles. The main conclusions of the Camden LCA are the following:
-Vehicle size is as important a determinator of emissions impact as the fuel or the technology type
-Moving down one passenger car category reduces the life cycle impact by 12%-16%
-CNG and LPG are 18%-19% below the baseline (Conventional gasoline car)
-100% Biodiesel vehicles are 11%-24% below the baseline
-100% Bioethanol, battery electric using average mix electricity and petrol-hybrids vehicles are 23%-26% below the baseline.
-The battery electric vehicle with renewable energy for electricity is 70% below the baseline. It is the cleanest one.
-The vehicle manufacturing and fuel production are responsible for 20% of the total lifetime greenhouse gas emissions.

III.4 An LCA look to the future implementation of a scenario

LCA is also a prediction tool. It allows assessing and quantifying the potential impact of future developments (environmental law implementation, product improvement, recycling technologies development…). Such an LCA is more focused on one life cycle phase or on some specific parameters. Ecobalance UK has performed such an LCA entitled 'A life Cycle Assessment of the Implications of Implementing the Proposed End of life vehicles Directive in the United Kingdom' [21]. Three systems were assessed:
-The situation of End-of-Life vehicle recycling in 2000 in the UK (75%)
-The implementation of the objectives of the Automotive Consortium on Recycling and Disposal (ACORD) in UK (82% of reuse/recycling, 18%d of energy recovery)
-The implementation of the objectives of End-of-Life vehicles directive (85% of reuse or recycling, 10% of energy recovery and less than 5% of land filling)
The three systems were compared on the following basis: treating the total yearly amount of End-of-life vehicles in the United Kingdom. An End-of life vehicle of 1043 kg is taken as a reference and all of the outcomes will refer to it.
The LCA was modeled with the Team software .The main conclusions of the study are the following:

- The increase of the recycling rate and the energy recovery rate of End-of-Life vehicles improves the environmental balance of their eliminations.
- The scenario of the end-of-life Vehicles directive has the best environmental balance. However, the difference between the European scenario and the ACORD one is not significant.
- The impact of the End-of-life phase is little in comparison to the impact of a vehicle life cycle.
- The European scenario and the ACORD one will generate significant improvements of the environmental balance of End-of-Life vehicles treatment in comparison with the 2000 situation.

Conclusion

In this report, we notice that several environmental vehicle assessment tools exist. Some of them are focused only on the use phase while others try to take into account the whole life cycle of vehicles. Among all the studied methodologies, life cycle assessment is the most complete and the most adapted one. However, the tool still needs to be developed through the clever project. It allows assessing a product system from "Cradle-to-Grave". It also allows avoiding pollution transfer from one life cycle phase to another.
The ISO 14040 series make LCA more reliable by providing it with a clear and detailed framework.
Even though LCA is the most developed tool, LCA practitioners are facing some problems in the field of environmental vehicle assessment:
How to classify vehicles per category or market segment in order to compare vehicles which really provide the same service? How to define a functional unit which reflects the reality? How and where to get high quality inventory data?
These are some questions that will need to be clarified all along the CLEVER project.

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Clean Vehicle Research: LCA and Policy Measures
(CLEVER)

(Report of task 1.3)

Overview of policy measures

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

CLEVER (Clean Vehicle Research) is a research project sponsored by the Belgian Science Policy which aims at promoting the purchase and use of clean vehicles in a Belgian context. In this project, an overall assessment will be carried out on the basis of the results of several assessments:

- A life cycle assessment will allow quantifying the environmental impacts of different vehicles types from cradle-to-grave
- A life cycle cost assessment will determine the cost per kilometre for the life cycle of the car and will include the purchase price, estimated salvage value, fuel costs, insurance costs, costs of technical control, maintenance costs, battery costs and taxes.
- The social barriers and the fleet analysis will reveal the obstacles confronting new vehicle technologies and limiting the purchase and/or use of clean vehicles.
- The influence of fiscal and other policy measures will be assessed in order to investigate possible policies towards a more sustainable car choice.

In order to assess possible policy measures to promote a more sustainable car choice it is important to gain insight in possible measures and their impact. This report has the objective to give an overview of relevant policy measures implemented in different countries. Important in the analysis of the different policy measures or instruments is which definition of ‘cleaner vehicles’ is used and what the impact of the instrument is on the purchase or use of cleaner vehicles. The analysis is based on reviewing literature and other resources, a first start was the literature review on policy measures undertaken in the ecoscore-project on behalf of the Flemish Government (Govaerts et al., 2005).

The analysis will be used in the next tasks in CLEVER for the development of policy strategies in Belgium for the promotion of cleaner vehicles. The policy strategies that will be developed will be discussed by different stakeholders and will lead to policy recommendations.

2. Policy measures

The objective of this report is to investigate the effectiveness of various measures for the promotion of cleaner vehicles. In the IEA project 'deployment strategies for hybrid, electric and alternative fuel vehicles' (IEA, 2002) an overview, presented in Figure 1, of possible policy measures is given depending on the market stage of a certain technology and indicating which market stakeholders are involved in the different deployment strategies.

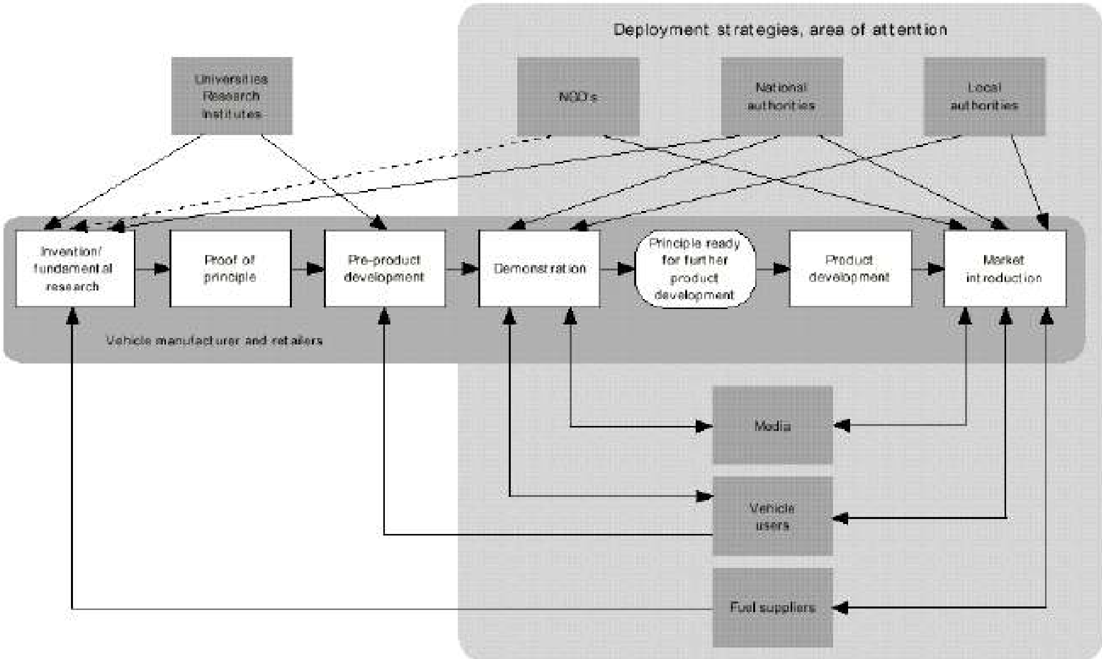


Figure 1. Stages in cleaner vehicle product development in relation to deployment strategies and stakeholders involved.

The CLEVER project focuses on the last stage of the product development chain, namely creating mass market introduction of cleaner vehicles starting from a technology neutral approach on cleaner vehicles. The policy measures included in the assessment are directed at ready-to-market technologies. This implies that the assessment won't deal with the effectiveness of measures to support the technology development like R&D support, pre-product development or demonstration activities.

An exhaustive list of supporting measures in the stage of market introduction based on IEA (2002), is given in Table 1. Policy measures that are not included in the CLEVER assessment are indicated in grey.

Table 1. List of supporting measures in the stage of market introduction of clean vehicles (IEA, 2002).

Command and Control Instruments
□ **Standards**
□ **Emission-regulations**
□ **Licensing**
inclusion of environmental criteria in licensing procedures
□ **Quality Contracts**
inclusion of environmental criteria in contracts for procurement of public services and public vehicles, etc.
□ **Mandates**
- *for procurement of clean vehicles*
- *for selling of clean vehicles*
□ **Exemptions from certain restrictive regulations**
- *access to restricted zones, bus lanes, etc.*
- *exemptions from parking and driving restrictions*
Economic Instruments
□ **Direct investment**
- *in research and development*
- *in infrastructure*
- *in demonstration-projects*
□ **Pricing policies**
- *road pricing*
- *parking fees*
- *internalisation of external cost of transport*
□ **Subsidies**
- *for vehicle purchase and conversion*
- *for infrastructure construction and operation*
□ **Tax incentives**
□ **Financing schemes**
Procurement Instruments
□ **Green procurement**
□ **Leadership by example**
□ **Common procurement**
Collaborative Instruments
□ **Network-management and co-ordination**
□ **Certification and labels**
□ **Voluntary agreements**
□ **Public-private partnerships**
□ **Private-private partnerships**
Communication and Diffusion Instruments
□ **External information**
□ **Marketing**
□ **Vehicle buyers' guides and vehicle labelling**
□ **Internal information**
□ **Education and training measures**
□ **Persuasion and lobbying activities**

The classification of measures used in CLEVER is similar and based on the classification used in the ecoscore project (Govaerts, 2005), as presented in Table 2.

Table 2. CLEVER classification of policy measures for the promotion of cleaner vehicles

Pricing instruments		
	Fiscal measures	
		Car taxation
		Company car taxes
		Income tax reduction
	Road pricing	
		Distance and/or time based pricing
		Cordon based charges
	Subsidies	
Mandates		
	Public fleets	
	Private fleets	
	Car industry	
Collaborative instruments		
	Voluntary agreements	
		Public fleets
		Private fleets
		Car industry
	User (dis)advantages	
		Restricted areas
		Variable parking fees

A last remark to be made is that this report is focussed on the analysis of vehicle related instruments and not fuel related policy instruments, like fuel taxation or subsidies for refuelling infrastructure. The latter instruments are meant to promote the use of specific fuels and not directed to the promotion of cleaner vehicles in general.

3. Car taxation

Car taxation can be divided into 3 types: acquisition taxes paid with the purchase or registration of a car ; ownership taxes which are paid annually like circulation taxes and taxes related to the use of a car, namely fuel taxes (excise duties) and road taxes. The analysis of this chapter deals with the first two types of taxes.

Transport related taxes are significant in the total of fiscal income in Belgium.

The graph below presents the share of environmental taxes in the GDP of the EU member states divided into 3 categories. In Belgium the fiscal income of vehicle taxation (registration and circulation tax) amounts to 0.7% of the GDP as presented in Figure 2, which is 1.5% of total fiscal income. This amount excludes fuel taxes as they are included in the energy related environmental taxes and also income of road pricing which is not a direct tax income. In the EU there is a trend for reducing the income of car taxes (especially registration taxes) in favour of road pricing income (EUROSTAT, 2007). Transport fuel taxes represent another 3% of total tax income in Belgium (EC, 2005a).

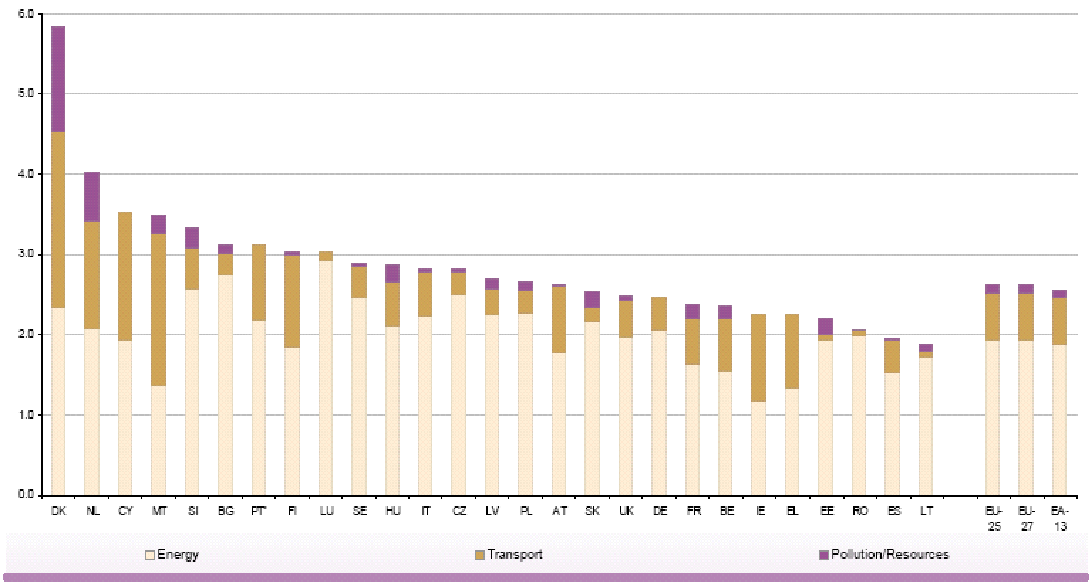


Figure 2. Share of environmental and transport taxes as % of GDP (2005) for EU-27

Table 3. Overview of car taxation systems in the EU (EC, 2005a)

Member State	Registration taxes	Approximate amount of registration taxes and charges (EUR)	Annual circulation taxes and charges	Approximate amounts, annually (EUR)
Belgium	Registration tax (on the first registration) Tax base is cc	Range from 61,5 to 4,957	Road tax (based on engine rating) varies according to fluctuations in the retail price index. A supplementary tax on cars, estate cars and minibuses diesel	Range from 57 to 1,458
Germany	None		Road tax base on cc, weight and EU emission standards (private cars)	
Denmark	Registration tax. Tax base is price incl. VAT. Advantages for save and eco-friendly cars	Rate is differentiated with price, 105% up to DKK 62,700 and 180% of remainder	Green owner's tax, weight tax and equalisation tax	
Spain	Registration tax. Tax base is price excl. VAT	Rate is differentiated with cc and diesel or gasoline. Range from 7 to 12 %.Rates can be increased up to 10% by Regional Government	Road tax based on engine rating	Established by local government
Greece	Registration tax. Tax base is the higher between ex-factory value of the vehicle+ freight+insurance or paid price	Rates take into account engine capacity and anti-pollutant technology	Circulation tax levies on a half-yearly basis	Between 38 and 483 € depending of the engine capacity and FH
France	None		Different taxes settled annually : -Graduated tax on motor vehicles (vignette), on company cars and certain commercial vehicles -Tax on company cars	Rates depending of the engine capacity, the age and the district in which it is registered
Italy	Registration tax. Fixed amount that can be increased by each Province up to 20%	150.81 (180.97)	Ownership tax calculated on the basis of Kw	Rates can be differentiated depending on the Regions
Ireland	Registration tax. Tax base is price incl. VAT	Rates depending on the cc between 22,5 and 30%	Ownership tax calculated on the basis of cc	From 151 to 1343 € per year
Luxembourg			Ownership tax calculated on the basis of cc	From 18.59 to 337.14 € per year
Netherlands	Registration tax. Tax base is price excl. VAT	Rate is differentiated between petrol(45,2%) /diesel(45,2%)	Road tax based on the dead-weight, type of fuel used and the region	Rates can be differentiated depending on the Regions
Austria	Registration tax. Tax base is price excl. VAT. Bonus-malus system for particle emissions	Rate is differentiated with fuel consumption. Maximum 16%	Vehicle tax based on the horse powers	Rates in function of the Kw.
Portugal	Registration tax. Tax base is cm3		Municipal car tax based on the cc and the age of the vehicle	

Finland	Registration tax. Tax base is price excl. VAT.	28%	Basic tax Power tax	Cars registered before 1/1/94-26 cents/day After 1/1/94-35cents/day 24.45/a for every 100kg
Sweden	None		Annual road tax based on the weight and the fuel used	
United Kingdom	None		Road tax based on engine size (existing cars) and on CO_2 emissions and fuel type (new cars)	
Czech Republic	None		Road tax but only for passenger cars used for commercial purposes. Various reductions for meeting EURO emission limits etc Technical and emission inspections	From1200 to 50400 CZK 13-26 (determined by petrol or diesel driven)
Hungary	Consumption tax (RT) - based on engine size and catalytic converter or not. Wealth tax, based on size of engine	10% -20% of purchase price of car. Differentiated petrol and diesel cars 15HUF/cm3 <1890cm3 20 HUF/cm3 >1890cm3	Environmental examination depending on fuel type and engine size Motor vehicle tax based on weight, paid annually	14-33 8000HUF
Latvia	Motor vehicle tax based on vehicle's age at time of acquisition	373 for new vehicle 223 for 2 year old vehicle	Road traffic tax based on weight	18 – 107
Malta	Registration tax (1st registration)	Vary from 50,5% of car value if <1300cc, up to 75% if>2000 cc	Road tax paid annually	Rate depends of the engine capacity
Slovakia	None		Road tax (only payable on passenger cars used for commercial purposes based on engine size)	From 1700 to 5900 Sk
Slovenia	Registration tax (1st registration)	1% -13% purchase price	None	
Cyprus	Registration tax on new vehicles based on cc, type of vehicles and with a CO_2 emissions adjustment	Rates ranging from 0.51 CYP per cc for cars <1450 cc up to 8.01 CYP for cars >2650 cc. -15% for cars emitting <150 g CO_2 Km, but +10% for cars >2250 emitting >275g CO_2 Km	Road tax based on cc and with a CO_2 emissions adjustment	Tax rate depends on the engine capacity
Estonia	None		None	
Lithuania	None		None	
Poland	Registration tax based on the value/price and the years of the vehicle	Tax rate between 3.1 and 65%	None	

An overview of CO_2-based taxes at the beginning of 2007 is given in Table 4.

Table 4. Overview of CO2-related taxes in the EU status January 2007 (ACEA, 2007)

COUNTRY	CO2/FUEL CONSUMPTION TAXES
AUSTRIA	A **fuel consumption tax** (Normverbrauchsabsage or NoVa) is levied upon the first registration of a passenger car. It is calculated as follows: - Petrol cars: 2% of the purchase price x (fuel consumption in litres – 3 litres) - Diesel cars: 2% of the purchase price x (fuel consumption in litres – 2 litres)
BELGIUM	1. **Tax incentives** are granted to private persons purchasing a car that emits less than 115g CO2 /km. The incentives consist of a reduction of the purchaser's taxable income under personal income tax with the following amount: - Cars emitting less than 105g/km: 15% of the purchase price, with a maximum of € 4,270 - Cars emitting between 105 and 115 g/km: 3% of the purchase price, with a maximum of € 800 2. **Company car tax** is based on CO2 emissions.
CYPRUS	1. The rates of the registration tax (based on engine capacity) are adjusted in accordance with the vehicle's CO2 emissions. This adjustment ranges from a 30% reduction for cars emitting less than 120 g/km to a 20% increase for cars emitting more than 250 g/km. 2. The rates of the annual circulation tax (based on engine capacity) are reduced by 15% for cars emitting less than 150 g/km.
DENMARK	**Annual circulation tax** is based on fuel consumption. - Petrol cars: rates vary from 520 Danish Kroner (DKK) for cars driving at least 20 km per litre of fuel to DKK 18,460 for cars driving less than 4.5 km per litre of fuel. - Diesel cars: rates vary from DKK 160 for cars driving at least 32.1 km per litre of fuel to DKK 25,060 for cars driving less than 5.1 km per litre of fuel.
FRANCE	1. **Regional tax on registration certificates** ("carte grise") is increased for cars emitting more than 200 g/km. - The basic tax varies between € 25 and € 46 according to the region - Cars emitting more than 200 g/km pay an additional € 2 for each gramme between 200 and 250 g/km and € 4 for each gramme above 250 g/km - For example, a car emitting 275 g/km will pay an extra tax of (50 x 2) + (25 x 4) = € 200 2. **Company car tax** is based on CO2 emissions. Tax rates vary from € 2 to € 19 for each gramme emitted depending on the car's total CO2 emissions: - ≤ 100 g CO2/km : € 2 per gramme - > 100 and ≤120: € 4/g - > 120 and ≤ 140: € 5/g - > 140 and ≤ 160: € 10/g - > 160 and ≤ 200: € 15/g - > 200 and ≤ 250: € 17/g - > 250 : € 19/g
ITALY	A **tax incentive** of € 800 and a two-year exemption from annual circulation tax is granted for the purchase of a new passenger car complying with the Euro 4 or Euro 5 exhaust emissions standards and emitting not more than 140 g of CO2 /km, provided a Euro 0 or Euro 1 car is scrapped simultaneously. The exemption from annual circulation tax is extended to three years for cars with a cylinder capacity below 1,300.
LUXEMBOURG	**Annual circulation tax** is based on CO2 emissions. Tax rates are calculated by multiplying the CO2 emissions in g/km with 0.9 for diesel cars and 0.6 for cars using other fuels respectively and with an exponential factor (0.5 below 90 g/km and increased by 0.1 for each additional 10 g of CO2 /km).
THE NETHERLANDS	The rate of the **registration tax** (based on price) is reduced or increased in accordance with the car's fuel efficiency relative to that of other cars of the same size (length x width). The maximum **bonus** is € 1,000 for cars emitting more than 20% less than the average car of their size, the maximum **penalty** is € 540 for cars emitting more than 30% more than the average car of their size. Hybrid cars benefit from a maximum bonus of € 6,000.
PORTUGAL	**Registration tax** is based on engine capacity and CO2 emissions. The CO2 component is calculated as follows: - Petrol cars emitting less than 120g pay € 0.41 per gramme. Diesel cars emitting less than 100 g pay € 1.02 per gramme. - The highest rates are for petrol cars emitting more than 210g [(€ 29.31 x g/km) – 5,125.01] and for diesel cars emitting more than 180g [(€ 34.20 x g/km) – 4,664.64]
SWEDEN	**Annual circulation tax** for cars meeting the Euro 4 exhaust emission standards is based on CO2 emissions. The tax consists of a basic rate (360 Swedish Kroner) plus SEK 15 for each gramme of CO2 emitted above 100 g/km. For diesel cars, this sum is multiplied by 3.5. For alternative fuel vehicles, the tax is SEK 10 for every gramme above 100 g/km.
UNITED KINGDOM	**Annual circulation tax** is based on CO2 emissions. Rates range from £ 0 (up to 100 g/km) to £ 210 (petrol)/ £ 215 (diesel) for cars emitting more than 225 g/km. **Company car** tax rates range from 15% of the car price for cars emitting less than 140 g/km to 35% for cars emitting more than 240 g/km. Diesel cars pay a 3% surcharge.

3.1. European legislation

Situation

At present, all EU Member states have different tax systems for passenger cars. For the car industry, wide differences in passenger tax systems have a negative impact on their ability to achieve the expected benefits of operating within a single market. Current passenger car market fragmentation prevents industry from exploiting economies of scale, or in producing passenger cars with similar specifications for the entire internal market, resulting in significant differences in pre-tax and consumer tax prices.

Fiscal measures constitute one of the three pillars of the Community's strategy to reduce CO_2 emissions from passenger cars. The optimal use of fiscal measures, together with the commitments made by the car industry (ACEA, JAMA and KAMA) and consumer information, is a critical instrument in achieving the Community's target of 120 g CO_2 per Km by 2010 at the latest.
For this reason, the European Commission wants to adopt a new Directive on passenger car taxation (EC, 2005b). The purpose of the current proposal is therefore two-fold: to improve the functioning of the internal market and to implement the Community's strategy to reduce CO_2 emissions from passenger cars. The proposal does not intend to introduce any new passenger car related taxes, but only aims at restructuring such taxes if they are applied by Member States, without obliging them to introduce such taxes.

There are three main measures introduced by the proposal:
- Abolition of registration tax that can be compensated by increased circulation taxes.
- Establishment of a registration tax (RT) refund system to avoid double taxation for passenger cars that are exported to another European Member State.
- Restructuring the tax base of RT and annual car taxation (ACT) to be totally or partially CO_2 based for applying the third pillar of the European Strategy to reduce CO_2-emissions of passenger cars.

Concerning ACT, which are the taxes applied by most Member States, the proposal provides for the restructuring of their tax base in order to apply ACT partially or totally based on the carbon dioxide emissions of each particular passenger car by 2010. With regard to RT, Member States applying such taxes should also insert a CO_2 based element into their tax base by 2010 while at the same time they are proceeding with their gradual abolition. The period envisaged for carrying out the restructuring of the tax base of both the ACT and RT takes into account the commitment taken by the European Community to reduce carbon dioxide emissions from passenger cars to 120 g/km by 2010 at the latest. To avoid further internal market fragmentation based on potential diversified application by Member States of the carbon dioxide element, the Commission proposes that by 1 December 2008 (the start of the Kyoto period) at least 25% of the total tax revenue from registration and annual circulation taxes respectively should originate in the CO_2 based element of each of these taxes. By 31 December 2010, at least 50% of the total tax revenue from both the annual circulation tax and the Registration tax (pending its abolition) should originate in the CO_2 based element of each of these taxes.

The proposal has not been approved yet by the European Council and European Parliament. In the meanwhile, different EU Member States have introduced a CO_2-element in the car taxation (see further examples).

In 2007, the European Commission made a review of the strategy for reducing CO_2-emissions of passenger cars which was first published in 1995 (EC, 2007a) which aimed at a reduction of CO_2-emissions to an average of 120 g/km by 2012. The review showed that this target will not be met with current policy instruments, so further possible legislative actions have to be considered. One of the additional measures proposed in the review is urgent action on the implementation of fiscal measures promoting cleaner cars.

Fiscal incentives would also be a powerful way of encouraging the cleanest light-duty vehicle classes into the market. Such incentives should refer to a common EU definition applied across the Community, to avoid a fragmentation of the internal market, and cover all relevant emissions taking into account both air pollution and greenhouse gas emissions requirements. For this purpose, a Light-duty Environmentally Enhanced Vehicle (LEEV) should be defined as a vehicle that both meets the next stage of pollutant emission limit values as laid down in the relevant legislation, and stays below a certain level of CO_2 emissions. At present, this level should be the Community objective of 120 g CO_2/km. The definition of a LEEV should be subject to regular reviews in order to remain focused on the most advanced end of the new car fleet.

Definition clean vehicles

The proposal for Directive on car taxation focuses on CO_2-emissions of passenger cars. In the review of the CO_2-strategy, an new harmonised definition is proposed which also includes regulated emissions:
LEEV: Light-duty Environmentally Enhanced Vehicle: light duty vehicle that meets next stage emission standard and with CO_2-emissions lower that specified level to be determined.

Impact analysis

In COWI (2002), an impact analysis of introducing a CO_2-element in the RT and ACT was investigated for 9 EU Member States including Belgium. The main conclusions of the study were:

- It is essential to apply a tax scheme, which is directly or indirectly CO_2 related in order to provide for significant reductions in the average CO_2 emissions from new cars.
- It is essential to differentiate the taxes in such a way that taxes for very energy effective cars are significantly lower than taxes for cars with poor energy efficiency.
- Replacing the existing taxes with purely and directly CO_2 related taxes that are sufficiently differentiated provide the largest reductions.
- Adding a differentiated CO_2 element to existing taxes provides smaller, but still quite large, CO_2 reductions. If allowance were made for a subsidy to the most energy efficient vehicles, this would however increase the rate of progression and thus lead to even more CO_2 reduction.
- The level of the potential CO_2 reductions does not depend on the type of taxes, e.g. registration or circulation tax, but more on the CO_2 specificity and the level of the tax differentiation.
- Fuel tax increases provide only very small reductions of the average CO_2 emissions of new cars compared to vehicle taxes. Fuel taxes may however still be a very effective means of controlling the total CO_2 emissions that are attributable to passenger car transport.

Table 5. Impact of CO2-differentiated car taxation in 9 EU Member States

	B	D	DK	I	NL	P	S	SF	UK
Target CO_2 reduction, % points	**10.8**	**10.5**	**9.9**	**11.4**	**10.2**	**10.8**	**10.2**	**10.7**	**10.3**
Enhanced differentiation of existing taxes									
• registration tax	2.5	-	3.3	-	3.6	1.8	-	2.5	-
• circulation tax	2.4	4.4	5.4	2.7	3.6	1.9	2.4	0.1	4.8
Adding a CO_2 element to existing taxes									
• registration tax	3.3	-	4.6	3.0	3.4	2.1	-	2.8	-
• circulation tax	2.9	4.4	5.0	3.3	4.0	2.1	3.2	3.1	4.6
Purely CO_2 differentiated taxes									
• registration tax	3.5	-	8.4	1.8	5.5	3.2	-	4.3	-
• circulation tax	4.2	5.0	5.5	4.1	6.0	2.3	3.9	3.5	4.7
• combination	5.1	4.9	8.5	4.0	7.0	3.3	3.8	4.3	4.5

Source: COWI Study, Table 1.8: *Summary of main results*

Table 5 shows the impact of CO_2-differentiated taxes for Belgium and 8 other EU Member States. Increasing the differentiation in the existing tax system based on fiscal horsepower would result in a 2.5% (RT) and 2.4% (ACT) CO_2-reduction of new passenger cars. With a purely CO_2-based tax system, the impact on CO_2-reduction can be increased to 5.1% when both RT and ACT are CO_2-based.

All calculations were made under the assumption that the following boundary conditions would be respected:

- Revenue neutrality has to be ensured, in a sense that no changes in overall tax revenues from vehicle related taxes for new cars should occur (i.e. the total of RT, ACT and fuel taxes).
- Unchanged proportion of diesel cars, which means that the proportion of diesel cars in the total sales of new cars should remain constant at today's level.
- No downsizing, which implied that the CO_2 reductions should be achieved without major implications for the demand structure in terms of moving demand downwards towards smaller, and hence, more energy effective cars.

The abolition of the RT does not need to be an obstacle for achieving the CO_2-reduction of the average new passenger car, providing that the ACT is differentiated in an effective way and revenue neutrality is ensured. A negative effect of abolishing the RT is that more cars will be sold so total CO_2-emissions would rise. On the other hand, this would lead to a more rapid renewal of the car fleet which has a positive effect on regulated polluting emissions.

3.2. Car taxation in Germany

Situation

From 1997, Germany introduced environmental criteria in the annual circulation tax which is calculated based on the cylinder capacity of the engine (Govaerts, 2005). There is no registration tax to be paid in Germany. From April 2007, the system was revised for supporting the purchase of particulate filters, or for retrofitting existing cars or for new passenger cars. Diesel cars with a particulate filter receive a reduction of 330 EUR on the ACT which is 50% of the additional cost of the particulate filter. Diesel cars that are not equipped with a particulate filter pay an elevated ACT. The reductions on the ACT that were given before for cars with extra low fuel consumption (below 3 or between 3 and 4 liters / 100km) were abolished (Bundesministerium, 2007).

The schematic overview of the calculation of the ACT is given in Figure 3.

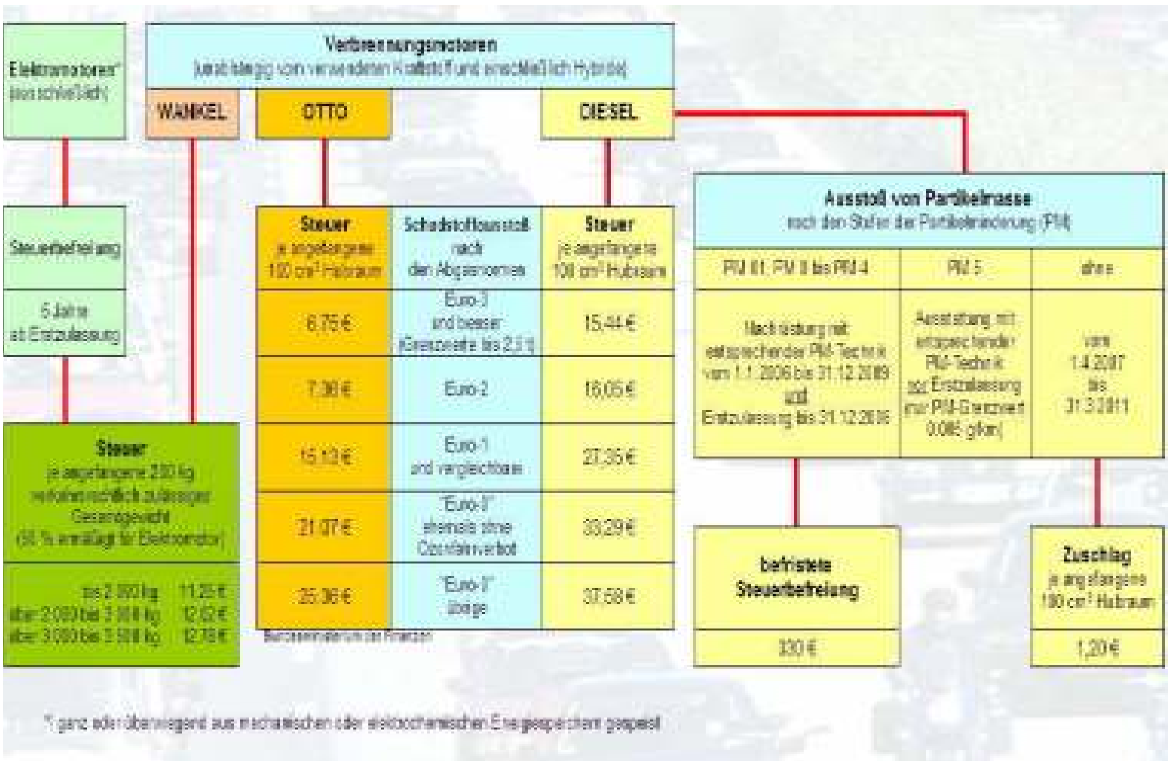


Figure 3. Annual Circulation Tax in Germany (http://www.steuer.niedersachsen.de/Service/Kfz.htm)

Related measures for supporting cleaner vehicles in Germany are the introduction of restricted city areas where only vehicles that meet a certain environmental standard can enter the city.

Definition clean vehicles

Emission standard of the vehicle
Particulate filter class based on the PM-reduction of the filter.

Impact analysis

The first results of the introduction of the emission standard based taxation scheme were promising towards a quick introduction of euro 3 vehicles compared to European average (Govaerts, 2005), though no further information is found on the impact assessment of the euro-standard based taxation scheme.
From January until July 2007, 250.000 of the 9 million German diesel cars have been retrofitted with a diesel particulate filter which is about 3%[1].

3.3. Car taxation in the Netherlands

Situation

Following the European legislation on consumer information on fuel consumption and CO_2 emissions of new passenger cars, all cars that are displayed at a point of sale must have a fuel consumption label which indicates the fuel consumption and CO_2-emissions of the passenger car. In the Netherlands, the fuel efficiency of a car is expressed in relation to the average of cars with the same size, so in all market segments there is a differentiation between fuel efficient (A-C labelled cars) and fuel inefficient (E-G labelled cars) (Govaerts, 2000). The relative fuel efficiency is recalculated annually because the average fuel consumption of new vehicles changes in course of time.

Since July 2006, a reduction from the registration tax (BPM) for new cars is given to relative fuel efficient cars with an A and B label. An additional reduction for hybrid cars meeting the same relative fuel efficiency is given. Cars who have a relative high fuel consumption pay an extra registration tax. The reductions and increases of BPM are given in Table 6 (VROM, 2007).

Table 6. reductions on BPM (EUR) depending o relative fuel efficiency.

energielabel	A	B	C	D	E	F	G
Hybride auto	-6.000	-3000	0	+135	+270	+405	+540
Niet-hybride auto	-1.000	-500	0	+135	+270	+405	+540

The reduction for energy efficient cars was also implemented in 2001-2002 but abolished for budgetary reasons (Govaerts et al., 2005). The reductions at that time were also 500 EUR for B-labelled and 1000 EUR for A-labelled cars.

[1] Press release Deutsche Umwelt Hilfe 13.08.2007, www.duh.de

Since the 1st of February 2008, an additional registration tax is implemented, the so called 'slurptax'. If a petrol vehicle has a CO_2-emission which is more than 232 g/km, the BPM increases with € 110 per additional gram. For diesel vehicles, the limit is defined at 192 g CO_2/km. The extra tax to be paid is also € 110 per additional gram. These limits will further decrease to respectively 222 and 184 g CO_2/km.

E.g. a petrol vehicle with a CO_2-emission of 250 g/km, will have to pay an additional € 1980 in registration tax.

$$(250\text{ g} – 232\text{ g}) \times 110\text{ €/g} = \text{€ } 1980$$

Since 2006 the BPM is also reduced for new diesel cars that are equipped with a diesel particulate filter. The reduction is 600 EUR[2]. In April 2008, this reduction for particulate filters will be replaced with by the so called 'soot tax'. The amount of mg of particulate matter emitted (PM_{10}-value, found on the type approval certificate) will be multiplied with 200, and deducted by 900. This will be the amount of tax to be paid.

E.g. a diesel vehicle with an emission of 20 mg PM_{10}/km will have to pay (20*200 – 900) = € 3100 extra. Diesel vehicles with an emission of 1 mg PM_{10}/km will have to pay (1*200 – 900) = -700 €, or in other words can benefit form a 'subsidy' of € 700.

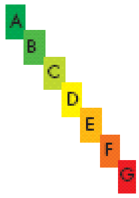
Vehicles with particulate filters have an average of 2 mg PM_{10}/km, so the average 'subsidy' for these vehicles will be € 500.

In the Netherlands, several cities are introducing restricted areas for cars only meeting an environmental standard from 2008, in the beginning this will only apply to heavy duty vehicles but in the future also light duty vehicles will have to meet a certain standard to enter the restricted areas. The Dutch government is also working on differentiating the MRB (annual circulation tax) on the environmental performance of a vehicle. There is also a subsidy of 500 EUR for retrofitting old cars with a particulate filter (see chapter 6.3).

Definition clean vehicles

Relative fuel consumption of the vehicle compared to average fuel consumption of cars with same size and fuel type.

[2] www.vrom.nl



A : > 20% more energy efficient than average
B : 10 - 20% more energy efficient than average
C : 0 - 10% more energy efficient than average
D : 0 - 10% less energy efficient than average
E : 10 - 20% less energy efficient than average
F : 20 - 30% less energy efficient than average
G : > 30% less energy efficient than average

The additional taxes and/or subsidies (‘slurp tax’ and ‘soot tax’) are based on the exact CO_2- and PM_{10}-emissions of the vehicles, which can be found on the type approval certificate.

Impact analysis

For the reduction on the BPM in 2001-2002, the Dutch ministry of environment analysed the market share of new fuel efficient cars in 2001-2002 and compared it to the market share in the first 6 months of 2003 when the reductions were abolished. The result is summarised in Table 7.

Table 7. market share energy efficient cars 2001-2003 in NL

	Market share A-labelled cars	Market share B-labelled cars
2001	0.3 %	16 %
2002	2.8 %	16 %
1st half 2003	0.8 %	12.4 %

For the impact on the sales of energy efficient passenger cars or cars equipped with a particulate filter since 2006 no official figures were found. An analysis of sales figures of the first half of 2007 compared to the first 6 months of 2006 by the Dutch car manufacturers association shows that especially smaller car segments (small cars and city cars) are taking a larger market share in new car sales. This trend was also seen from 2005 to 2006 so it’s difficult to assess if the BPM-reduction had an influence on this increasing market share as shown in Table 8.

Table 8. market share car segments in first half of 2005, 2006, 2007 in Netherlands

	2005	2006	2007
A-Small	9,10%	11,20%	12,60%
B-City	19,00%	21,70%	22,30%
C-Lower Family	21,50%	18,90%	18,80%
D-Upper Family	17,80%	16,70%	13,70%
E-Executive	3,80%	3,60%	3,50%
F-Lower Luxury	0,40%	0,40%	0,30%
G-Lower Sports	0,70%	0,60%	0,90%
H-Upper Sports	0,40%	0,30%	0,30%
I-Upper Luxury	0,00%	0,00%	0,00%
J-Medium MPV	16,70%	16,00%	15,10%
K-Upper MPV	2,70%	2,10%	2,40%
L-Lower Utility	4,30%	4,70%	5,50%
M-Upper Utility	1,60%	1,70%	1,90%
N-Commercials	1,80%	1,80%	1,80%
Total Others	0,40%	0,40%	0,70%

The impact of the very recent 'slurp tax' and 'soot tax' can not be estimated yet.

3.4. UK Vehicle Excise Duty

Situation

For vehicles registered since March 2001, the CO_2-emissions is used as the basis for applying VED (annual circulation tax) for new passenger cars. For cars registered before 2001, the old system based on engine size is still in place. In 2006, smaller changes were made to the system by introducing an extra tariff for passenger cars with very high CO_2-emission [3]. Alternative fuel cars (at present these are hybrid cars, ethanol flexi-fuel cars and cars running on natural gas) have lower VED also depending on the CO_2-emissions. The rates are presented in Table 9.

[3] Vehicle Certification Agency, www.vcacarfueldata.org.uk

Table 9. VED rates in UK

Vehicles registered on or after 1st March 2001		Diesel Car TC 49	Petrol Car TC 48	Alternative Fuel Car TC 59
Bands	CO_2 Emission Figure (g/km) *	12 months rate £	12 months rate £	12 months rate £
Band A	Up to 100	0.00	0.00	0.00
Band B	101 to 120	35.00	35.00	15.00
Band C	121 - 150	115.00	115.00	95.00
Band D	151 - 165	140.00	140.00	120.00
Band E	166 - 185	165.00	165.00	145.00
Band F	186 - 225	205.00	205.00	190.00
Band G[4]	226+	300.00	300.00	285.00

Following the impact assessment of the VED it was decided to increase the differentiation between the CO_2-bands for the VED starting from 2009 similar to the CO_2-bands of the company car taxation (see chapter 4.1) (SMMT, 2007).

Definition clean vehicles

The CO_2-emissions of the passenger cars are divided in different CO_2-bands. The bands correspond to the band on the fuel consumption label displayed at the car on the point of sale.

Impact analysis

In 2005, the UK Department for Transport assessed the impact of the VED (DfT, 2005). The analysis was done by means of discussion groups of consumers and industry representatives (car manufacturers, car dealers) and a larger quantitative survey on the impact of the VED. The main conclusions are summarised below:
Overall, the graduated VED scheme has had minimal impact on the UK car industry. The key reason for this is perceived to be that the differential between the bands are not enough to factor into the decision making process. The impact of taxation linked to car capacity for business drivers, however, has made a significant impact.
Car fleet operators suggest that the Government can learn from the impact of changes to company car tax policies. In instances where company car drivers can make savings of around £1,000 (ca. € 128) then changes are being seen in car choices. *Car vendors* are less likely to see that they have a role in reducing the environmental impact of the car. They say that they are driven by market forces, and currently there is not the demand for environmental information or the desire to make the available cost savings on car tax. Vendors are of the opinion, supported by the research amongst new car buyers, that the

[4] Band G only applicable for cars registred after March 2006

current price differential between VED bands means it will never be part of the decision making process.

New car buyers have limited awareness of the graduated VED scheme. Some are aware it is based on CO_2 emissions but the majority believes it is still linked to engine size. Once the scheme is explained, car buyers say it would not be a consideration in any future new car purchases due to the lack of cost saving. They suggest that a differential of £100 (ca. € 12,8) may begin to make a difference, others say it would have to be nearer to £1,000 (ca. € 128).

When the scheme is explained to respondents, those who have bought a car privately after March 2001 say that it was not part of their decision making process. Those who are planning to buy indicate that it may be a factor that they will consider in the future, however, given the behaviour of those who actually have purchased since the introduction of graduated VED it is possible that this intention will not be followed through. Focusing on recent private purchasers the data supports the qualitative research conclusion that the current graduated scheme does not offer a large enough incentive to encourage behavioural change. And indeed across both recent and potential buyers there is a significant minority who believes that the current scheme and any subsequent increase to the differential will not help to reduce CO_2 emissions.

The survey also questioned how large the tariff differentiation should be before the VED had an impact on the purchase decision of the private consumer.

Looking to the future and possible changes to the scheme, a differential between bands of £50 (ca. € 6,4) would be enough for some buyers to choose a different car (33%). Others would consider it. At a differential of £150 (ca. € 19,2) 55% would change to a lower emission car to benefit from the saving. There is however a core of buyers who would not change their vehicle choice regardless of the differential (28%). This hard core is typically older, of higher social class and own or intend to buy a larger sized engine vehicle. These figures are presented in Figure 4

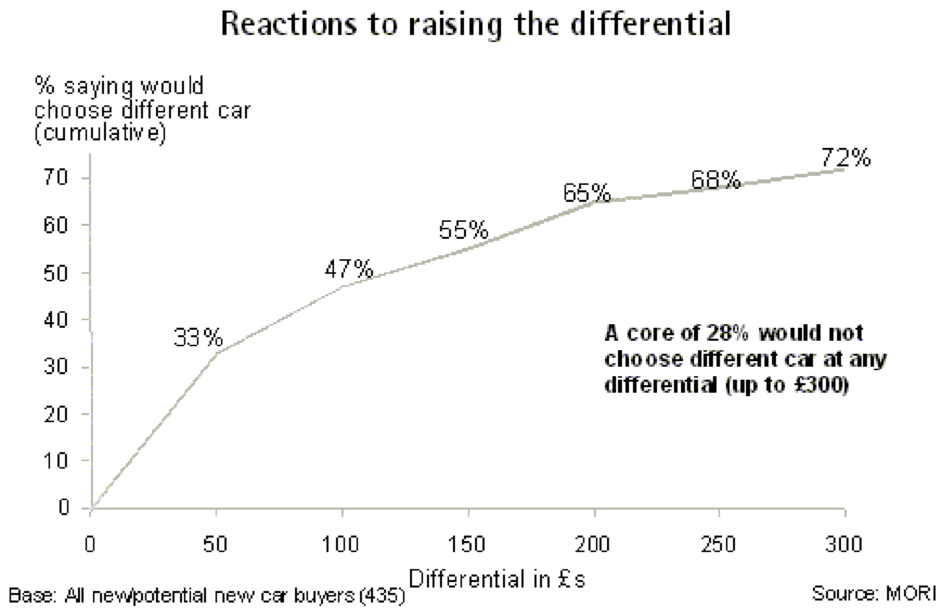


Figure 4. % of consumers that would choose another car depending on differential VED tariff

A similar analysis for the RAC foundation says that the differential between the CO_2-bands must be at least £1.100 (ca. € 141) before private consumers would switch to a smaller car or alternative fuelled car (Veitch, 2007).

Figure 5 shows the average CO_2-emissions of passenger cars sold to private consumers versus fleet clients. Since 2001-2002 when the CO_2-based VED for private consumers and the CO_2-based company car tax were introduced, the average CO_2-emissions of new fleet passenger cars has decreased substantially, while there was a stagnation for the average CO_2-emissions for new private vehicles since 2002.

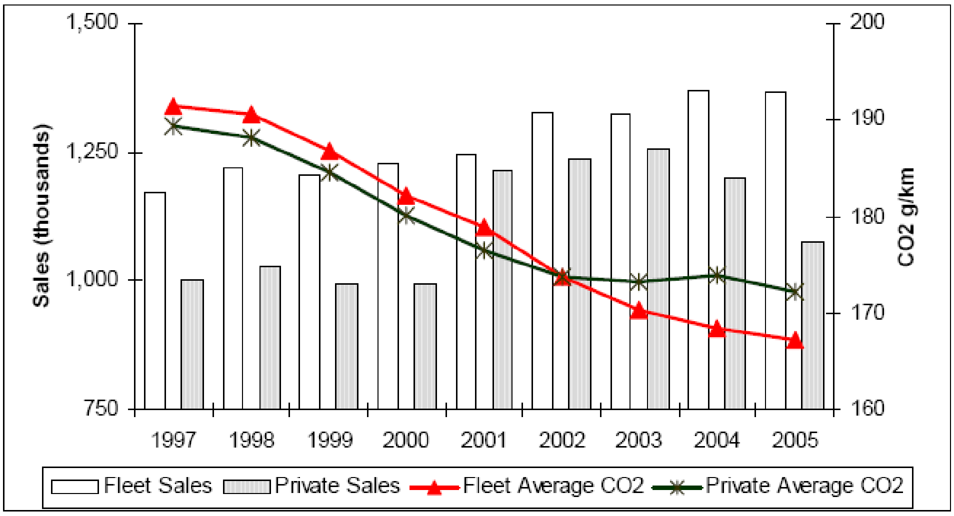


Figure 5. Fleet sales and private sales in relation to CO2-emissions in UK from 1997-2005 (Veitch, 2007)

4. Other fiscal incentives

4.1. UK Company car tax

Situation

From April 2002 the benefit-in-kind tax charged for company cars has been based on the CO_2 emissions of a vehicle. The employee has to state the benefit-in-kind income for private use of his company car as a percentage of the purchase price of the car, which is based on the CO_2-emissions of the car. This applies to all company cars registered from January 1998 onwards[5]. For certain fuels and vehicle technologies, the rates are increased or reduced following the environmental friendliness of the technology. From 2008, the rates will be adapted with a new 10% rate for low CO_2-cars for encouraging the take up of low CO_2 emitting cars (SMMT, 2007).

Definition clean vehicles

The percentage of the purchase price varies from 15% to 35% (from 2008: starting from 10%), the percentages are presented in Table 10. Diesel cars that don't meet the EURO4 standard have a supplement of 3% on the purchase price. The rate for alternative fuelled vehicles is reduced with 2 to 6% as presented in Table 11.

[5] Vehicle Certification Agency, www.vcacarfueldata.org.uk

Table 10. benefit in kind company cars in % of purchase price for UK company car taxation[6]

CO_2 emissions (g/km)	2005–06 to 2007–08	2008–09 onwards
135	15%	15%
140	15%	16%
145	16%	17%
150	17%	18%
155	18%	19%
160	19%	20%
165	20%	21%
170	21%	22%
175	22%	23%
180	23%	24%
185	24%	25%
190	25%	26%
195	26%	27%
200	27%	28%
205	28%	29%
210	29%	30%
215	30%	31%
220	31%	32%
225	32%	33%
230	33%	34%
235	34%	35%
240	35%	35%

Table 11. reduction or supplement to tax rates depending on fuel or technology

Type of fuel	P11D code	Standard adjustment from 2006/07	Other adjustments
Petrol	P	none	none
Diesel (car not Euro IV)	D	supplement: 3% (see note 4)	none
Diesel (Euro IV car – note 1) first registered before 2006	L	cancel type D supplement, above	none
Diesel (Euro IV car – note 1) first registered in or after 2006	L	supplement: 3% (see note 4)	none
Electric only	E	reduction: 6%	none
Hybrid electric (note 2)	H	reduction: 3%	none
Gas only	B	reduction: 2%	none
Bi-fuel with CO_2 emissions figure for gas (note 3)	B	reduction: 2%	see note 5
Bi-fuel conversion, or other bi-fuel not within type B	C	none	none

[6] UK HM Revenue and Customs, http://www.hmrc.gov.uk/cars

Impact analysis

In 2006, the Inland Revenue office made an evaluation of the second stage of the company car tax reform (HM Revenue, 2006). Main conclusions of the evaluation 4 years after the introduction of the CO_2-based company car taxation are summarised below:

- Around 90% of employers and drivers claim to know about the reform of which nearly half know that the new system is based on purchase price and CO_2 (or at least pollution or fuel consumption in a more general sense). Around 60% of company car drivers were influenced by the reform and choose a car with lower CO_2-emission.
- The company car tax reform is encouraging substantial numbers of people to choose cars with lower CO_2 emissions figures. Average CO_2 emissions figures from company cars were around 15g/km lower in 2004 than would have been the case if the reforms had not taken place which is significantly better than the CO_2-reduction for private cars (see also chapter 3.4).
- The evaluation suggests that if drivers no longer have company cars, on average, they will choose private cars with CO_2 emissions figures that are around 5g/km higher as a result.
- The number of company cars has reduced to around 1.2 million in 2005 compared with around 1.6 million in 2001.
- The modelling work suggests that the company car tax reform has led to overall losses in revenues because many employers and drivers are choosing company cars with lower CO_2 emissions figures as a result of the reform and some employers and drivers have stopped having company cars because of it.
- The central estimates are that these losses amounted to around £40 million for 2002/3, £135 million for 2003/4, £145 million for 2004/5 and £120 million for 2005/06.
- There has been a substantial increase in company cars running on diesel to around 50 – 60% at the end of 2004 from around 33% in 2002, a somewhat faster rate of increase than for the vehicle stock as a whole. The proportion of company cars running on diesel is forecast to rise to 60 – 70% over the next few years.
- The proportion of company car drivers receiving free employer provided fuel for private use has also decreased significantly from around 57% in 1997 to around 30% now.
- This means a reduction of 70 – 100 million private miles in cars in 2005 due to the reduction in the number of company car drivers getting free fuel since 1997, although this is less than 0.1% of the total amount of mileage done in cars in the UK in 2005.

In two years time the number of company cars with lower CO_2-emissions increased rapidly as shown in Table 12. The average CO_2-emission of new company cars was reduced with 7.8% in two years and also the number of new company cars decreased with 12% between 2002 and 2004.

Table 12. Market share per CO2-band company cars UK (SMMT, 2007)

	2004/05	2003/04	2002/03
CO_2 emissions g/km			
<=145	27.5%		
150&155	20.8%	42.0%	
160&165	8.3%	8.4%	41.6%
170&175	10.8%	11.5%	12.4%
180&185	9.2%	9.9%	10.9%
190&195	7.5%	8.4%	9.5%
200&205	4.2%	5.3%	7.3%
210&215	3.3%	4.6%	4.7%
220&225	2.5%	3.1%	4.4%
230&235	1.7%	2.3%	2.9%
240&245	1.7%	1.5%	1.8%
250&255	0.8%	3.8%	1.1%
>=260	2.5%		3.6%
Diesel	54.2%	44.3%	33.6%
Petrol	46.7%	56.5%	66.4%
Total Volume (000s)	1,200	1,310	1,370
Average weighted CO_2 g/km	171.0	177.9	185.5

4.2. Belgium company car taxation

Situation

When an employer gives a company car to the employee that is used for private transport, this is taxed in two ways. The employee has to state the net benefit-in-kind that he receives from his employer and this is calculated based on the average mileage and the fiscal horsepower of the car. For the employer, the benefit-in-kind is seen as a kind of salary on which social security contributions have to be paid.
Since January 2005, the social security contribution is not calculated based on fiscal horsepower any more but based on the CO_2-emissions of the cars (Willems, 2005).

The calculation of the annual social security contribution is as follows:
Petrol cars: (CO_2-emission * 9€) – 768€
Diesel cars: (CO_2-emission * 9€) – 600€
LPG cars: (CO_2-emission * 9€) – 990€

Starting from april 2007, the percentage of costs for the purchase of a company car that a company can deduct from it's taxable income is also depending on the CO_2-emissions of the car, replacing the overall tariff of 75%. The percentages per CO_2-category and fuel type are given in Table 13.

Table 13. Deductable % of costs of company cars

CO2-class Diesel	Petrol	Deductable % of purchase costs
0 - 105 g/km	0 - 120 g/km	90%
105 – 115 g/km	120 – 130 g/km	80%
115 – 145 g/km	130 – 160 g/km	75%
145 – 175 g/km	160 – 190 g/km	70%
> 175 g/km	> 190 g/km	60%

From April 2008, the percentages that can be deducted will be applied to the total costs of the company fleet (Envirodesk, 2007).

Definition clean vehicles

The Belgian company car taxation is based on the CO_2-emissions of the company car.

Impact analysis

The total company car cost for the employer is raised on average with 8 to 10%. For cars with low CO_2-emissions, the social contribution can be lower than it was before but on average most of the company cars are taxed higher (Willems, 2005). A detailed analysis for FLEET magazine on the fiscal pressure on company cars, concluded that total fiscal costs of company cars is around 40% of total leasing costs (including fuel taxes, VAT, car taxation and CO_2-tax). The absolute amount of fiscal costs is lower for smaller, fuel efficient cars, but the relative amount is around 40% for small and larger more consuming cars. Only for a very fuel efficient car with 102 g/km CO_2-emission, the fiscal costs were only 32% of total leasing costs compared with a similar car with emissions of 122 CO_2 g/km (Willems, 2006).

There were no figures found on the impact of the new company car taxation on the purchase behaviour of company fleet owners or car choice by employees. Several lease companies introduced ‘green lease products’ where CO_2 is a prominent criterium in car choice. Belgacom for example announced to introduce a new car policy where the CO_2-emissions of the vehicle determine the remaining budget for other options for the employee: for a car with low CO_2-emissions the employee will receive a relative higher budget for options compared to the employee who chooses a car with high CO_2-emissions in the same category (Verhelst, 2007).

4.3. Belgium income tax reduction

Situation

In Belgium, car taxation is based on fiscal horsepower (calculated from cylinder capacity) and engine power of the car. With the registration of a car, registration tax is paid. Circulation tax is paid annually. The three regional authorities (Brussels, Flemish and Walloon region) are authorised to change the car taxation but a principal agreement exist between the regions not to make unilateral changes to the car taxation system. In 2009, the regions will not only be authorised for the system of car taxation but also receive the income of the car taxation. Flanders already announced to change the system of car taxation to relate it to the environmental performance of the car indicated with the ecoscore (Vlaanderen, 2006).

Since January 2005 a reduction from the private income taxes for the purchase of private passenger cars with low CO_2-emissions is granted by the Belgium government. The reduction is based on the purchase price of the car: 15% reduction for cars with CO_2-emissions equal or lower than 105 g/km and 3% for cars with CO_2-emissions equal or lower than 115 g/km. In 2006, the maximum reduction is 4080 EUR for the category with lowest CO_2-emissions and 760 EUR for the category with CO_2-emissions between 106 and 115 g/km (MIRA, 2006).

Since July 2007 the reduction on the income taxes has been replaced by a direct reduction of the purchase price given by the dealer who is responsible for claiming back the money of the federal administration (KB, 2007). The reduction is also given for the purchase of a car with particulate filter. This measure is further described under the chapter 6.2.

Definition clean vehicles

The measure is based on absolute CO_2-emissions of the passenger car:
Very low: $0 \leq CO_2\text{-emissions} \leq 105$ g/km
Low: 105 g/km $< CO_2\text{-emissions} \leq 115$ g/km

Impact analysis

Figure 6 presents the evolution of the share of new passenger cars qualifying for the income tax reduction from 2002 until 2005 in Belgium.

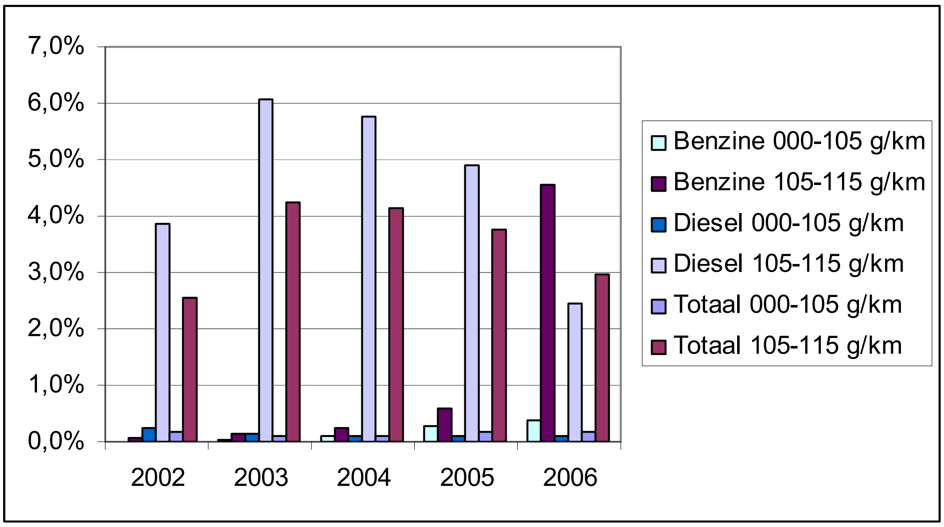


Figure 6. Evolution share new registrations passenger cars qualifying for income tax reduction (Belgium, 2002-2006) (Source: VITO based on DIV data)

These figures give an indication of the effectiveness of the measure, but of course a lot of other market related factors have an influence on car registrations. An important external factor is the technological evolution (resulting from the voluntary agreement between the car industry and the European Commission, see chapter 9.1) that results in an average CO_2-reduction of new passenger cars about 1% annually in the period 2002-2005.

From 2002 to 2004, the share of passenger cars with low CO_2-emissions has almost been doubled from 2.5% to 4.1%, mainly due to the increase of the share of diesel cars with low CO_2-emissions. From 2005, the share of gasoline cars with low CO_2-emissions has increased substantially, but this could not compensate the decrease of the share of diesel cars with low CO_2-emissions. Since the diesel segment represents 75% of new car registrations, the decrease of the registrations of diesel cars with low CO_2-emissions made that the total market share of passenger cars that qualified for the reduction of income taxes decreased from 4.1% in 2004 to 3% in 2006, despite of the measure that was initiated in 2005.
The decrease of market share of cars of low CO_2-cars indicates that the impact of this measure is zero or very low.

4.4. Feebates in Canada

Situation

A feebate is a fiscal incentive which combines a fee for a high polluting vehicles and a rebate for cleaner vehicles. Canada so far is the only country where a feebate system is installed for passenger cars since March 2007 (ICCT, 2007). The rebate for eligible light duty vehicles ranges from 1000 to 2000$. Passenger cars with CO_2-emissions above 302 g/km pay an extra tax (fee) up to 4000$.

The tax system is called the ‘green levy’. In Canada there is also a voluntary agreement with the car industry from 2005 to lower fuel consumption of new vehicles, which will become mandatory starting from 2011.

Definition clean vehicles

The feebate is based on the fuel consumption of the vehicle. Passenger cars are eligible for a fuel consumption of 6.5 liter/100km and light duty trucks for a fuel consumption of 8.3 liter/100km. Also E85 Flexi Fuel vehicles qualify for a fuel consumption of 13 l/100km or lower.

Impact analysis

Since the measure is only in place since March 2007, there is no information on the impact of the green levy yet.

5. Road Pricing

This section covers a type of pricing mechanism to encourage reductions in vehicle travel and shifts to other modes of travel: road pricing. Distance and/or time based pricing and cordon based charges are the most common types of road pricing. These measures change the variable cost of driving either per kilometer, per time of day or per trip. The variable cost is in this case expressed as roadway usage fees that amount to a toll for either each unit of distance traveled, or entry into a specific area.
The purchase cost of a vehicle, which is a fixed cost, represents a high percentage of the costs associated with owning and operating a vehicle. Such fixed costs are not likely to enter into the decision about whether to take a particular trip. By shifting some of these fixed costs to variable, paid each time the car is used, a much stronger signal could be sent to drivers regarding the real costs of each trip (IEA, 2001). This in turn may encourage reductions in vehicle use and shifts to car pools and to other modes of transportation. If pricing is implemented for travel on specific routes, at specific times, it may reduce vehicle travel in a very targeted manner, with some drivers choosing simply to switch the route or time of particular trips. Such a targeted approach may be very useful for reducing congestion and eliminating traffic bottlenecks. Moreover, when benefits are given to drivers of clean vehicles, e.g. lower tolls, a higher share of clean vehicles using the route or entering the city may be expected.

5.1. Distance and/or time based pricing

5.1.1. Road charging in Europe

On the European level, Directive 99/62/EC, as modified by Directive 2006/38/EC sets common rules on distance-related tolls and time-based user charges for goods vehicles (above 3,5 tonnes) for the use of certain infrastructure (EC, 2007b).
The Directive:

- regulates the functioning of the internal market through the approximation of the conditions of competition in the transport sector by reducing the differences in the levels and in the systems of tolls and user charges applicable in member states of the European Union.
- takes account of the principles of fair and efficient pricing in transport by providing for greater differentiation of tolls and charges in line with costs associated with the road use

The Directive lays down certain rules to be followed by member states if they wish to have tolls and/or user charges. The most important of these framework conditions are:

- Tolls shall be levied according to the distance travelled and the type of vehicle; user charges are scaled according to the duration of the use made of the infrastructure and to vehicles emission classes.
- Both tolls and user charges can only be imposed on users of motorways or multi-lane roads similar to motorways as well as on users of bridges, tunnels and mountain passes.

- The directive does not permit to impose a toll and a user charge at the same time. However, tolls can be levied on networks where user charges are already imposed for the use of bridges, tunnels and mountain passes.
- National tolls and charges should not be discriminatory and should be set out in such a way to cause as little hindrance as possible to the free flow of traffic as well as to avoid mandatory checks at the internal borders. It is to be noted that at national level specific taxes or charges for the registration of the vehicle or for its abnormal weights/dimension can be imposed and all needed measures to combat road traffic congestion can be adopted.

The Directive fixes:

- a maximum level for user charges in accordance with the given period and with the environmental performance of the vehicle as follows:

Table 14. Maximum level of annual charge until 09/06/2008

Class	Up to 3 axles	4 axles or more
pre Euro	€ 960	€ 1550
Euro 1	€ 850	€ 1400
Euro 2	€ 750	€ 1250

Monthly and weekly charges are proportionate to the duration of the use of the infrastructure. The daily charge is € 8 for all vehicle categories.

Not later than 10 June 2008 the thresholds (in €) will be according to the following table, while the daily charge is 11 € for all vehicle categories.

Table 15. Maximum level of annual charge as from 10/06/2008

Class	Up to 3 axles	4 axles or more
pre Euro	€ 1332	€ 2233
Euro 1	€ 1158	€ 1933
Euro 2	€ 1008	€ 1681
Euro 3	€ 876	€ 1461
Euro 4 and less polluting	€ 797	€ 1329

- the maximum weighted average tolls by requiring that tolls are set in relation to the costs of constructing, operating and developing the infrastructure concerned. Member states may vary the toll rates according to vehicle emission classes and the time of the day and in certain sensitive areas, under certain conditions, tolls may be increased to reflect the environmental sensitivity of the area and provide a further fiscal incentive to reduce traffic.

Although the application of tolls and user charges is not mandatory for member states, all framework conditions set out in the directive should be fulfilled in case of their opting for levying such charges.

Eurovignette

A specific provision of the directive allows member states to co-operate for the purpose of introducing a common system of user charges. In this respect Belgium, Denmark, Luxembourg, the Netherlands and Sweden have a common system of user charges for heavy goods vehicles above 12 tonnes called the 'Eurovignette' system. According to this system the payment of a specified amount grants conveyers the right to use motorways of the participating member states for a given period (i.e. a day, a week, a month or a year). This regulation is applicable on domestic and foreign conveyers.
Each participating country is responsible for all aspects related to the payment of the Eurovignette on its own territory.

The cost of the Eurovignette corresponds with the amounts listed in Table 15 (FOD Financiën, 2007).

Road Charging Interoperability

Currently in Europe, different road charging systems are being operated by professional companies making use of different technologies. Despite the fact that current road charging schemes are successful, a public standard is needed for interoperable road charging solutions that work all over Europe, as demanded by the EC. Interoperability of road charging solutions is a long-term objective of the EC. In April 2004, the directive 2004/52/EC of the European Parliament and Council on the interoperability of electronic road toll systems in the Community was adopted. The Directive places constraints on the technologies that may be used in future new road charging systems:

- Satellite positioning
- Mobile communications using the GSM-GPRS standard
- 5,8 GHz microwave technology

The new road charging service that is interoperable throughout Europe on the basis of one or more of the mentioned technologies is called the European Electronic Tolling Service (EETS). In a summary this directive describes the following (RCI, 2007):

- Operators and Member States are obliged to accept interoperable On Board Equipment (OBE) that are compliant with the EETS;
- Operators are obliged to provide this service and OBE to end users;
- The end user can make use of this service and onboard equipment on a voluntary basis.

The EC envisages a final definition of the EETS service by 2007 (one year delay with respect to the original directive) and deployment of the service for heavy good vehicles by 2009 and for private vehicles by 2011.
The three-year Road Charging Interoperability (RCI) project, which is partially funded by the DG Energy and Transport of the European Commission, started on 29 June 2005. The main objective of the RCI project was to develop an open and integrated framework enabling road charging interoperability at a technical level, based on the key existing and planned road charging deployments in Europe (RCI, 2007). The 26 partners in the RCI-project recently agreed on the architecture and specifications to be applied for European interoperable tolling. It is in line with the Directive 2004/52/EC, which can be summarized as one contract and one on-board equipment (OBE) that can be used in every tolling system used within the European Union. On the 28th of February 2007, the European Commission endorsed the RCI architecture for European tolling. The approved architecture will be the basis for all existing and future European road charging systems that need to comply with Directive 2004/52/EC.

5.1.2. Germany Motorway Toll

Situation

On 1 January 2005, Germany introduced an electronic heavy goods vehicle tolling system covering its highway network: approximately 12,000 kilometers of highways, more than 2,200 highway junctions and more than 250 interchanges (Toll-Collect, 2007).
According to the German federal government, there were a number of objectives why this system was introduced (BMVBS, 2007):

- Tolling helps to mobilize additional funds for improving transport infrastructure.
- The toll allows to recuperate the infrastructure costs from those who impose them, in other words the ‘user pays’ principle.
- Tolls provide an incentive for a more economic use of transport capacities in the field of road haulage.
- The fact that tolls are charged according to the emissions produced provides a incentive to purchase cleaner vehicles or convert older ones.
- A fairer competition between the road and rail modes is intended.

The German tolling system is a dual one, comprising a manual booking option but also satellite-based automatic tolling. The automatic system uses a combination of satellite navigation and mobile communications technology to achieve a free flow system. This means that trucks do not have to stop or slow down at toll gates. The principle of automatic tolling is based on the establishment of so-called "virtual toll charging stations" on each section of the motorway. The geographical co-ordinates of the sections of the motorway where toll has to be paid, are stored in an on-board-unit (OBU) in the form of a digital map. When a truck drives along the motorway its current position is continually registered by GPS satellite positioning. As soon as the current position of the truck matches the virtual coordinates stored in the OBU, the unit recognizes that the truck is on a tolled section of the motorway. The OBU then calculates the toll due in accordance

with the declared number of axles and the emission class concerned. This data is periodically transmitted to the back office, where the bill is prepared. The transmission of the toll information between the OBU and the computing centre is conducted via cellular communications networks (GSM). The same cellular communication is used in the opposite direction to automatically transmit software or database updates to the OBU's.
In addition to the satellite based automatic tolling, the OBU is equipped with 'tag and beacon' technology. In specific conditions, with respect to the highway geometry, support beacons are required in addition to the GPS signal to differentiate exactly whether a vehicle is on the highway or on an adjacent road. This concerns short segments with many parallel roads in a narrow corridor.
The alternative to the automatic system is manual log-on. This is primarily foreseen for truck drivers and transport companies that seldom use German highways. Under this alternative, the user logs on at one of about 3500 toll station terminals or over the internet, and provides details of the route he intends to drive. The amount of toll is calculated, and a ticket, which should be kept in the vehicle, is issued upon payment.

The toll amount is based on the truck's emission category and number of axles, as well as on the length of the toll route the vehicle drove on. Each vehicle is classified into one of the three categories (A, B or C) depending on its emission category. Correct submission of the emissions classes is the responsibility of the users; users are obliged to make correct declarations in this regard (principle of self-declaration). For all trucks registered in Germany, the vehicle registration certificate or motor vehicle tax statement serves as sufficient proof of a vehicle's emission category. Emission categories of vehicles registered outside of Germany are assumed based on the vehicle's age. This rule applies unless the emission category can be proved by some other means, such as through a statement of compliance with the specific environmental standards.

Table 16. Categories based on emission category in the German Motorway Toll

	Category A		Category B	Category C
From 01/10/2006 to 30/09/2009	Euro 5 and	EEV Class 1	Euro 3 and 4	Euro 1 and 2, and vehicles that do not belong to any emission standard
From 01/10/2009	EEV Class 1		Euro 4 and 5	Euro 1, 2 and 3, and vehicles that do not belong to any emission standard

Table 17. Toll rates per km from 01/09/2007 until 30/09/2008 in the German Motorway Toll

	Category A	Category B	Category C
Up to 3 axles	€ 0,10	€ 0,12	€ 0,145
4 or more axles	€ 0,11	€ 0,13	€ 0,155

The only roadside infrastructure needed are the support beacons and a few toll gantries for enforcement purposes. This means infrastructure maintenance cost is very low. The OBU is provided free of charge, the installation however is to be paid by the truck-owner.

The automatic tolling system is capable of remote updating of the software. Since the introduction of the tolling scheme the tolling network has been updated to include new sections and new junctions by means of data transfer via the mobile communications network (GSM). Tolling was extended to cover several sections of federal secondary roads. This was done for safety reasons, as a result of traffic diverting from the highway to the secondary road.
In addition, the German tolling system has an interface for interoperability with microwave systems. If, for example, an agreement is reached between the German and Austrian operators, trucks using the German OBU will be able to pay their tolls in Austria as well. The German systems also complies with the RCI architecture and specifications.

Enforcement is fulfilled by the Federal Office for Goods Transport (BAG) and performs it with the support of Toll Collect, which is the private company responsible for operating the system. The level of violations is below 2 %. This applies both to domestic vehicles and vehicles from abroad.
The system of checks comprises the following four elements:

- automatic checks using 300 control bridges;
- stationary checks carried out behind control bridges;
- mobile checks carried out by using approximately 280 control vehicles; and
- checks carried out at the conveyer's premises.

When Germany decided to introduce a tolling scheme it was clear that Germany had to accept European law. The Directive 99/62/EC, as modified by Directive 2006/38/EC (see 5.1.1), lays down common principles for tolls and user charges for heavy goods vehicles. The tolls have to be based on the actual costs caused by the use of the motorway, the costs for the construction, operation and upgrading of the motorway network. The infrastructure costs on the federal motorways amount altogether to € 7,5 billion. Heavy trucks impose nearly the half of the costs – € 3,4 billion. The trucks which have to pay toll travel 22,7 billion kilometers per year. This results in an average toll level of € 0,15 per kilometer. The German government planned fuel tax rebates for German trucks to accompany the introduction of its truck km charge. However, the European Commission ruled out their introduction as it was not convinced that they would be introduced in a way that ensured no discrimination in practice between German and foreign conveyers (ECMT, 2006). The German government is examining the possibility of alternatives (reducing motor vehicle tax to the minimum level permissible under EU law or grants to encourage the purchase of cleaner trucks). It has stated that it will not raise the km charge from its current discounted average rate of € 0,124 per km to the initially planned € 0,15 per km until a compensationary reduction of € 600 million in another charge is agreed (ECMT, 2006; BMVBS, 2007).
Revenues are used entirely for the transportation infrastructure: 50% for the federal highways, 50% for federal railways and the inland waterways.

Definition clean vehicles

The amount of toll that needs to be paid is based on the emission standards (see Table 16 and Table 17): the higher the emission standard, the lower the toll per kilometer.

Impact analysis

While in January 2005 the proportion of automatic toll booking (with an OBU) was around 72 %, the current share has increased to nearly 90%. More than 580.000 trucks now have an OBU installed, an increase of 60% over the January 2005 figure. 35% of foreign, non German trucks are equipped with an OBU. This share increases continually which indicates an acceptance of the automatic system as well as the traffic increase in international transport services.
The truck manufacturers also have adopted the OBU: Daimler Chrysler, DAF, MAN, Volvo, Scania and Iveco propose a pre-installation of an OBU when a new truck is ordered, and Renault should start soon to offer the same service.
Over the last 24 months, Toll Collect has sent around 2,06 million toll statements to transport companies (each of them dealing from one to 1.744 trucks). The challenged statements resulted in less than 0,003% reimbursement. The number of violators in the first month was around 4% of the customers. This number decreased to less than 2% (Springer, 2007).

The impact of the toll scheme on different topics was investigated as well (Kossak, 2006; Schulz, 2006; Springer, 2007):

- No traceable increase of the freight charges;
- No traceable impact on the consumer prices;
- A reasonable amount of trucks use/ used alternative toll-free routes;
- No significant shift from heavy trucks to light trucks;
- Significant tendency to a higher average load-factor;
- The number of loaded runs increased by 2.1% to a total of 82.1 %;
- There was an approx. 15% reduction in the number of empty runs;
- The number of containers carried by rail increased by about 7 %;

And as indicated in Figure 7, the share of registered trucks having a “bad” emission class has diminished and the clean ones have increased between December 2004 and December 2006. When they renew their fleets, the transport companies buy cleaner vehicles. This seems to be valid for new vehicles as well as for second hand vehicles (Springer, 2007). This should evolve further, as class 2 and 4 trucks are being charged two more Eurocents as from October 1, 2006 (that means that a truck driving 100 000 km a year will have to pay 2,000 Euros more than before a year).

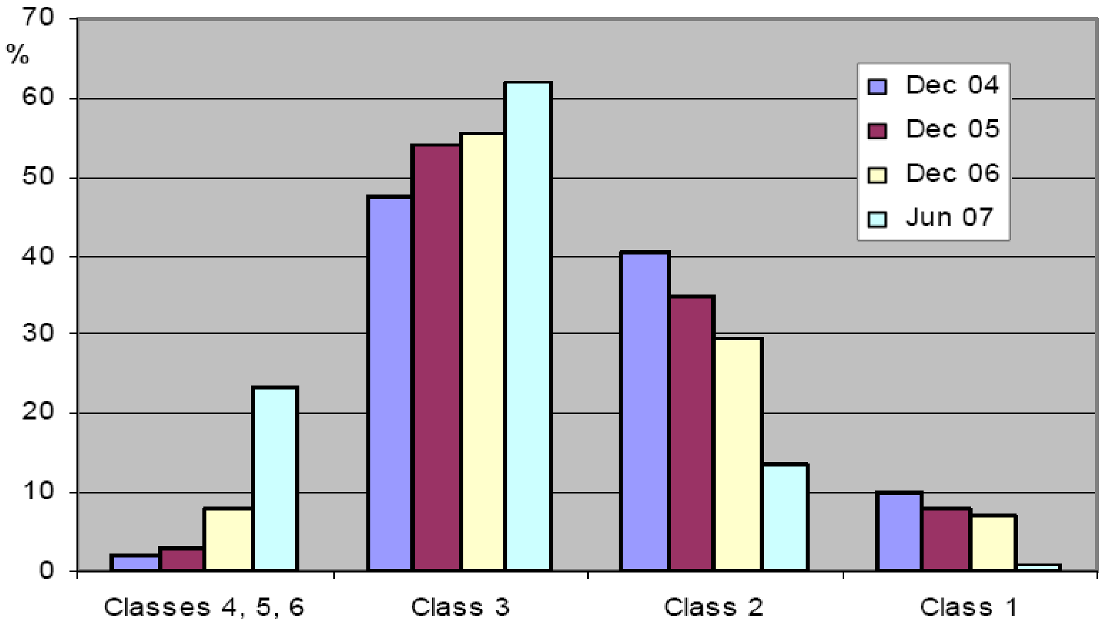


Figure 7. Evolution of the pollution classes of German heavy goods vehicles (class 1 is the most polluting, class 6 the least) (Springer, 2007)

The total investment cost mounted up to € 2.200 million, while operating cost on a yearly basis is € 620 million. Enforcement by the federal office BAG costs € 50 million per year. The fee income in 2005 was € 2.860 million, where € 3.000 million was the expected income. Costs, including capital and operating costs but excluding enforcement, are estimated to be 20 – 22 % of the revenues (ECMT, 2006; Oehry, 2006). This quite high percentage compared to Austria (10 – 12%, see 5.1.4) and especially Switzerland (6 – 8 %, see 5.1.3), is due to the lower cost per kilometer in Germany.

5.1.3. Switzerland

Situation

Switzerland was the first European country to install an automatic toll charging system for heavy goods vehicles. It became operable on 01st of January 2001. Aim is to charge the real costs, internalise external costs, limit the growth of heavy goods vehicles and thus diminish the impact on the environment (Oehry, 2006; ARE, 2007). New railway infrastructure will be financed with the revenues. The toll scheme is valid on every road in Switzerland, not only on highways or secondary roads as in Austria (see 5.1.4) or Germany (see 5.1.2).
The toll replaced fixed annual road taxes for vehicles registered in Switzerland, and is based on distance travelled, the highest authorised weight and the emission standard of the vehicle (see Table 18) . Average toll is estimated to be € 0,67/km, which is planned to be increased to € 0,76/km in 2008 (ECMT, 2006) (see Table 19).

Table 18. Vehicle classes and toll rates from 01/01/2005 until 31/12/2007 in the Swiss Heavy Vehicle Fee (EZV, 2007).

Classes	Emission standard	Toll rate (€ / ton.km)
1	pre-Euro and Euro 1	0,0175
2	Euro 2	0,0153
3	Euro 3 and higher	0,0131

Table 19. Vehicle classes and toll rates from 01/01/2008 in the Swiss Heavy Vehicle Fee (EZV, 2007).

Classes	Emission standard	Toll rate (€ / ton.km)
1	pre-Euro, Euro 1 and 2	0,0186
2	Euro 3	0,0162
3	Euro 4 and higher	0,0137

The technology used is a combination of GSM and GPS technology in an on board unit (OBU), number plate recognition and supported by the information on the digital tachograph.

Definition clean vehicles

The amount of toll that needs to be paid is based on the emission standards (see Table 19): the higher the emission standard, the lower the toll per kilometer.

Impact analysis

The total investment cost was € 200 million, while operating cost on a yearly basis is € 35 million. The total revenue in 2005 was € 800 million. Costs, including capital and operating costs, are estimated to be 6 – 8 % of the revenues (ECMT, 2006; Oehry, 2006). The effects of the Heavy Vehicle Fee are being constantly monitored and evaluated. The most important result five years after the implementation of the fee is a clear change of the trend in kilometres travelled by heavy goods traffic on the roads. After a steady increase in the years before implementation, the kilometers travelled decreased remarkably in the two years afterwards. By the end of 2005, the corresponding figure was still 6,5% lower than in 2000. Further important effects were a significant renovation of the lorry fleet and some concentration in the road conveyer business (ARE, 2007).

5.1.4. Austria

In Austria, a similar system as in Germany and Switzerland has been installed. All vehicles above a permissible gross weight of 3,5 tons are obliged to pay toll. Aim is to finance the extension and operation of the highway network (Oehry, 2006).
The toll is based on the distance travelled and the number of axles of the vehicle (2, 3 or more axles). Average toll is € 0,27/km. Toll collection takes place with a fully electronic toll-system, that allows payment in proportion to the distance travelled without an obstruction of the traffic flow. It uses a mandatory OBU, which is for sale for € 5, and a microwave based 5,8 GHz DSRC technology with roadside radio-antennas on gantries in each motorway section between junctions. It is designed to be interoperable with the Swiss and German systems (Hofstetter, 2006).
The total investment cost mounted up to € 370 million, while operating cost on a yearly basis is € 35 million. The total revenue in 2005 was € 770 million. Costs, including capital and operating costs, are estimated to be 10 – 12 % of the revenues (ECMT, 2006; Oehry, 2006).

The system does not consider any environmental standards of the vehicles, so this system will not be discussed more in detail.

5.1.5. The Netherlands

Situation

The Netherlands initially planned to implement a tolling system using gantries in and around the 4 major cities in a densely populated, mainly urban area called 'Randstad'. The main purpose was to tackle congestion during the morning rush hour, which is a major problem in the Netherlands. Table 20 indicates the effect of implementing a road-building package on road traffic trends in the 2000-2020 period, assuming a business-as-usual situation, i.e. without a pricing policy. In the business-as-usual situation, road traffic is estimated to grow by 50% in the Netherlands. There would be twice as much congestion on the main road network in 2020 compared to the situation in 2000. In the rest of the country, the expected growth in congestion is greater than in the Randstad (ABvM, 2005).

Table 20. Traffic growth projections with business-as-usual scenario, 2000-2020 and impact of road-building package of € 14.5 billion (ABvM, 2005)

	Traffic growth			Congestion					
	Neth.	Randstad	Rest of Neth.	Netherlands		Randstad		Rest of Netherlands	
				main roads	other roads	main	other	main	other
Traffic growth projections with business-as-usual scenario, 2000 - 2020.	+50%	+44%	+54%	+101%	+182%	+80%	+172%	+191%	+199%
Trends between 2000-2020, with road-building package of € 14.5 billion	+53%	+52%	+54%	+42%	+188%	+16%	+173%	+154%	+216%
Impact of road-building package on traffic volumes in 2020	+2%	+6%	0%	-29%	+2%	-35%	0%	-13%	+6%

The tolling system project was to start in the years 2000-2001. Due to the high cost and heavy opposition against the system, the Dutch government decided to abandon its plans. Instead, it investigated the feasibility of implementing road pricing, or a 'kilometre charge', on all roads and for all vehicles. Conventional car taxation would disappear in favour of a system that focuses purely on the use of vehicles (Eurlings, 2007).
In December 2007, the Dutch Minister of Transport announced that the new kilometre charge would be implemented in 2011. In the first year only heavy goods vehicles would be involved. In 2012, road pricing would apply on all vehicle categories. The technology used would be a satellite based system that uses an on-board unit in every vehicle to determine the location of the vehicle, and the distance travelled. In the first phase, toll rates would only be differentiated on the environmental class of the vehicle (most probably the emission standard and/or the CO_2-emission). In a second phase, also the time of day and the type of road would be taken into account. The total revenues should not increase, which means that average drivers would not pay more taxes than nowadays.
In 2008, numerous research projects will be initiated that investigate the different aspects of the road pricing scheme.

Definition clean vehicles

The charge would be differentiated on the environmental class of the vehicle (most probably the emission standard and/or the CO_2-emission) (ABvM, 2005; Eurlings, 2007). Details are unknown.

Impact analysis

The Dutch Ministry of Transport ordered a study to investigate the effect on congestion of certain policy measures. This paragraph is based on the results of this study (ABvM, 2005).
The study concluded that those policy measures that involve paying per kilometre, like a kilometre charge or a charge through fuel taxes, would mitigate the growth of car travel. With these measures, average travel distances would decrease, both as regards commuter

and leisure travel. Over time, the increase in variable car costs leads motorists to seek work and leisure activities closer to home. The number of car journeys declines slightly. More kilometres are travelled with other means of transport, primarily through the use of slow transport modes and rail. This increase depends on the level of the charge and could reach a maximum of 8%.

The calculations include the current progressive tax rates: the heavier the car, the higher the rate per kilometre, as is currently the case with the conventional car taxation. Accordingly, no effects on the composition of the vehicle fleet are expected. In the case where the rates would only be progressive to a limited extent, an effect on the composition of the fleet may be expected: the share of heavy cars and diesel cars would increase.

In the case where a kilometre charge is implemented, a slower growth in car travel is estimated, which means that the growth in congestion is mitigated. Business traffic grows more because of increased locational accessibility. The level of the charge determines the extent of the effects. This relationship, however, is not linear: the higher the charge, the smaller the additional decrease in road travel growth.

Compared to the ‘kilometre charge’, a charge collected through a fuel duty increase would lead to more efficient use of fuel and an increase in the use of petrol stations outside the Netherlands. This means that in the event of a duty increase, the expected effects are smaller than with the kilometre charge.

Implementing the kilometre charge would result in a large environmental gain: the greatest reduction in NOx of all studied measures and to a lesser degree PM_{10} emissions. There is an important relationship between the rate structure and the composition of the fleet. If the rate structure contains no incentives promoting fuels and vehicles that are relatively environmentally friendly, there will be more diesel vehicles and heavier vehicles. In that case, the basic condition of the study in terms of the environment – at least the same effects as in the situation without a price policy – would not be achieved. Environmental effects may improve through further optimisation of the rates in environmental aspects. Differentiation by polluting emissions (emission standard or model year) for passenger cars as well as trucks may result in an incentive to accelerate the renewal of the fleet, with favourable effects for NOx and particulates.

The implementation of the different policy options differs to a large extent. This applies in the first place to the required provisions in the vehicle of the users: no On-Board Unit (manual declaration system), a simple On-Board Unit (DSRC technology) or a more complex On-Board Unit (GPS technology). The consequences for roadside infrastructure are also different: DSRC technology requires more gantries than manual declaration systems and satellite-based systems, but the latter two require more roadside investment for enforcement equipment and other enforcement strategies and tactics. The kilometre charge would implicate a satellite-based system and the use of a complex on-board unit in every vehicle. The kilometre charging scheme for all road users on all roads is new in terms of the scope of the number of road users and the area of application, so no comparison with systems abroad could be performed. Even though technology, organisation and enforcement are scaleable in principle, there are still risks. The risks involved with this innovation result in higher costs and longer introduction periods.

The investment cost of a kilometre charging scheme was estimated at € 2.100 to 3.800 million, operating cost was estimated at € 400 to 1.100 million. The year the scheme could be introduced was estimated to be no earlier than 2011.

5.2. Cordon based charges

5.2.1. London

Situation

In February 2003, the London Congestion Charging scheme was introduced. It was part of a strategy to:

- reduce congestion;
- make radical improvements to public transport, bus services in particular;
- improve journey time reliability for car users;
- make the distribution of goods and services more efficient.

Furthermore, by reducing traffic levels it would also contribute to reduce vehicle emissions. It would also generate net revenues to support the Mayor’s Transport Strategy more generally. The congestion charging scheme is one of the most important initiatives that attempts to fulfill one of the main points in the government's 10-Year Transport Plan: to introduce schemes to reduce congestion and to fund public transport alternatives.

The congestion charging scheme was preceded by a large public and stakeholder consultation of 20 months, as well as an extensive research regarding expected impact of the scheme on environment, business, traffic etc. in London. From the beginning it was clear that if the scheme were to be introduced, the impacts of congestion charging should be comprehensively measured and understood (see further, ‘Impact analysis’).

At first, it was only implemented in a part of central London, but since February 2007, the Western Extension was added to the central London Congestion Charging zone (see Figure 8).

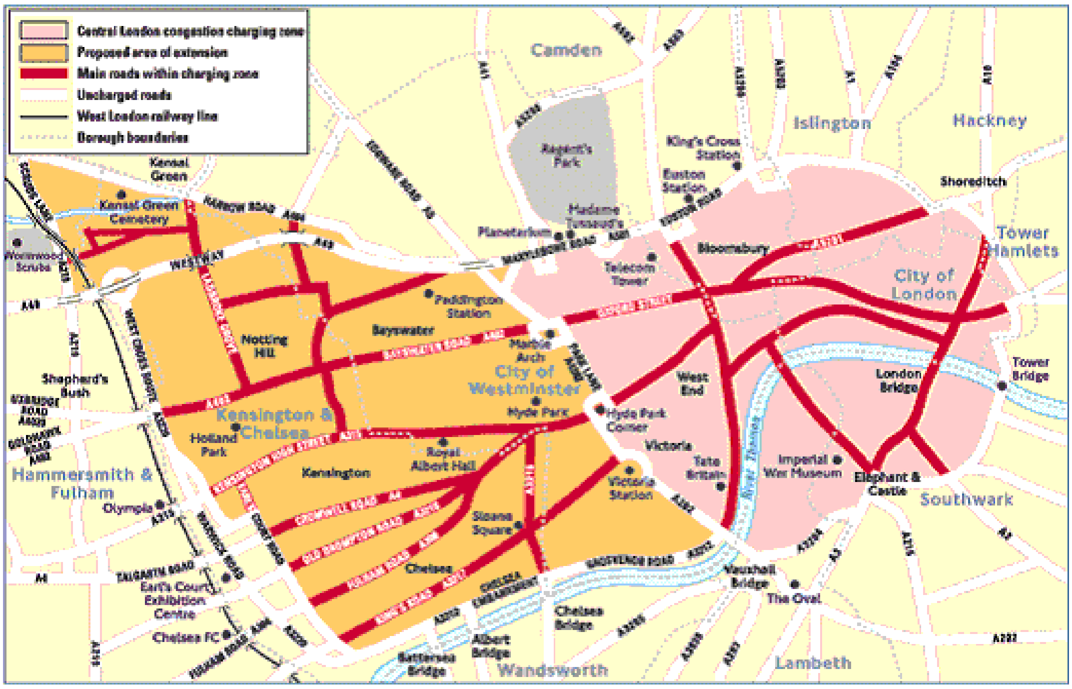


Figure 8. London Congestion Charge : Central Zone (pink) and Western Extension (orange) (CFIT, 2007)

A daily charge must be paid by the registered keeper of a vehicle that is on a public road in the congestion charge zone between 7 am and 6 pm, Monday to Friday, excluding some public holidays. Initially, the charge was set at £5, and raised to £8 in July 2005. The charge has to be paid either in advance, on the day of travel or a day later. This can be done before, during or after the journey or by midnight the following charging day. The charge is £8 if you pay by midnight on the day of travel or £10 if you pay by midnight the following charging day. Failure to pay the charge results in a fine of £100, reduced to £50 if paid within 14 days, but increased to £150 if unpaid after 28 days.
The charge can be paid for a week, for a month or for a whole year in one transaction. Reductions in the form of charge free days are given to drivers who pay monthly (3 free days) or annually (40 free days).
While residents of the congestion charging zone are eligible for a 90% discount, some vehicle categories and/or drivers are exempt from the charge (TfL, 2007a):

- Vehicles with 9 or more seats;
- Taxis;
- Disabled people, or institutions for disabled people;
- Emergency service vehicles;
- Motorcycles;
- Drivers of environmentally friendly vehicles (see further 'Definition clean vehicles').

Vehicles on the 'automated fleet' scheme receive a discount of £1 resulting in a daily charge of £7 per charging day. This is mainly for companies with vehicle fleets over 10 units.

Drivers of foreign-registered vehicles are not exempt from the charge but the current lack of an international legal framework for the assessment and collection of traffic fines makes enforcement and recovery difficult.

Several payment methods are provided (TfL, 2007a):

- Online;
- At selected shops, petrol stations and car parks;
- By post;
- By telephone;
- By SMS text message from a mobile phone;
- At BT Internet kiosks

The charge may be paid the day after at an increased cost of £10. Failure to pay the charge results in a fine of £100, reduced to £50 if paid within 14 days, but increased to £150 if unpaid after 28 days.

There is a network of camera sites monitoring every entrance and exit to the Congestion Charging zone along the boundary road, and monitoring journeys made solely within the charging zone. Each camera site consists of at least one colour camera plus a monochrome camera for each lane of traffic being monitored. The colour camera is used to show a vehicle in the context of its surroundings, whereas the mono camera is used specifically for reading number plates. The cameras send the recorded images to the back office, where Automatic Number Plate Recognition (ANPR) software reads and records each number plate. The new set of cameras in the Western Extension are equipped with a module containing the ANPR-software within the camera. This way only the recognized number plates have to be sent to the back office, instead of all recorded video footage.
The registered vehicle number plates are then compared with the database of vehicles which have paid their congestion charge for that day. If the number plate is matched, showing that the charge has been paid or does not have to be paid (because vehicle is exempt), then the pictures will normally not be kept for longer than 24 hours (TfL, 2007a). Following a final check at midnight (the following charging day), the computer will keep the registration numbers of vehicles that should have paid the charge but have not done so (including charges paid for the previous charging day). Each recorded image is then manually checked before issuing a Penalty Charge Notice.

Definition clean vehicles

Electrically propelled vehicles and vehicles which are on the PowerShift register are fully exempt from the congestion charge. Approval for the PowerShift register is based on the particular combination of vehicle (make, model and model year), equipment (either LPG, CNG or hybrid) and manufacturer or converter.

During 2007 a large consultation was performed regarding the 'Emissions Related Congestion Charging'-proposal. According to this proposal, the congestion charge would be differentiated based on the CO_2-emission of a vehicle. A euro 4 vehicle emitting less than 120 g CO_2/km would be exempt, a vehicle emitting more than 120 but less than 225 g CO_2/km would pay the same as in the current scheme, £8. Vehicles emitting more than 225 g CO_2/km would pay £25, an increase of more than 300% (TfL, 2007a). The report on the consultation is currently being prepared which will be submitted to the Mayor of London.

Impact analysis

In June 2003 Transport for London (TfL) published the First Annual Impacts Monitoring Report (TfL, 2003). This described the scope of the monitoring work that had been put in place to ensure that the impacts of congestion charging were comprehensively measured and understood. Conditions applying before charging across a range of key indicators were set out, and information given describing how and when any changes to these indicators would be measured. This monitoring work is performed every year.
In July 2007, the Fifth Annual Impacts Monitoring Report was published (TfL, 2007b). As with previous reports in this series, it provides a summary and interpretation of the growing amount of data from the central London congestion charging scheme. It makes comparisons with conditions before charging started and, where appropriate, with Transport for London's (TfL's) expectations for the scheme before it was launched in 2003. This chapter summarizes the main findings listed in the Fifth Annual Impacts Monitoring Report.

Developments in the original central London congestion charging zone during 2006

- Traffic patterns: Traffic patterns in and around the charging zone remained broadly stable during 2006. Traffic entering the charging zone (vehicles with four or more wheels) was 21 % lower than in 2002, creating opportunities over this period for re-use of a proportion of the road space made available. Traffic circulating within the zone and on the Inner Ring Road, the boundary route around the zone, remained comparable to previous years following the introduction of the scheme.

- Congestion: During 2006, TfL has observed a sharp increase in congestion inside the central London charging zone. This has occurred despite the fact that traffic levels have continued to remain stable. Congestion levels are being influenced by an increase in activity that has affected the capacity of the road network for general traffic – particularly an increase in roadworks in the latter half of 2006, notably by utilities. In addition, there is some evidence, as first reported in TfL's Fourth Annual Impacts Monitoring Report, of a longer-term 'background' trend of gradual increases to congestion. This is likely to reflect a combination of traffic management programmes that have contributed to fewer road traffic accidents, improved bus services, a better environment for pedestrians and cyclists, and improvements to the public realm and general amenity. But these interventions have also reduced the effective capacity of the road network to accommodate general vehicular traffic. The impact of congestion charging therefore needs to be assessed in this context. The reduced levels of traffic mean that, when compared to conditions without the scheme, congestion charging is continuing to deliver congestion relief that is broadly in line with the 30 % reduction achieved in the first year of operation. The factors discussed above mean that a comparison of congestion levels in 2006 against pre-charging baseline is potentially misleading. However, carrying this comparison through, congestion was 8 % lower in 2006.

- Scheme operation, enforcement and revenues: The scheme generated net revenues of £123 million in 2006/2007 (provisional figures). These are being spent on transport improvements across London, in particular on improved bus services. The operation and enforcement of the scheme continue to work well, with several further improvements and innovations introduced during 2006, alongside TfL's preparations for the introduction of the western extension scheme in early 2007.

- Public transport, accidents and air quality: Public transport continues to successfully accommodate displaced car users, and bus services continue to benefit from the reduced congestion and ongoing investment of scheme revenues. Reductions in road traffic casualties and in emissions of key traffic pollutants in and around the charging zone continue to be apparent, alongside continuing, favourable 'background' trends in both of these indicators for 2006.

- Business and economic impacts: The overall buoyancy of the London economy has contributed to growth in public transport patronage, although volumes of travel to the charging zone by Underground in 2006 were only slightly higher than those that prevailed in 2002. Further economic trend data and comparative analyses continue to demonstrate that there have been no significant overall impacts from the original scheme on the central London economy. General economic trends are considered to have been the predominant influence on the performance of central London businesses over recent years. The central London economy has performed particularly strongly since the introduction of congestion charging, with recent retail growth (value of retail sales) in central London at roughly twice the national growth rate.

The availability of five years of monitoring data in relation to the original central London congestion charging scheme allows a longer-term perspective on the role of congestion charging. In general, charging is seen to have helped accentuate trends that were positive, such as reduced road traffic accidents and emissions; to have helped counteract trends that were negative, such as increasing congestion; whilst having a broadly neutral impact on general economic performance. A cost-benefit analysis of the central London scheme suggests that the identified benefits exceeded the costs of operating the scheme by a ratio of around 1.5 with an £5 charge, and by a ratio of 1.7 with an £8 charge.

Western extension zone: the first three months

The western extension to the central London congestion charging zone was successfully introduced on schedule on 19 February 2007. From this date, the extension zone operated alongside the existing central London zone, creating an enlarged central London congestion charging zone. From the outset all major operational elements of the scheme functioned well, and there were no traffic or other problems of significance. Early findings from the monitoring work indicate a set of outcomes that accord closely with TfL's expectations for the scheme. However, these results must still be regarded as provisional and more data is required to confirm and consolidate the longer-term picture.

- Traffic entering the extension zone over the first three months of operation is typically down by between 10 and 15 % against equivalent levels in 2006.
- The volume of traffic circulating within the extension zone is typically down by 10 % against comparable values in 2006.
- Traffic on the free passage route running between the original and extended zones is effectively unchanged in aggregate terms by the extension scheme.
- Traffic on the remainder of the western extension boundary route has increased in aggregate by a small amount (generally up to 5 %), as expected by TfL. There is no evidence of any significant traffic operational problems on this key route.
- There is some evidence from counts of traffic entering the original central zone of small increases (generally up to 4 %) following the introduction of the scheme, as anticipated by TfL. However, indicators of traffic circulating within the original charging zone are tending to indicate small reductions.
- TfL's current assessment would therefore be that aggregate traffic volumes in the original central zone have not changed significantly as a result of the extension scheme. Similarly, congestion levels in the central zone during this period are commensurate with those in 2006, and do not appear to have been affected by the introduction of the western extension zone.
- The first comprehensive survey of congestion in the western extension suggests that congestion has reduced by between 20 and 25 % against comparable values in 2005 and 2006. A value for excess delays of 1.2 minutes per kilometre for March/April 2007 compares to a value for equivalent months in both 2005 and 2006 of 1,5 minutes per kilometre.

5.2.2. Stockholm

Situation

In June 2003, the Stockholm City Council adopted a proposal to introduce congestion charging on a trial basis, and decided to ask the Swedish government for permission. A few days later, the Swedish Parliament adopted the Congestion Charges Law, with an annex relating to the Stockholm Trial. The National Road Administration, was given responsibility for the technical design, and the City of Stockholm was tasked by the government with responsibility for evaluating the trial and providing information about it. The trial was financed by state funding (Stockholmsförsöket, 2006a).

The main objectives of the trial were to investigate if the implementation of congestion charging in the city of Stockholm would lead to (Hugosson, 2006):

- a reduction in traffic volumes on the most congested roads (expected to be -10 to -15% during rush hour);

- an improvement in traffic flows, or in other words an increase in average speed;
- a reduction in the emission of CO_2 and pollutants harmful to human health (mainly particulate matter and NOx);
- an improvement of the urban environment as perceived by Stockholm residents.

The congestion charge was one of 3 pillars of the Stockholm Trial, next to improved/extended public transport and park & ride facilities. The Stockholm Trial began in August 2005 with extended public transport, and ended on July 31, 2006. The actual congestion charge was levied between January and July 2006. A referendum was held in the city of Stockholm, on the question of whether the congestion tax should be made permanent in Stockholm. The result was in favour of maintaining the congestion tax (Stockholmsförsöket, 2007): 51,3% of the voters in the city of Stockholm voted in favour. Apart from the city of Stockholm, 14 other municipalities in the county of Stockholm held referendums on the implementation of the congestion charges. The result here was opposite: only 39,8 % voted in favour. As a result of the referendum, a permanent system was implemented in August 2007.

The congestion charge is levied on an area of 47 km², and by means of 18 control points on roads entering the city (see Figure 9).

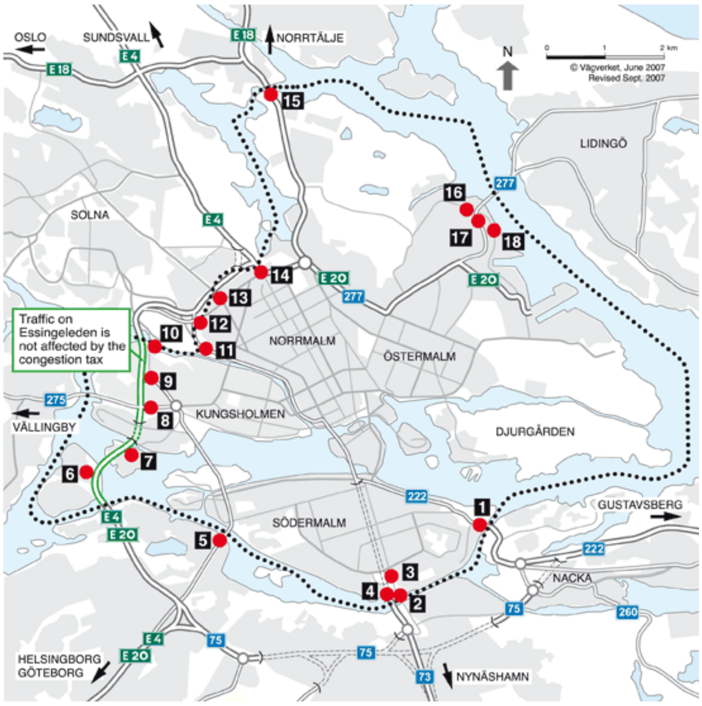


Figure 9. Control points in the city of Stockholm used in the congestion charge scheme (Vägverket, 2007).

Since a combination of antennas, lasers and cameras on gantries above the roads is used to register the license plates of vehicles entering the city, traffic is not obstructed (see Figure 10).

Figure 10. Congestion charge gantry in the city of Stockholm (Hugosson, 2006).

Vehicles are registered automatically at the control points during the times when the tax is charged. The cost of each passage into or out of the inner city zone depends on the time of day (Vägverket, 2007), and is shown at the control points on variable signs:

- during peak hours (7.30-8.30 am and 4.00-5.30 pm): SEK 20 or € 2,20;
- during semi-peak hours (7.00-7.30 am; 8.30-9.00 am; 3.30-4.00 pm; 5.30-6.00 pm): SEK 15 or € 1,65;
- during medium-volume periods (6.30-7.00 am; 9.00-3.30 pm; 6.00-6.30 pm): SEK 10 or € 1,10;
- no charge is levied between 6.30 pm and 6.30 am, and on Saturdays, Sundays, public holidays, the day before a public holiday and during the month of July.

The accumulated passages made by any vehicle during a particular day are aggregated into what is called a “tax decision”. The maximum amount charged per day and vehicle is SEK 60 or € 6,6 per day.
The congestion tax is to be paid retroactively. There is no possibility to pay at the control points. The tax must be paid into the Swedish Road Administration’s congestion tax account no later than 14 days subsequent to passage. It is the vehicle owner who is responsible for paying the tax. No invoice is sent out. The congestion tax can be paid through as follows:

- Direct debit: The tax is drawn automatically from the bank account specified, meaning you don´t have to keep track of when or how much to pay.

- Pressbyrå kiosk and 7-Eleven shops: the charge can be paid over the counter at Pressbyrå kiosks or 7-Eleven shops throughout the entire country.
- Internet payments using a credit or charge card can be done at the Swedish National Road Administration's website.
- Bank and PlusGiro: the charge can be paid at the bank, via Internet banking or using envelope services provided by banks.

Vehicle owners can see the tax amount they are liable to pay through logging into a dedicated website. Users can log in by using either an e-identity or the authorisation code found on the vehicle registration certificate. This is a code that is printed on all registration certificates.

Some vehicles are exempt from paying the congestion charge:
- Emergency vehicles;
- Vehicles with disability permits;
- Foreign vehicles;
- Transport services for the disabled;
- Taxis;
- Motorcycles;
- Buses over 14 tons;
- Clean vehicles (see further).

Definition clean vehicles

Clean vehicles are exempt from paying the charge, and are defined as vehicles that according to the Swedish Road Administration's vehicle registry are equipped with technology for running (Vägverket, 2007):
- completely or partially on electricity or a gas other than LPG;
- on a fuel blend that predominantly comprises alcohol.

This is a different definition of a clean vehicle than the one used in the city of Stockholm, e.g. for free parking permits granted to clean vehicles, where small petrol cars and diesel cars equipped with a particulate filter are considered a clean vehicle as well (see 10.2.2). This difference is mainly due to the fact that the congestion charge is regulated on the national level, whereas parking is a local competence**.** This difference in definition is mainly due to the fact that small cars are currently hard to identify in the car register, which is used by the congestion charge scheme to bill the vehicles. However, the car register is being changed and from February 2008 this should be possible. It is not clear whether the national definition of clean vehicles will be adopted. Opinions differ between the policy makers involved (Sunnerstedt, 2007).

Impact analysis

A comprehensive evaluation programme has been set up to assess the extent of goal achievement and the effects of the Stockholm Trial that ran the first half of 2006. This programme, the actual measuring work, analyses and reports have been performed by government institutions (a.o. the Swedish Road Administration), various research institutes, independent consulting companies as well as some city administrations. The three primary goals of the trial were reduced traffic, a better environment and perceived improvements to the city environment. In general it could be stated that the goal of traffic reduction has been achieved, and thereby also the environmental goal. The degree of achievement of the city environment goal is more difficult to interpret. Both the general public and business owners have gradually become more positive to the tax and the trial from their own experiences and when the benefits started to emerge

This paragraph on impact analysis is based on the final report of the evaluation programme (Stockholmsförsöket, 2006b).

- Motor traffic decreased more than expected: The trial cut traffic flows more than expected, and the reduction was stable if normal seasonal variations are taken into account (the annual spring increase in traffic, also from cyclists and pedestrians). A reduction of 10-15% was expected, but the actual reduction for the entire congestion tax periods over 24 hours was about 22%. In addition, the effects were noticeable further away from the congestion-charge zone than first anticipated. There was no noticeable negative impact on suburban link roads, which was one of the feared side effects.

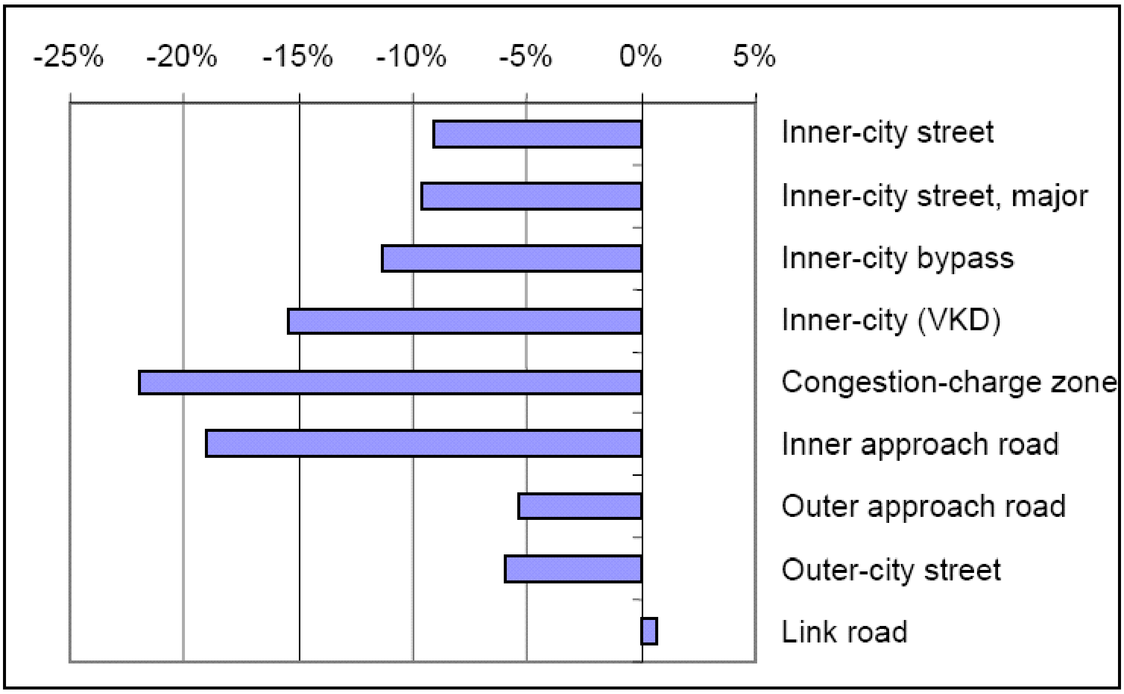


Figure 11. Average traffic reductions for different types of roads and streets (Stockholmsförsöket, 2006b)

The decrease in traffic across the cordon was largest during the morning and afternoon rush hours. The largest reduction occurred in the afternoon, which was probably due to the fact that afternoon journeys are not as fixed in terms of times and destinations as morning commuter journeys. Traffic also fell in the evenings after the congestion tax period.

- Access improved: Access improved and travel times fell as a result of the reduction in motor traffic. Travel times for motor traffic fell in and around the inner city. Particularly large reductions were noted on approach roads, where queue times decreased by a third in the morning rush hour and were halved in the afternoon rush hour. This also had a positive impact on the reliability of travel times. Traffic decreased on most major roads, but increased on others. In generally these increases were significantly smaller and fewer in number than the larger-scale decreases. Traffic fell more in the afternoon than in the morning, and more across the actual charge zone cordon than within the inner city or further away, outside the cordon.

- Traffic reductions lead to less environmental impact and better health: The amount of emissions caused by traffic are estimated by vehicle kilometres driven (VKD) combined with emission factors. The emission factors used were affected by the distribution of different types of vehicles and by how the vehicles were driven: a driving pattern with large variations in speed produces more emissions than driving at an even speed. Since these calculations were based on estimates, exact calculations of how much the Stockholm Trial decreased emissions was difficult. However, the different emissions models arrive at similar conclusions.

The Stockholm Trial reduced CO_2 emissions, and the drop is approximately in proportion with the reduction in VKD, which means that the contribution from traffic in the county has been reduced by 2-3 %, and in the inner city by about 14 %.
Total particle emissions have fallen by about the same amount as traffic volumes, but in the case of these substances, the place where these emissions decrease is of primary importance, because they contribute to concentrations at local level. The Stockholm Trial reduced the contribution from traffic by about 5% for the whole county and 10% for the inner city.
Due to the complexity of factors, such as chemical reactions, it was not expected that congestion charging would make a major contribution to achievement of environmental quality values for NO_2.
Due to the limit for people's ability to discern a difference in noise level is 3 dB(A), which in traffic contexts corresponds to an approximate doubling or halving of the traffic volume, the Stockholm Trial only had a marginal impact on perceived noise levels (-1 to -2 dB(A) for average levels over 24 hours).

Calculations based on effects linked to premature death as a result of exposure to air pollutants show that the reduction in traffic due to the Stockholm Trial saves about 5 life years. Calculations, according to new research findings, demonstrate that up to 25-30 premature deaths can be prevented per year. This corresponds to about 300 life years.
The authors of the evaluation report stated that congestion charging potentially has a greater effect on health per equal amount of emissions than a tax increase on fuel. This is because the reduction of emissions can be controlled by deciding where to debit the congestion tax, i.e. where people are more exposed to pollution. The reduction in emissions as a result of congestion charging in the inner city has a health benefit for the whole county that is about three times higher than the benefit that would have been gained had the reduction in emissions been achieved through an increase in fuel prices evenly distributed throughout the county.

- Difficult to determine if city environment improved: The city environment is a complex and diffuse concept, without a given definition. It is also difficult to measure. It is therefore risky to comment on the goal on a more general level. It is clear however that people perceive the city environment improved in those respects for which changes can be measured. The results show that there is perceived improvement of the factors that are linked to the reduction in traffic: traffic speed, air quality and access for motor vehicles.

- Use and sale of clean vehicles: An adaptation for avoiding the charges was to use a clean vehicle, which reduced the environmental impact to a small extent. Increased use of clean vehicles did not however reduce congestion. Since even the use of clean vehicles gives rise to negative environmental consequences, the congestion charge could reduce positive effects on the environment, if people with access to clear cars exploit available increased access to increase their own car travel. In the travel pattern study, there were no signs of such an effect.

During the trial there was about 4 % clean vehicles in the zone as opposed to 2,5 % clean vehicles in the region at that time. Clean cars were slightly over represented in the zone. Registration statistics show that the number of new clean vehicles reached a record level during 2006 and amounted to 36.611 vehicles on a total of approximately 700.000, an increase by 156 % compared to 2005. Since the introduction of free parking in 2005 (see 10.2.2) and the exemption from congestion tax in 2006, 19% of all vehicles sold in Stockholm are clean vehicles. Nationwide, this figure is 13% (Blom et al ., 2006 ; Sunnerstedt, 2007). In December 2005, around 30% of the new Volvo's and 90% of the new Saab's were considered clean vehicles. The increase was realized especially in the region of Stockholm (Miljöforden, 2006b).

- <u>Performance of the system:</u> It can be concluded that on an average day in May, 371.300 passages took place across the charge zone, leading to 115.100 tax decisions and a revenue of over € 330.000. Of the 115.000 tax decisions, 100 were asked to be reviewed by the Swedish Tax Agency and 5 were appealed to the Stockholm County Administration Court. On the basis of these figures, the authors of the evaluation report conclude that the system worked well on the whole. The case studies that were made indicate that certain adjustments in the system are required to reduce cumbersome administration for companies.

- <u>Marginal affect on regional trade and commerce:</u> The short-term influence on commerce and other business sectors that were studied shows only minor average effects. These effects often disappear among other factors with greater impact, such as newly established businesses in the commerce sector. The turnover surveys that have been done indicate that the Stockholm Trial has had little effect on the retail trade in the region. The study of sales of consumer durables in shopping centres, galleries and department stores during the period shows that they developed at the same pace as in the rest of the country. The conclusion cannot be drawn that the Stockholm Trial has had a negative influence on small-scale businesses as a whole within the charge zone. However, it was impossible to state that individual workplaces or companies were not adversely affected.
  In most cases the congestion tax had only a marginal effect on companies' total transport expenses. For households, the congestion tax according to the Stockholm Trial's model during one year corresponds to approximately 0,1 % of combined disposable income. The groups who, on average, paid most congestion tax per person consisted of men, high-income earners, married/cohabiting couples with children, and residents of the inner city. This means that purchasing power in the county was not influenced markedly, even if the tax may have had significant consequences for individual households. The model-calculated long-term effects are not greater than the normal price variation between two quarters of the year.

- <u>Congestion charges are (macro)economically profitable:</u> A permanent implementation of the congestion tax system is calculated to yield a significant annual cost-benefit surplus, about € 83,6 million (after deductions for operating costs). The congestion tax system's investment cost after four years would be "repaid" in the form of benefits to society. That is a very short repayment time compared for example with road or public transport investments, which in moderately favourable cases "pay off" in economic terms in 15-25 years. From the viewpoint of benefit to society, the most relevant decision perspective is to ignore the investment cost – the trial cannot be undone and the investment money is spent and gone. But the congestion tax is economically profitable even if the cost of investment is taken into consideration.

The cost-benefit surplus of the congestion tax consists, among other tings, of shorter travelling times (worth € 66 million annually), increased road safety (€ 13,75 million annually) and health and environment effects (€ 9,9 million annually). The revenue from the congestion tax is estimated to be about € 60,5 million annually (when the system's operation costs are deducted). For every € collected in congestion tax, there is a cost-benefit profit to society of a further € 0,90.

6. Subsidies

Subsidies are all kind of direct incentives given at the moment of purchase of a car or retrofitting the car which can not be qualified as fiscal incentives. European subsidy regulations are quite complicated and there is a clear shift from subsidies towards fiscal incentives for cleaner vehicles. One of the larger subsidy programs in the EU was the UK Powershift and Clean Up program (Govaerts, 2005). This program has been abolished because it was not in line with the European legislation on subsidies. Also the Swiss program is not a subsidy program anymore but gives fiscal incentives for the purchase of energy efficient vehicles[7].

6.1. Clean vehicle incentives in Sweden

Situation

In Sweden already for several years different initiatives are set up for the promotion of cleaner vehicles on the local and national level. Sweden, especially the bigger cities like Stockholm, Götheborg and Malmö, were and are forerunner in the demonstration of new vehicle technologies. Apart from legislation supporting alternative fuel infrastructure (all fuelling stations are obliged to supply at least one renewable fuel like biogas of bioethanol) several incentives are in place to promote the purchase and use of cleaner vehicles. The Swedish case is also presented in the chapters on road charging and voluntary agreements.

Following cleaner vehicle incentives are in place at present for promoting the purchase of cleaner vehicles, most of them have been implemented since 2000 or later (Goldman, 2007 ; Brentebraten, 2007).

- Fiscal measures: reduction of company car tax of 20-40% (since 2004) ; lower registration tax
- Subsidies: 1100 EUR bonus (10.000 SEK) for private consumers for purchasing cleaner cars ; reduced vehicle insurance premium of 20%
- Public fleet quota: 85% of new vehicles of national authority (since 2006)
- User advantages: free parking in 16 cities
- Road charges: exemption from congestion charges in Stockholm and other cities.

The target of the cleaner vehicle strategy is to avoid the sales of 'fossil-fuels-only' cars in 2015. (Goldman, 2007).

The combination of all incentives makes the use of alternative fuelled vehicles competitive compared to the fossil fuelled vehicles. The payback period for investing in cleaner vehicles is 30 months for private cars and 15 months for company cars (taking

[7] www.infovel.ch

annual mileage of 15.000 km as a side condition). For taxis this pay back period is estimated at 8 months (annual mileage of 90.000 km) (Goldman, 2007).

Definition clean vehicles

Several local authorities initiated initiatives to promote cleaner vehicles the last 20 years but were not working with the same definition of cleaner vehicles (Goldman, 2007). In December 2005 the Government issued a new decree comprising criteria for the purchase and lease of vehicles for the state and stressed the importance of authorities, county councils and municipalities using the new criteria (Miljöforden , 2006a). Recently, the definition of cleaner vehicles which is especially fuel/technology based is harmonised for all supporting measures by local and national authorities:

Cleaner cars are:

- Cars that run on renewable fuels with a fuel consumption no more than 9,2 l/100 km petrol equivalent;
- Fuel-efficient cars that run on non-renewable fuels, no more than 120 g CO_2/10 km and low emissions of particulate emissions (at least euro 4 or better).
- Electric and hybrid cars

Impact analysis

For the impact analysis, it's difficult to assess the impact of the individual measures. Registration statistics show that the number of new clean vehicles reached a record level during 2006 and amounted to 36,611 vehicles, an increase by 156 per cent compared to 2005. During 2006 13.5 per cent of all new cars were clean vehicles, compared to 5.2 per cent during 2005. The increase of the percentage of clean vehicles has however slowed down during the latter part of 2006 as a consequence of the Government's slow progress in delivering information about the promised premium for private persons who purchase clean vehicles. (Miljöforden , 2007a). In total approximately 40.000 cars which is almost 1% of the total Swedish fleet run on alternative fuels. It is expected that in 2007, 20% of new car registrations will be cleaner cars[8].

Figure 12 shows that the majority (70%) of cleaner car registrations are flexi-fuel cars which run on E85. Total cleaner car registrations are 13% of total new car registrations in Sweden (Brentebraten, 2007).

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[8] Official Gateway to Sweden (www.sweden.se)

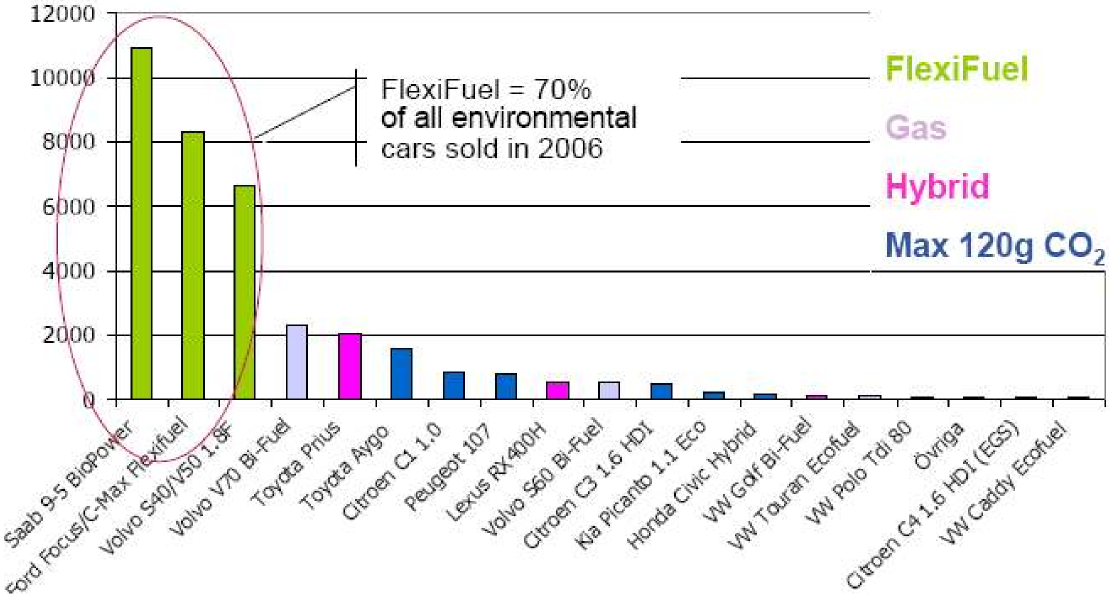

Figure 12. clean vehicle sales per technology (Sweden, 2006)

For the specific analysis of fleet quota (chapter 9) , user advantages (chapter 10) and road charging (chapter 5) promoting purchase and use of cleaner vehicles in Sweden, we refer to the dedicated chapters.

6.2. Subsidies in Belgium

Situation

In Belgium, private persons could benefit from a reduction of income taxes for cars with very low CO_2-emissions purchased (see chapter 4.3). One of the disadvantages of that system is that the benefit for the consumer is paid back only 2 years after investing in a fuel efficient car so the impact on the purchase decision was said to be limited.

From July 2007, the system changed into a subsidy which is given directly as a reduction on the purchase invoice by the car dealer, who has to claim the reduction from the federal administration. The reduction is given for passenger cars with low CO_2-emissions and passenger cars equipped with a particulate filter. The subsidy is only given to private persons and not to companies. The amounts of the reduction are the same for cars with low CO_2-emissions as the old system (15% of purchase price for cars with very low CO_2 with maximum of 4350 EUR and 3% of purchase price for cars with low CO_2 with maximum of 810 EUR). The basic fixed reduction for a particulate filter is 150 EUR which is around 200 EUR indexed in 2007.

Definition clean vehicles

- Passenger car with very low CO_2-emissions: $0 \leq CO_2 \leq 105$ g/km
- Passenger car with low CO_2-emissions: $105 < CO_2 \leq 115$ g/km
- Passenger car equipped with particulate filter providing that CO_2-emissions are lower than 130 g/km. There is no certification scheme for the particulate filter, but it has to be equipped by the manufacturer and the particulate emissions can not exceed 5 mg/km.

Impact analysis

Since the recent introduction of the measure, the impact of the measure on sales of new cars with low CO_2 and/or particulate filter is not yet known.

6.3. Retrofit subsidy in Netherlands

Situation

In the Netherlands, a reduction on the registration tax is given for passenger cars equipped with a particulate filter since June 2006. At the same time, subsidies are given for the purchase of particulate filters for retrofitting old diesel light duty vehicles and heavy duty vehicles. The subsidy amounts to 500 EUR for the purchase of a particulate filter, which almost covers the full price of the filter.

Definition clean vehicles

The subsidy is given for the purchase and installation of a half-open particulate filter which reduces particulate emission with 30-50%. A list of certified filters which can receive the subsidy is available online.

Impact analysis

Since the start of the subsidy program, already 27000 retrofit filters have been subsidized by the Dutch Government of which the majority after an information campaign which started in April 2007. In August 2007, the Dutch government decided to increase the total budget for retrofitting from 20 to 40 million EUR, which will allow subsidizing 80.000 filters[9].

[9] Platform Schone Voertuigen, Nieuwsbrief Juli/Augustus 2007, http://www.platformschonevoertuigen.nl

7. Voluntary agreements and quota for public fleets

In the next chapters incentives and legislation towards fleets are discussed. Per fleet type the measures are discussed: measures or incentives directed to public fleet operators (public transport fleets, vehicle fleets of national or local authorities) ; measures or incentives directed to private fleet operators and measures or incentives directed to car industry (and thus total new vehicle fleet). For each of the fleet types, we see 3 different types of initiatives: voluntary agreements where the fleet operators or car industry commit themselves for purchasing and using cleaner vehicles (possibly combined with information programs or procurement initiatives) ; fleet quota where legislation is in place to purchase a certain % of cleaner vehicles or mandatory targets are set to share of cleaner vehicles in the total fleet. Fleet quota can be accompanied by emission trading where fleet operators or car manufacturers who can't meet the quota can trade clean vehicle certificates with others who achieve a surplus on the quota.

7.1. European legislation

End of 2005, the European Commission published a proposal for the promotion of clean road transport vehicles which has the objective to set mandatory targets for the integration of cleaner vehicles in public heavy duty fleets (EC, 2005c). This proposal uses the existing "Enhanced environmentally friendly vehicle" ("EEV") for Heavy Duty Vehicles standard (above 3.5 t weight) as basis for part of the fleet. Public bodies are required to allocate minimum quota of their annual procurements (purchasing or leasing) of heavy duty vehicles to vehicles meeting the Enhanced environmentally friendly vehicle performance standard.
The clean vehicle procurement obligation proposed in this Directive is limited, in a first stage, to vehicles above 3.5 t weight in order to allow the smooth introduction of environmental award criteria into the vehicle procurement process and to prepare public bodies and industry for a possible extension to other vehicle categories in later stages. This category of vehicles includes buses and most utility vehicles, such as
refuse collection lorries. An extension of the clean vehicle procurement obligation to passenger cars and light duty vehicles based on a thorough impact assessment could be considered at a later stage, once environmentally enhanced performance standards have been developed for them. This Directive is expected to result over the long term in a general improvement in the environmental performance of the whole fleet through economies of scale, lower costs and wider deployment of enhanced environmentally friendly vehicle technologies.
The principal conclusions of a consultation of experts and involved organisations were that this directive could have a positive impact on the market of clean vehicles and on the environment, that the effect of such an initiative was optimal for certain categories of vehicles, and that it could support industry in the development of cleaner technologies. A technology neutral approach was recommended in order to allow flexibility for industry to adjust to technical and economic progress.
In the proposal, a quota of 25% in the public heavy duty fleet is proposed. This quota represents about 10% of the total heavy duty market, as this consists of $1/3^{rd}$ of public

procurement. This would be about the minimum required for mass production series large enough to achieve economies of scale. Procurement of environmentally better performing vehicles also should not go beyond what is required to bring cost down in order to optimise the use of public money and confine it to the support necessary to get these technologies economically viable so that they are taken up by the wider private markets on a competitive basis. This broader market uptake will then provide also much larger environmental gains.

At present, the proposal for directive has not been approved yet. The stakeholder consultations held in the framework of the adaptation of a new Green paper on Urban Transport nevertheless stress the importance of such green procurement in opening the market for cleaner vehicles and ask the European Commission to proceed with the approval of the green procurement directive, possible extended to light duty vehicles as well. An integrated well-to-wheel approach defining the 'environmentally enhanced light duty vehicle' will be necessary when setting quota for light duty vehicles as well (MVV, 2007)

The European NICHES project on sustainable transport summarised following conclusions on the impact of joint procurement of cleaner vehicles:

- shows the vehicle manufacturers the demand of AFVs;
- supports the introduction of new models of AFVs on the market;
- speeds up the market introduction of new technology;
- can also be a way to reduce the price of AFVs.

A public authority can have a double role in joint procurement. It can join a buyers' consortium of cities that jointly procure cleaner vehicles or it can establish a local buyers' consortium of local private or public buyers to exploit the economies of scale. The first type is mostly focussed on the introduction of alternatively fuelled vehicles and organised in large European demonstration projects like for example in the ZEUS project on electric vehicles or the CUTE project on fuel cell buses (Niches, 2007).

CIVITAS is the program of the European Commission which support the implementation of initiatives in clean urban transport in European cities. The evaluation results of CIVITAS I were made public in 2006 (METEOR, 2006). The introduction of cleaner vehicles in public fleets is a seen as a very efficient measures for promoting the use of cleaner vehicles in general. In Table 21 an overview is given of the cities implementing cleaner vehicle initiatives in public fleets, in the framework of the CIVITAS I program.

Table 21. cleaner vehicle initiatives in public fleets in CIVITAS I project (Meteor, 2006)

City	Measure code	Measure title
		Public Fleets
Barcelona	12.3	Extension of the CNG bus fleet
Bristol	5.1	Clean and efficient buses
	5.2	Clean fleet vehicles
Bucharest	12.5	Clean & silent public transport fleet
Cork	12.2	Municipal Fleet Vehicles
Göteborg	12.7	Introduction of clean vehicles in public and private fleet
	12.8	Introduction of clean waste collection vehicles
Graz	12.3	Clean and user friendly bio-diesel bus fleet
Lille	12.2	Biogas bus fleet
	12.5	Clean municipal fleet
Nantes	IP 1 – IM 1	Clean and efficient buses
Rotterdam	12.1	Clean & silent public transport fleet
	12.3	Cleaner Vehicles for Waste Collection
	12.4	Electric vehicles in public fleets
Rome	12.1	Clean Vehicles Buses
Stockholm	12.1	Clean and efficient heavy vehicles
	12.4	Clean municipal fleet
	12.6	Waste collection with biogas-vehicles
Winchester	12.1	Clean Vehicles Buses
	12.2	Cleaner Municipal Fleets

In the following chapter, the Swedish case study is further documented.

7.2. Green procurement in Sweden

Situation

Since the nineties, Stockholm and other Swedish cities participated in several European funded projects on the introduction of cleaner vehicles and joint green procurement initiatives more specific. Stockholm joined other cities for jointly procuring vehicles with alternative fuels or drivelines, for example electric vehicles in the ZEUS project and fuel cell buses in the CUTE project. Stockholm also organized joint procurement of local (private) consumers for the buying cleaner vehicles like in Trendsetter project and the ongoing BEST project on bio-ethanol cars.

In Trendsetter (CIVITAS I project), local small transport companies and companies with larger vehicle fleets have been invited to take part in the procurement. Both biogas and electric hybrid vehicles were included. The purpose has been to push car manufacturers to introduce more clean vehicles onto the market. The long-term goal is a self-supporting market of clean vehicles in Stockholm.

The common procurement process was split into three phases. The first step was a market study to find out the interest among 10,000 enterprises and public institutions with potential buyers. Another market survey looked into what vehicles models were already on the market and the price for them. The second step was an information campaign and the forming of a buyers' consortium. The last step was the procurement itself, which was a European wide tender invitation to vehicle manufacturers. The procurement resulted in framework agreements for purchasing 5,000 vehicles to prices that, depending on model, were 4–15% lower than market prices. It contributed strongly to the early introduction of the Toyota Prius electric-hybrid vehicle in Sweden. Trendsetter has funded part of the additional cost of the clean vehicles for qualified buyers. There has also been continuous information, education and seminars for the buyers as well as environmental monitoring and evaluation of a part of the vehicles. During the project, a network called "At least one clean vehicle" was started by the Swedish Television company. Members are companies in Stockholm that have at least one clean vehicle in the organisation. Many of them received subsidies from Trendsetter. The network now has about 40 companies as members and more than 200 clean vehicles have been sold to them. Besides being "ambassadors" for clean vehicles, the network tries to increase the number of fuelling stations for biofuels.

The City of Göteborg also participated in the CIVITAS I program aiming at increasing the amount of clean vehicles both in the city as a whole and within the municipal fleet. This was achieved by developing new methods and working with more active information strategies such as communication directed towards special target groups, well-directed incentives and demands on procurement (Meteor, 2006).
All clean vehicle initiatives in Swedish cities are supported by a clean vehicle task force which hosts a webportal with information and results of the cities' initiatives.

In 2003, the Swedish government decided that 25 per cent of all vehicles bought by governmental authorities should be clean vehicles. Since there is no all encompassing national definition of what a clean vehicle is, the National Road Administration has been commissioned to work out such a definition. (Miljöforden , 2004a). At the end of 2004, this quotum was increased to at least 50% of all vehicles (Miljöforden , 2005).

Definition clean vehicles

In the past, the different local authorities worked with different definitions of cleaner vehicles. Only since 2005 this definition is harmonised for most of the measures and local initiatives. Cleaner vehicles are vehicles that:

- Run on renewable fuel for more than 50%;
- Low CO_2-emitting vehicles (below 120 g/km) providing that particulate emissions are below EURO4 limit;
- Electric and hybrid vehicles

Impact analysis

The impact on the introduction of cleaner vehicles compared to the target in the CIVITAS I project is given in Table 22.

Table 22. results of CIVITAS I initiative in Stockholm and Göteborg public fleet (Meteor, 2006)

Stockholm	Purchase of 26 heavy biogas vehicles (distribution trucks and/or buses).	26 heavy biogas vehicles purchased	Notable
	Purchase of 200 clean municipal fleets vehicles.	200 clean municipality fleet vehicles purchased	Notable
	Purchase of 7 biogas refuse collection vehicles to replace diesel vehicles.	7 Biogas refuse collection vehicles purchased	Notable
Göteborg	1) 250 new clean vehicles in municipal fleet; 2) Increased awareness for retailers and end users.	1) About 200 new clean vehicles; 2) Increased number of visitors to the national website of clean vehicles, as well as acceptance and satisfaction.	Notable
	1) 1500 new private clean vehicles; 2) Increased awareness for retailers and end users.	1) About 3000 new private clean vehicles. 2) Increased number of visitors to the national website of clean vehicles, as well as acceptance and satisfaction.	Notable
	Purchase of 4 clean heavy waste collection vehicles.	4 clean heavy waste collection vehicles purchased	Notable

Approximately 70 per cent of the Göteborg municipality's vehicle fleet of private cars and light transport vehicles is now clean vehicles. For several years is has been difficult to develop gas powered transport vehicles but there are now several models available that are suitable for municipal services and maintenance operations (Miljöforden , 2007a).

In Stockholm, using clean heavy vehicles is a step in the right direction to solve the problem of global warming and local emissions. One measure aimed at demonstrating that clean heavy vehicles (buses and lorries) could replace conventional diesel vehicles in an efficient way. Another project was to accelerate the take up of clean vehicles within private companies and in the municipal fleet. This project was successful and more than 3000 clean vehicles were introduced during the project. The successful introduction of clean (biogas) waste collection vehicles in Stockholm city centre has now led to a decision to use only clean waste trucks in the whole municipality (Meteor, 2006).

In the end of 2005, the City of Stockholm operates 465 clean vehicles, which is 43% of the municipal fleet. At the moment the number of clean vehicles in Stockholms is about 25 000 but it is constantly increasing. Clean Vehicles constitute 13 % of the total car sales in Sweden and 18 % of the car sales in Stockholm (www.stockholm.se).

7.3. Clean vehicle quota in Brussels

Situation

In the framework of the air quality strategy for the Brussels region, the Brussels government decided to impose a mandatory target of 20% of cleaner vehicles in the fleet of the Brussels government and administration and institutes that fall under its responsibility (BS, 2003). The target has to be reached by 2008 the latest.

Definition clean vehicles

Under the definition of cleaner vehicles, a list of fuel and driveline technologies is given:

- Vehicles that comply earlier as mandatory with EURO 4 or EUR 5 emission standard.
- Vehicles using one of the alternative fuels: CNG, LPG, biodiesel, methanol, ethanol.
- Vehicles with following driveline technologies: Battery electric vehicles, fuel cell electric vehicles, hybrid vehicles, compressed air vehicles
- Diesel heavy duty vehicles retrofitted with CRT or particulate filter (no certified list provided).

Impact analysis

No information is available regarding impact of the measure.

7.4. Flanders cleaner vehicle strategy

Situation

In 2003, The Flemish Government approved the strategy on the promotion of cleaner vehicles (Vlaanderen, 2003). Besides the greening of the vehicle taxation, the introduction of cleaner vehicles in the public fleets of the Flemish Government and the local authorities are part of this action plan.
The instruments for introducing cleaner vehicles in the public vehicle fleet in Flanders are (Denys, 2007):

- Voluntary agreements with local authorities (cities, municipalities and provinces) to introduce cleaner vehicles in their fleet for which they can receive a subsidy. For supporting the local authorities in the analysis of the environmental performance of the fleet, the Flemish Government offers them a free software application. This voluntary agreement already existed from 2002;
- Target for minimal environmental performance of total fleet of Flemish Government;
- Mandatory criteria for the environmental performance of new passenger cars purchased by Flemish government and linked institutes.

Starting from 2007, the voluntary agreement with local authorities will be revised. The local authority will be obliged to perform an environmental screening of the fleet and has to make an action plan for greening the fleet. This action plan should aim at an improvement of the environmental performance of the fleet with 5% or better. For procurement, environmental criteria have to be inserted in the request for tender. Minimum environmental standards for the purchase of new vehicles are set.

Definition clean vehicles

The basis for all instruments is the ecoscore (well-to-wheel indicator integrating harmful emissions, greenhouse gases and noise).

For the voluntary agreement for local authorities, a subsidy is given of 30% of the extra cost of a cleaner vehicle with a ecoscore of 65 or higher (limited to 4000 EUR per local authority). This system runs from 2005 until 2007, after this period the minimum ecoscore limit for passenger cars will be increased to 68 for period 2008-2010 and 70 for period after 2010.
Starting from 2007, not only environmental standards for new vehicles are set but also targets for the environmental performance of the fleet are defined based on the weighted ecoscore of the fleet. The proposal is that fleets with a weighed ecoscore of 42 or lower should target an improvement of the environmental performance to 45 ecoscore points ; if the ecoscore of the fleet is 45 or higher than an improvement of 5% has to be achieved. This proposal is not confirmed yet.

Towards the greening of the fleet of the Flemish government, following targets are defined:
By 2007, 60% of the vehicles has an ecoscore of 62 or higher. By 2008, 70% of the fleet has to meet that minimum environmental performance. By 2009, 70% of all vehicles should have an ecoscore of 65 or higher, in 2010 this should be 80% (Vlaanderen, 2006b).

For the purchase of new vehicles for the Flemish government , minimum ecoscore limits will be defined for the different car segments. A draft proposal has been worked out, but this is not confirmed yet.

Impact analysis

Actions that were subsidized in the first phase of the voluntary agreement (2002-2004) for local authorities were (De Vocht, 2006):

- 94 screenings of environmental performance of the fleet;
- Purchase of 23 bicycles
- Purchase of 15 cleaner vehicles

In 2005-2006 3 municipalities performed an environmental screening of the fleet and received a subsidy of 50 EUR for this work. The purchase of 12 cleaner vehicles were subsidized in this period.

7.5. Conclusion public green procurement

Green public procurement is an effective measure to support the market. The most striking example in this area is the Swedish case where public buying consortia and green public procurement have supported the market of biogas and ethanol flexifuel vehicles to a large extent.
European legislation on mandatory green procurement is in the pipeline, at first stage only focused on heavy duty vehicles and possibly also integrating light duty vehicles in the longer term. A consistent definition of ‘light environmentally enhances vehicle’ will be necessary for integrating green public procurement for light duty vehicles.

8. Voluntary agreements and quota for private fleets

The introduction of cleaner vehicles in public fleets has the primary objective to show to the private consumers the availability of cleaner vehicles on the market and serve as an example for private consumers. In the public sector, both voluntary and mandatory instruments are in place to integrate cleaner vehicles in the public fleets. For the private sector it is very hard to set mandatory standards towards the environmental performance of the company fleet which are more stringent than emission regulations, but different initiatives are taken to promote cleaner vehicles in the private fleets.

8.1. UK fleet programme

Situation

In the UK an extensive programme for promoting cleaner fleets has been set up by the Department of Transport which offers 'green fleet consultancy' for private companies. The green fleet reviews in England are aimed at organisations with a business fleet of over 50 vehicles and vans under 3.5 tonnes (it excludes freight vehicles). In Scotland, the programme is offered to companies with a fleet of minimum 20 vehicles.

The Energy Saving Trust (EST) Transport Advice Team, funded by the Department for Transport (DfT) provides the qualifying organisation with up to five days of free company specific consultancy to green their fleet and reduce their costs. The consultant writes a green fleet review report for the organisation which is context sensitive and typically covers recommendations on:

- Fleet composition
- Vehicle and fuel choice – including vehicle acquisition
- Fuel Management
- Mileage management
- Opt-out fleet
- Grey fleet (privately owned cars – not including Cash opt out cars – used for business) and grey fleet management
- Policy documents – environmental and health and safety
- CO_2 footprint of the organisation's fleet based on the appropriate methodologies
- Conclusions and recommendations - a practical consolidated action plan with timescales to reduce the carbon footprint of the organisation.

The Energy Saving Trust also offers sub 50 fleets up to four hours of telephone advice with a green fleet consultant. Training workshops for up to 20 delegates written and run by a green fleet specialist consultant at locations throughout England. A variety of literature is available for fleet operators and regular newsletters on best practices are distributed to the public.

Account managers visit companies in the UK to persuade them to participate in the programme. This account manager also does the follow up of the implementation of the action plan, six months after the green fleet review a progress review is completed. At this point customers are encouraged to join Motorvate and become a case study. Case studies and testimonials are an effective way to encourage new organisations to have green fleet reviews. Motorvate is a member's organisation and accreditation scheme run by EST which acknowledges and rewards green fleet best practice.

Definition clean vehicles

The green fleet review not only focuses on cleaner vehicles but also on reduction of mileage, driving style and so on. Concerning cleaner vehicles the definition is rather broad as a cleaner vehicle is a vehicle which has lower emissions (CO_2 an/or regulated emissions) than the existing vehicle of the fleet.

Impact analysis

From April 2006 until April 2007, 102 organisations joined the fleet programme. In total, it involves 66314 vehicles, the current average fleet size joining the programme is 650 light duty vehicles. The evolution of number of reviews that were done and the related emission savings are given in Table 23.

Table 23. Effectiveness of the UK Green fleet programme

Period	Number of fleet reviews	Average fleet size	Total Emission reductions (tons per year)		
			CO2	PM	NOx
2004-05	30	n.a.	4.477	1	8.6
2005-06	66	400	19.272	4.4	37
2006-07	102	650	n.a	n.a	n.a

From the view of the fleet operator, the EST claims that investing in greener fleets is cost efficient. An average fleet of 100 vehicles can save 90.000£ per year after implementing a green fleet policy.

Despite the programme already exists for several years, the willingness of companies to consider green fleet management initiatives is limited according to a review done by the EST (EST, 2007):
Less than half of companies surveyed (48%) have an environmental policy

- The smallest companies (1-10 employees) and the largest (more than 500 employees) are most likely to embrace an environmental policy (72% each)
- Only 42% of companies that have an environmental policy consider the impact of company vehicles as part of it
- Young companies are the most likely to supply company cars. Seven out of ten (69%) of businesses launched since 2000 provide vehicles. These young companies are also

the most likely to have an environmental policy (76%), but least likely to consider the impact of their cars as part of it (16%)

- Companies with between 26 and 100 employees are least likely to bother with an environmental policy (33%)

These figures should of course be compared with results of a similar survey in a country in which no fleet programme ran for the last years.

8.2. Green lease

Besides programmes that are initiated by the government for improving the environmental performance of private company fleets, the lease market also has more and more products on the market for fleet operators that want to integrate environmental criteria in their fleet policy.

At the end of 2006, a Belgian fleet magazine organised a survey amongst fleet owners to investigate to which extent environmental criteria are important in fleet strategy (Thonnon, 2007). For company car fleet operators, 176 questionnaires were returned.

Main conclusions of the survey are as follows:
Approximately 60% of companies pay attention to environmental issues, especially smaller companies. Cleaner vehicles are a priority in environmental policy of companies. Only 25% of fleet owners believe in a voluntary approach for greening fleets, approximately 60% is convinced that regulations and/or fiscal incentives are essential for using more cleaner vehicles.
Main drivers to improve environmental performance of fleets are:

- Cleaner vehicles consume less fuel (82%) ;
- Environmental strategy will become essential in the future, so fleets should be prepared (81%) ;
- Cleaner vehicles are taxed less than less clean vehicles (76%) ;
- Company wants an green image (53%)
- Cleaner cars have lower maintenance and repair costs (50%) ;
- Car drivers ask for cleaner cars (18%) ;
- Competitors are also promoting cleaner cars (12%)

When fleet operators are asked which stakeholder has the largest impact on improving environmental performance of vehicles, the car industry has the greatest responsibility (38%) followed by the car driver (35%) ; government (17%). The fleet owner has lowest impact (7%), so fleet owners don’t see a big responsibility in this matter.

Green car policy where extra car budget is given to cleaner cars and less budget for more polluting cars is valued as an interesting policy for more than 60%, but only 50% is considering to introduce this practice in own fleet policy. The detailed answers are presented in Figure 13.

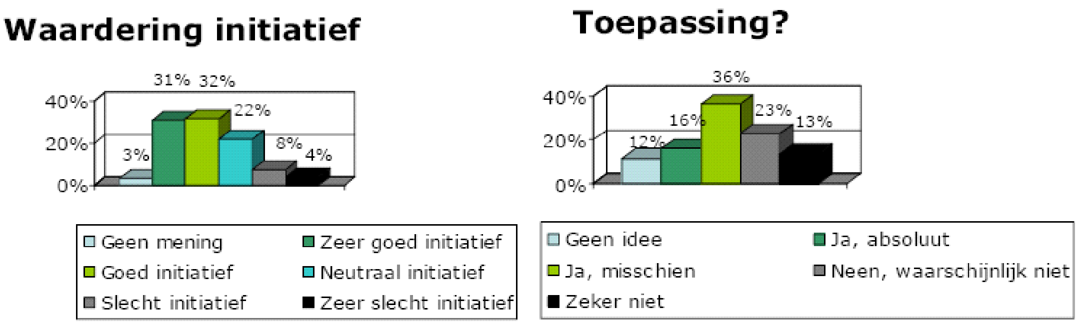

Figure 13. Valuation and plans of fleet owners towards green car policy (in Dutch) (Thonnon, 2007)

The general conclusion of the survey is that the general interest for environment is growing but slower for companies and fleet owners. The interest might be growing but the fleet sector is not prepared for taking actions. They feel they have a low responsibility in the whole picture and point to car manufacturers to make sure they produce cleaner cars. It is recommended that the fleet sector is better informed on the role they can play in improving the environmental performance of transport activities.

Fleet Europe published in 2006 an overview of initiatives of international leasing companies to support fleet owners to green their fleet activities. This overview was an update of a market analysis that was done in 2004 and showed that in two years more and more initiatives are set up. Examples of green leasing initiatives in Europe are given below. Different types of initiatives are taken: information ; driver training ; promotion of alternative fuels and vehicles ; leading by example ; CO_2 compensation and special green products.

Assessment & information

- In France, GE Fleet Services launched a green study, questioning some 968 fleet managers. Around 59% had taken green measures concerning their fleet. Following this enquiry, GE Fleet Services regularly advises and informs its customers, through brochures, newsletters and eco-driving tips included in the driver kit when vehicles are delivered. In France, the leasing company also offers its customer the Tax Solution Key (TSK), a simulator on Excel which enables the status and evolution of the fleet to be observed, as well as its fiscal and environmental situation involving consumption and CO_2 emissions.
- LeasePlan is going to launch a tool globally to assess the CO_2 emissions of cars in real traffic conditions based on an independent measurement programme and make up a ranking of cars based on CO_2 emissions.
- In Belgium, Arval offers all its clients information and advice concerning new taxes involving CO_2 emissions, which came into effect at the beginning of 2005. They receive a breakdown of their fleet which includes the CO_2 emissions for each vehicle currently under contract.

- Fleet Synergy International realised at the beginning of 2005 that fleet owners would need some tools to support them in launching a ‘greener’ fleet policy. FSI performs an environmental screening of the fleet and helps the fleet owner is setting realistic goals for improvement of the environmental performance.

Fuel race & driver training

In Denmark, Norway, Finland and in the Netherlands, ALD Automotive organized a fuel race offering prizes for the lease drivers with the lowest fuel consumption. In the Netherlands, 300 business drivers participated and they consumed approximately 10% less fuel than the average business driver. Furthermore ALD Netherlands organised ‘Training Days’. Some 100 lease customers were given a driving course.

Alternative drive vehicles

- In France ALD Automotive is testing four electric vehicles. The vehicles are being driven in a large scale test which will cover 18 months and help the company evaluate their suitability for professional use. The objective of ALD is to determine the cost price per kilometre, and if the results are encouraging, the company plans to offer such vehicles to its clients under long term.
- In Austria and Germany, Arval is renting out vehicles to its clients which use alternative fuels, principally gas, and hybrid vehicles.
- In Germany, Sixt Leasing hosted a forum where experts and fleet managers talked about the advantages and disadvantages of natural gas and hybrid vehicles as well as other alternative fuels. Sixt Leasing also provided several test vehicles that are already on offer. Despite lack of experience regarding residual values, as well as the unknown development of leasing rates of vehicles with alternative engines in general, the fleet managers participating demonstrated a positive attitude towards alternative engines and identified a significant growth potential.

Leading by example

- ING Car Lease has instigated a policy of replacing its personnel cars in the Netherlands – where it has a fleet of about 600 units – by lower emission cars when they become due for change. The only cars allowed are A, B or C energy label cars.
- GE Commercial Finance Fleet Services is also currently working on making its European fleet more environmentally-friendly. To reach this target, the leasing company plans to select not only hybrid cars but vehicles that are fuel efficient. Also the way cars are used is examined.
- In France, GE Commercial Finance Fleet Services has already changed its car policy. The upper management can now select a Toyota Prius, while lower categories can choose more environmentally friendly cars.

CO_2 compensation

This initiative has been gaining in popularity over recent times. For example, ING Car Lease, through its Eco Lease programme in the Netherlands plants forests to compensate directly for the CO_2 emissions of its clients taking part in the scheme.
In the UK, ALD has introduced measures to manage emissions from its own vehicle fleet and is offsetting the remainder by supporting the creation of new woods for all business mileage undertaken. ALD is offering the same scheme to its customers with its CARbon Offset plan.
LeasePlan also offers treeplanting schemes in the US, where this initiative is particularly popular, as well as in Australia, New Zealand, the UK, Norway and Portugal.

Special 'green offers'

- Many of the leasing companies have introduced special green programmes. Eco Lease is a product offered by ING Car Lease in the Netherlands. All Eco Lease cars have the A, B or C energy label, using up to 10% less fuel than the average car in the same class. Eco Lease also enables clients to check on fuel use on line. In order to further stimulate the drivers, the programme can include a bonus system for those drivers who, in average, perform a fuel consumption that is below the standard norm for a specific car.
- GE Fleet Services has set up the 'Green & Safe Solutions' programme for its clients, enabling them to evaluate driver behaviour both in terms of safety and respect for the environment. This evaluation, which leads to concrete rectification measures being taken, involves 5 areas: fuel consumption, brake equipment, non-recoverable damage, tyres and motoring offences– all elements which influence fleet costs. The eventual evaluation is linked to concrete actions.
- LeasePlan is currently assessing all the best green practices that are taken by its subsidiaries in order to ultimately launch these initiatives globally. In the UK, in Portugal and in Norway, for example, the company offers its 'GreenPlan' programme, which includes vehicles and fuel selection, scheduled servicing and maintenance, professional driver training, improved journey planning and a reforestation programme.
- In the Netherlands, LeasePlan offers Mobility Mixx, allowing customers to use alternative modes of transport, such as trains and taxis to avoid traffic jams. LeasePlan has also recently launched a pilot project to equip its 80,000 diesel cars with a retro particle filter, so as to reduce the number of noxious particles in the air.

8.3. Conclusion green private fleets

For the private fleet sector, it's not feasible to impose more stringent standards than the minimum environmental standards which apply to the whole vehicle market. Nevertheless, private companies can be stimulated to invest in cleaner vehicles and greening their fleets. The UK Motorvate programme is an intensive programme where private fleet operators are supported to green their fleets by offering consultancy and a quality label for meeting the set targets. The private lease market is also organising itself to put ‘green lease products’ on the market because companies have a demand for such green lease products, partly because of green company car taxation schemes which are being introduced in several European countries.

9. Voluntary agreements, quota and emission trading towards car industry

An important measure to promote the introduction of cleaner vehicles is the stimulate the car industry to bring the cleanest vehicles on the market, which can happen voluntary or mandatory. Important examples of this measure are the voluntary agreements or standards that exist world wide on fuel economy and CO_2-emmissions of light duty vehicles of which an overview is given in Table 24.

Table 24. Fuel economy standards world wide (ICCT, 2007)

COUNTRY/ REGION	STANDARD	MEASURE	STRUCTURE	TARGETED FLEET	TEST CYCLE	IMPLEMENTATION
Japan	Fuel	km/l	Weight-based	New	JC08	Mandatory
European Union*	CO_2	g/km	Single standard	New	NEDC	Voluntary
China	Fuel	l/100-km	Weight-based	New	NEDC	Mandatory
Canada*	GHG (CO_2, CH_4, N_2O, HFCs)	5.3 Mt reduction	Vehicle class-based	In-use and new	U.S. CAFE	Voluntary
California	GHG (CO_2, CH_4, N_2O, HFCs)	g/mile	Vehicle class-based	New	U.S. CAFE	Mandatory
United States	Fuel	mpg	Single standard for cars and size-based standards for light trucks	New	U.S. CAFE	Mandatory
Australia	Fuel	l/100-km	Single standard	New	NEDC	Voluntary
South Korea	Fuel	km/l	Engine size-based	New	U.S. EPA City	Mandatory
Taiwan, China	Fuel	km/l	Engine size-based	New	U.S. CAFE	Mandatory

*Europe and Canada are shifting to mandatory regulatory programs.

9.1. European strategy CO2-emissions of light duty vehicles

Situation

The basis for the European strategy COM(95)689 for the reduction of CO_2-emissions of passenger cars defined in 1995 targets a reduction of CO_2-emissions of new registered passenger cars with 35% by 2010 compared to the level in 1995. The strategy relies on 3 pillars: a voluntary agreement with the car industry ; consumer information on fuel consumption and CO_2-emissions and fiscal measures. The Member States are obliged to monitor the evolution of the CO_2-emissions of new passenger cars and report them to the EC. Most important pillar of the strategy is the voluntary agreement with the car industry to lower the CO_2-emissions by 2008/2009 with 25% compared to 1995 (from 186 g/km in

1995 to 140 g/km in 2008/2009). The reduction to 120 g/km has to be achieved by market shifts supported by the consumer information and the fiscal measures.
In 2005, an interim evaluation for further reduction to 120 g/km after 2008/2009 was done, but the car industry had the opinion that this further reduction would not be feasible because of the lack of supporting measures to evoke the necessary market shift.

In 2007, the European Commission published a communication COM(2007)19 with a revision of this strategy for lowering CO_2-emissions of new light duty vehicles because the targets of the 1995 strategy won't be met (EC, 2007a). The EC proposes a mandatory target combined with an integrated approach. The mandatory target of technological improvements to be achieved by the car industry is 130 g/km by 2012, the further reduction to 120 g/km is to be achieved by other measures:

- setting minimum efficiency requirements for air-conditioning systems;
- the compulsory fitting of accurate tyre pressure monitoring systems;
- setting maximum tyre rolling resistance limits in the EU for tyres fitted on passenger cars and light commercial vehicles;
- the use of gear shift indicators, taking into account the extent to which such devices are used by consumers in real driving conditions;
- fuel efficiency progress in light-commercial vehicles (vans) with the objective of reaching 175 g/km CO_2 by 2012 and 160 g/km CO_2 by 2015;
- increased use of bio fuels maximizing environmental performance.

The legislation for the revision of the CO_2-policy is expected by mid 2008 the latest.

Furthermore, the EC wants tot define a long term strategy to lower CO_2-emissions of passenger cars with 40% by 2020, which would mean an average CO_2-emission of 95 g/km for new passenger cars.

Impact analysis

Table 25 shows the evolution of fuel consumption and CO_2-emissions of new passenger cars in Belgium and the EU. For the EU, only figures until 2004 have been officially reported. For the analysis of Belgium, a stagnation of the annual CO_2-reduction can be noticed. From 2002-2004, on average 1.3% reduction was achieved each year, while from 2004-2006 this annual reduction is only 0.8%.

Table 25. Average fuel consumption and CO2-emissions of new passenger cars (Belgium, 2002-2006, data FOD Mobiliteit, EU-25, 2003-2004, data EC)

		Belgium					EU-15	
		2002	2003	2004	2005	2006	2003	2004
Average fuel consumption (l/100 km)	Petrol	7,1	7,0	6,9	6,7	6,6	7,2	7,2
	Diesel	5,8	5,8	5,7	5,6	5,7	5,8	5,8
	Average	*6,3*	*6,2*	*6,0*	*5,9*	*5,9*	*6,5*	*6,4*
Average CO_2-emission (g/km)	Petrol	170	168	165	162	158	171	170
	Diesel	155	154	152	152	152	154	153
	Average	*160*	*158*	*156*	*155*	*154*	*163*	*161*

For the EU, meeting the 140 g/km target by 2008/2009 is probably not feasible. An analysis of the progress for 2005-2006 was made by the NGO Transport & Environment based on the official EU-database, the results are shown in Figure 14. The average CO_2-emissions for the EU decreased from 162 g/km in 2004 to 160 g/km in 2006, which is a 0.6 to 0.7% decrease annually. ACEA's progress in 2006 dropped to an all-time-low: a reduction of just 0.2%. For the remaining two or three years, carmakers will have to reduce the CO_2 emission and fuel consumption of their products at an annual rate of 5 to 6 per cent for meeting the target of 140 g/km in 2008/09. This is an unprecedented rate and 3 to 5 times the rate of reduction achieved in previous years. Extrapolation of historic reductions would lead to ACEA missing the 140 g/km target by approximately 15 grams and JAMA and KAMA their 2009 target by 13 and 16 grams respectively.

Other sources project that average CO_2-emissions will be about 155 g/km by 2008/2009, which is 11% higher than the target (ICCT, 2007).

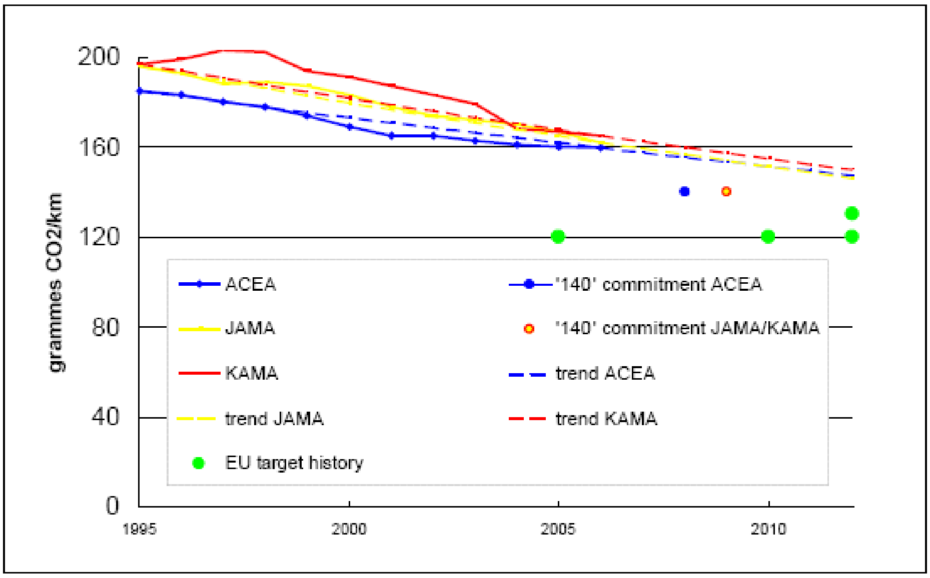

Figure 14. CO2-emissions new passenger cars EU-25 1995-2006 (T&E, 2007)

In Figure 15, the wide range from 142 to 238 g/km in average CO_2-emissions per car manufacturer in the EU market is shown, while average CO_2-emission is 160 g/km. This indicates that a system of mandatory targets with CO_2-credits trading would be an option in the EU market.

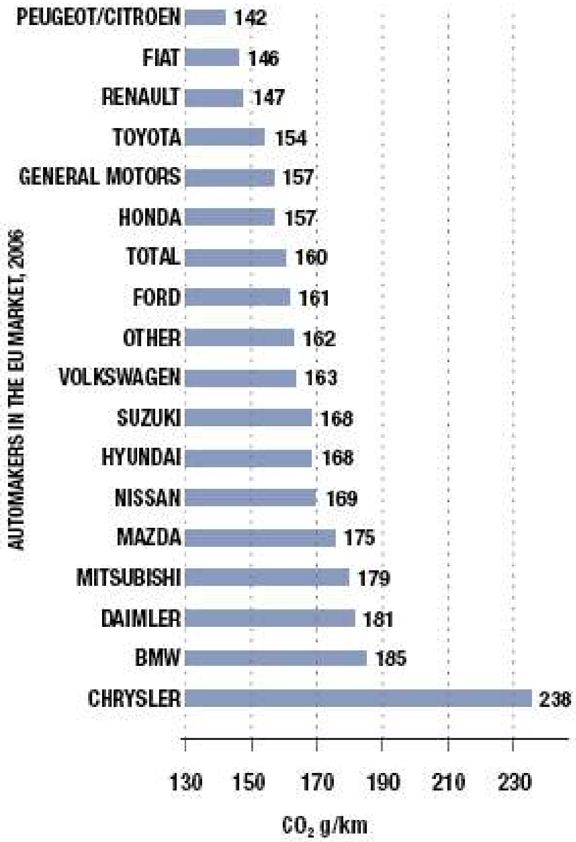

Figure 15. CO2-emissions new passenger cars in the EU-market 2006 per manufacturer (ICCT, 2006)

9.2. Japan fuel economy standards

Situation

The Japanese government first established fuel economy standards for light-duty passenger and commercial vehicles in 1999 under its “Top Runner” energy efficiency program. Fuel economy targets are based on weight class, with automakers allowed to accumulate credits in one weight class for use in another, subject to certain limitations. Penalties apply if the targets are not met, but they are minimal. The effectiveness of the standards is enhanced by highly progressive taxes levied on the gross vehicle weight and engine displacement of automobiles when purchased and registered. These financial incentives promote the purchase of lighter vehicles with smaller engines (ICCT, 2007).

In December 2006, Japan revised its fuel economy targets upward, and expanded the number of weight bins from nine to sixteen . This revision took place before the full implementation of the previous standards because the majority of vehicles sold in Japan in 2002 already met or exceeded the 2010 standards. This new standard is projected to improve the fleet average fuel economy of new passenger vehicles from 13.6 km/L in 2004 to 16.8 km/L in 2015, an increase of 24 percent. Based on our analysis, the new target reaches an average of 125 g/km for CO_2 emissions on the NEDC test cycle.
In 2010 Japan will introduce a new test cycle, the JC08, to measure progress toward meeting the revised 2015 targets. Relative to the previous 10-15 test cycle, the JC08 test cycle is longer, has higher average and maximum speeds and requires more aggressive acceleration. This means that the stringency of the fuel economy standards increases with 9% compared to the old test cycle. Figure 16 shows the difference in fuel economy standards between the old system and the new system, keeping the increased stringency of the new test cycle into account.

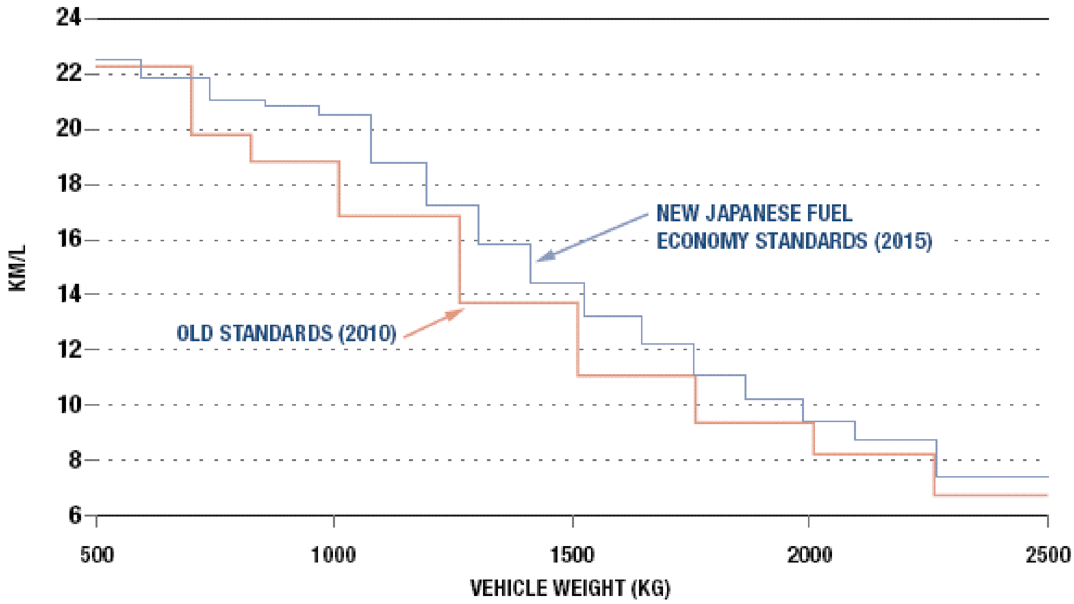

Figure 16. Fuel economy standards in Japan old compared to new

9.3. US CAFE standards

Situation

The U.S. adopted its CAFE (corporate average fuel economy) standards as part of a broad energy policy package in the wake of the 1973 oil crisis. The objective of the standards were lowering the dependency on imported oil and not environmental objectives (ICCT, 2007). The CAFE standards are less stringent for light trucks to protect small businesses and farmers, at that time private consumers did not make use of light trucks.

Two separate CAFE standards remain in effect for passenger vehicles. The standard for passenger cars has remained unchanged since 1985 at 27.5 miles per gallon (mpg), although it was rolled back for several years in the late 1980s in response to petitions filed by several automakers. The standard for light trucks was increased from 20.7 mpg in 2004 to 24.0 mpg for 2011 over seven model years from 2005 to 2011. In its most recent rulemaking, NHTSA began setting CAFE standards for light trucks based on vehicle size as defined by their "footprint" (the bottom area between the vehicle's four wheels). The new standard is based on a complex formula matching fuel economy targets with vehicle sizes. For the first three years, manufacturers can choose between truck-fleet average targets of 22.7 mpg in 2008, 23.4 mpg in 2009, and 23.7 mpg in 2010, or size-based targets. Beginning in 2011, manufacturers will be required to meet the size-based standards that are expected to result in a fleetwide average of 24.0 mpg.

Besides the US CAFE standards, several states (at present 12) beginning with the state of California introduced more stringent fuel economy standards applying to vehicles sold in their state applicable to passenger cars and light duty trucks. The first fleet caps will be introduced in 2009 and become more stringent annually. In 2016, the new vehicle fleet average should be 30% lower than 2009 level. The California standards apply to a well-to-wheel approach on all greenhouse gases: they include GHG emissions from fuel production ; CO_2, CH4, N2O from vehicle operations ; CO_2 emissions from fuel consumption due to airco-system ; HFC leakage emissions from airco-system.
The legal framework for the California standards is not finished yet and this might cause problems for introducing the standards by 2009.

Impact analysis

Because light trucks have more stringent fuel economy standards, automakers have introduced a number of crossover vehicles since the introduction of the CAFE standards, such as minivans and SUVs, that combine features of cars and light trucks. The use of these vehicles has shifted to primarily personal transport and market share has now surpassed passenger cars. As a result, there has been a 7 percent decrease in fuel economy of the overall light duty fleet since 1988.

The standard for light trucks was based on weight which has an adverse effect that the heavier the light truck, the less stringent standard it has to comply with, which increases the average weight of trucks. This is why recently size based standards are adopted to which the light trucks have to comply by 2011.

If the California standards will be legally approved, they will apply to more than 1 vehicle on 3 sold in the US and have a substantial impact on the US fleet average fuel consumption.

Figure 17 gives an overview of the actual and projected CO_2-emissions of the new car fleet in the different countries where voluntary agreements or mandatory standards with the car industry are in place. The average CO_2-emmissions of the fleet are calculated based on the European test cycle (NEDC) to get comparable figures.

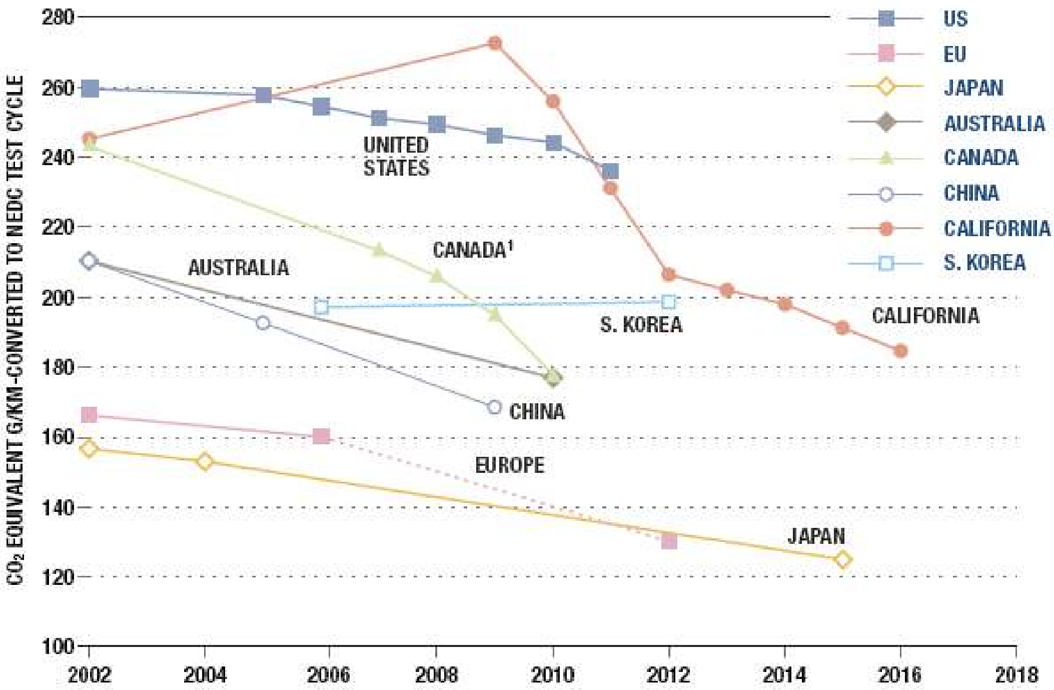

Figure 17 : Actual and projected CO2-emissions 2002-2016 in different countries

As shown on the figure, Europe and Japan are forerunners in fuel efficiency in the world, providing that the targets are met. CO_2-emissions in the US are the highest, but the more stringent targets in California and 11 other states will have a serious influence if the targets are met and will result in a substantial reduction of the average new fleet CO_2-emissions.

9.4. California ZEV programme

Situation

In September 1990, the Air Resources Board adopted a low-emission vehicle regulation whose aim is to drastically reduce pollution from passenger cars and light-duty trucks. As part of the newly created program, the Board included a goal of requiring large auto manufacturers to commercialize vehicles with zero emissions, beginning with 1998model-year vehicles. This ZEV requirement was included to catalyze efforts to commercialize sustainable transportation. The program would ultimately have the added benefit of prompting manufacturers to develop extremely clean conventional and alternative fuel and hybrid electric vehicles.

Since its inception in 1990, the program has been modified on several occasions to better reflect the pace of technological development, costs and realities of the marketplace. The ZEV program continues to push the development of clean vehicles and supports the vision needed to meet California's longer-term environmental goals.

The original ZEV program required that 10 percent of new vehicle sales by large manufacturers have zero emissions, starting with 1998 models. The Board modified the program in 1998 and 2001 to allow up to 60 percent of the requirement to be met with vehicles having extremely low emissions and specific attributes, as shown in Table 26. Each category receives a certain credit depending on how clean the technology is and can account for a certain percentage of ZEV.

In 2009 up to 85 percent of the requirements may be met with these vehicles. Vehicles meeting these standards are referred to as "partial zero emission vehicles" (PZEV) and "advanced technology partial zero emission vehicles" (AT PZEV). Staff refer to the categories of vehicles used to meet the ZEV regulation as gold (ZEV), silver (AT PZEV) and bronze (PZEV) to simplify discussion. PZEVs and AT PZEVs have achieved commercial success and are responsible for significant emissions reductions due to the large numbers of vehicles sold.

Table 26 : requirements of ZEV market share in California by 2009 (CARB, 2007)

Certification Standards				
% Requirement	% of Total Vehicle Sales[1]	Vehicle Type	Category	Technical Description
2.5%	< 1%	Zero Emission Vehicle (ZEV)	Gold	Zero tailpipe emissions: battery electric vehicles, and hydrogen fuel cells.
2.5%	5%	Advanced Technology (AT PZEV)	Silver	Vehicles certified to PZEV standards and employing ZEV-enabling technologies: e.g. hybrids or compressed natural gas vehicles.
6%	30%	Partial Zero Emission Vehicle (PZEV)	Bronze	Conventional vehicles certified to the most stringent tailpipe emission standards, zero evaporative emissions, and extended warranty.
11%	Total ZEV Requirement			

1. Percent of total California sales differs from percentage requirement because credits per vehicle type vary.

The Board's most recent amendments to the ZEV program in 2003 revised the percentage of ZEVs required to 11 percent starting in 2009, increasing to 16 percent in 2018.
The credits a manufacturer owns can be transferred to future years, this means if the manufacturer has a larger market share than required, he can transfer the surplus to the following year.

Specifically for supporting the development of fuel cell vehicle technology, an alternative compliance path has been defined which large manufacturers can apply to comply with the ZEV requirements. By reaching annual sales of fuel cell vehicles following four stages (see Table 27), large manufacturers comply with the ZEV regulations.

Table 27. alternative compliance path for ZEV market share based on FC vehicle sales

Phase	During Model Years	Manufacturer's Market Share of:
I	2005 to 2008	250 fuel cell vehicles
II	2009 to 2011	2,500 fuel cell vehicles
III	2012 to 2014	25,000 fuel cell vehicles
IV	2015 to 2017	50,000 fuel cell vehicles

There are currently twenty-one auto manufacturers subject to the ZEV regulation. All manufacturers are currently in compliance with the ZEV regulation. Most manufacturers have enough banked credits from zero emission vehicles already placed to comply with the regulation through approximately 2009. One manufacturer has produced more fuel cell vehicles than required to meet their Alternative Path obligation for 2005 to 2008.

Definition clean vehicles

The approach of the ZEV program is technology based, with implicit calculations on the emissions of the technologies. The different categories reflect the cleanliness of the technology and the credits that manufacturers receive are different for the different categories.

Impact analysis

Table 26 presents the approximate total number of gold, silver and bronze vehicles placed as of model-year 2005. Manufacturers have been producing PZEVs at a rate greater than their obligation in aggregate. For example, in 2005, manufacturers on the whole produced 40 percent more PZEVs than the industry wide PZEV requirement.

Table 28. Total sales of ZEV-vehicles per category from 1994-2005

Vehicle Type		Quantity[1]
ZEV	Fuel cell	130
ZEV	Battery electric	4,400
ZEV	Neighborhood electric	26,000
AT PZEV	Hybrid/Compressed Natural Gas	70,000
PZEV	Conventional	507,000

1 Estimates of total vehicle placements from 1994 through 2005

Because the ZEV program is under continuous review, an expert panel assesses the current status of clean technologies and prospects for technology advancement in nearand long-term. This is done by means of surveys and interviews with manufacturers worldwide. Figure 18 presents the conclusions of the expert panel of the research done in 2006.

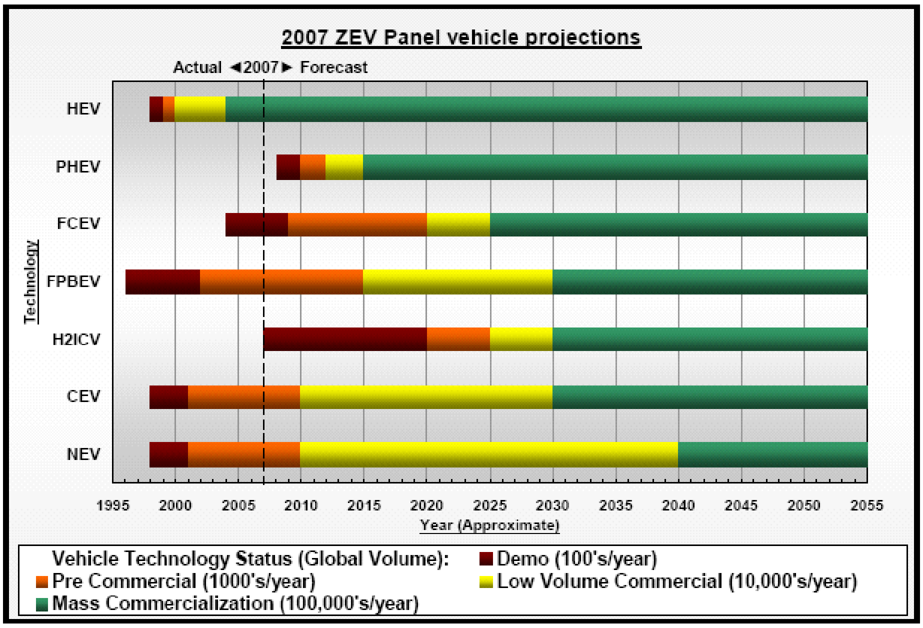

Figure 18. global forecast volumes of ZEV vehicles

One of the issues discussed at present is if plug-in hybrids which are demonstrated today can be integrated in the ZEV-credits. Plug in hybrids can drive a certain range in pure electric mode (AER: all electric range) and could be classified as 'gold' technology, however there is no guarantee how the electric mode will be used. For that reason, the plug in hybrids could be qualified as 'silver' technology like conventional hybrids, but account for higher credits for meeting the ZEV requirements. An example how the credits for plug in hybrids could work is given in Figure 19.

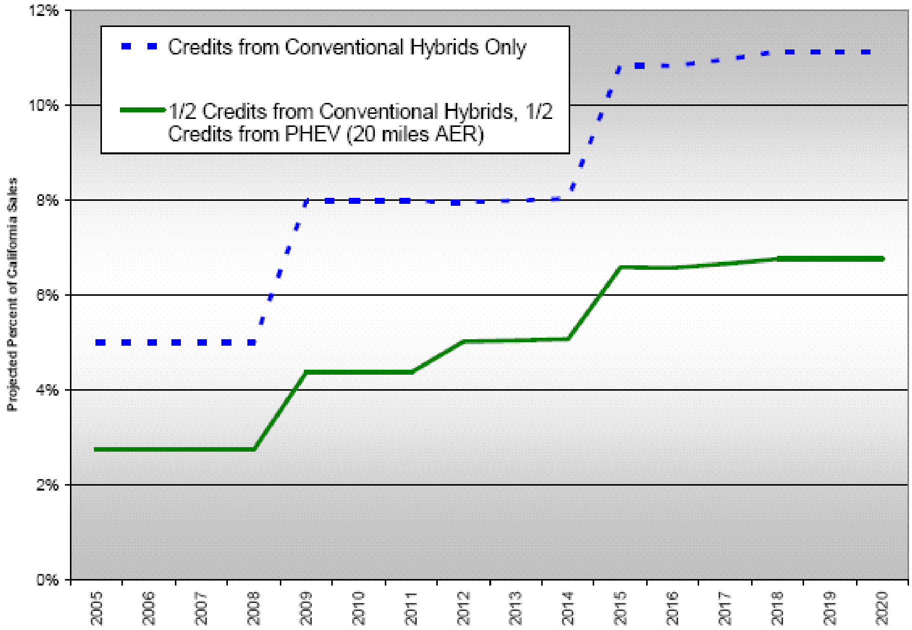

Figure 19. Example for introducing credits for plug in hybrids (PHEV) in ZEV requirements

10. User (dis)advantages

Local authorities can put into action a set of initiatives with the aim of promoting clean means of transport and a more sustainable environment. These initiatives are, due to their local applicability, often defined as user (dis)advantages.
User advantages can aim at offering benefits to consumers who drive environmentally friendly vehicles. In general, the benefits are of financial nature. A common example of this type of measure is reduced parking fees for clean vehicles. On the other hand, user disadvantages have the purpose to discourage the use of environmentally unfriendly vehicles. This can be obtained by e.g. prohibiting the entrance to a certain area and/or at a certain time, generally city centres, of vehicles not corresponding to a minimum emission standard.
In this chapter some of the examples of restricted areas (chapter 10.1) and variable parking fees (chapter 10.2) are discussed.

10.1. Restricted areas

A restricted area can be considered as an area where a selective admittance policy for vehicles is imposed in order to increase liveability. International research indicates that restricted areas are implemented to increase air quality, reduce noise and decrease congestion (Hoogma et al., 2003). The environmental zones that are implemented in Europe often are measures to ensure that cities will comply with the future air quality standards set by the European Union.
Examples in Europe show that this selective admittance policy often only applies on heavy duty vehicles (e.g. Prague, cities in Sweden, and cities in the Netherlands). There are a few cases where light duty vehicles are involved. The cost of a restricted area for heavy duty vehicles rests mainly upon the transport sector. New vehicles have to be bought, old vehicles are depreciated at a higher rate, etc. Costs of enforcement can be held relatively low: issuing an admittance tag for vehicles that may enter the area, can limit enforcement to visual inspection. The selective admittance policy is usually based on a technical requirement of the vehicles, like the emission standard (e.g. Amsterdam), presence of a particulate filter (e.g. Utrecht), load capacity of the vehicle (e.g. Prague, Kopenhagen), etc.

When the restricted area also applies to light duty vehicles, costs can increase substantially due to the fact that a greater number of vehicles are involved. In Greater London for example, heavy duty vehicles make up only 3 – 4% of all the vehicles that drive (at least once a year) through London. Restricting the access for heavy duty vehicles is easier to impose, but with improving technology like license plate recognition, this becomes more and more feasible for light duty vehicles as well. Benefits will increase when light duty vehicles are included: the effect on air quality is significantly higher, and revenues due to enforcement increase (AEA, 2003; Hoogma et al., 2003). Some cities in Germany (see 10.1.2) are implementing restricted areas based on admittances tags for light duty vehicles as well. However, no results regarding costs or effectiveness are available yet.

Considering the scope of this review of policy measures, only the restricted areas that apply to light duty vehicles and are based on environmental performance of the vehicles, are discussed in the following paragraphs.

10.1.1. Italy

Restricted areas in Italy began to be imposed due to two main reasons. On the one hand, the medieval character of many city centers in Italy together with an increase of traffic volume in the recent past quickly led to congestion. On the other hand, traffic is considered to be one of the main sources of pollution in Italian cities, especially in the northern region of the country. Small and medium sized cities began limiting access to the city center to heavy as well as light duty in the 70's, followed by large cities in the 80's. Some exceptions were made, for example for inhabitants, taxi's, delivery vans, mopeds, etc. Enforcement appeared to be a problem, since the police did not consider it to be a priority.
Initially, the effect on congestion and air quality was satisfactory. However, the further increase in traffic, the relatively small area's implicated, the lax enforcement and the fairly easy way to qualify for an exemption counteracted the positive effects.
In a next step, national government changed municipal law in order to allow cities to set selective admittance policy based on environmental characteristics of vehicles, like the presence/absence of a catalytic converter.

Many cities in Italy have installed a restricted area, and a few of them will be discussed in the next paragraphs.

10.1.1.1. Rome

Situation

In 1992 the city of Rome (Italy) decided to install a restricted area, with exceptions for inhabitants and other licensees. This area has been expanded in 2002 and now consists of 2 different zones: a low emission zone and a zone with limited traffic, where a selective admittance policy based on environmental characteristics is implemented.
The restricted area is the result of serious air quality problems in the city centre in the 90's, due to the large traffic flows that used to come into the city. On a daily basis, more than 1 million vehicles and 600.000 mopeds entered the city (Hoogma et al., 2003). These large traffic flows combined with the historic character of the centre of Rome, quickly resulted in congested traffic and air quality problems.

Low emission zone

This is the largest zone, with a surface of 60 km^2 and 65 access roads (see Figure 20). It lies within the circular railroad around Rome. From Monday until Friday this zone is forbidden for 4-wheeled vehicles that do not comply with any European emission standard (pre-euro).

Since January 2007 this zone is also forbidden for 2-stroke motorcycles and mopeds that do not comply with any European emission standard (pre-euro).

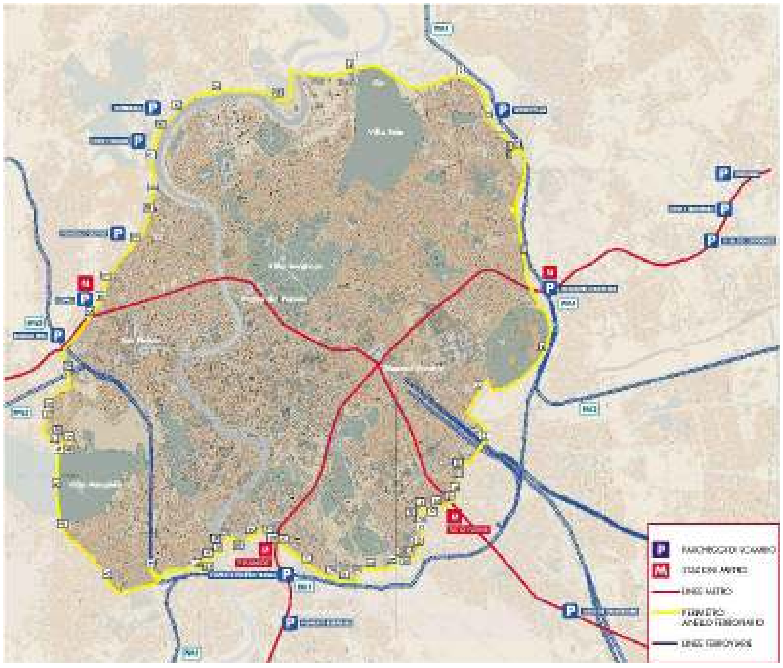

Figure 20. Low emission zone in Rome, Italy (Hoogma et al., 2003)

Zone with limited traffic

This zone has a surface of 7 km^2 and has 23 access roads (see Figure 21). From Monday until Friday, starting at 6 a.m. and ending at 6 p.m., and Saturday from 2 p.m. until 6 p.m. this zone is forbidden for all 4-wheeled vehicles. In some parts of the zone, this time frame has been widened to Friday and Saturday from 11 p.m. until 03 a.m., due to heavy traffic related to leisure activities. Electrical vehicles are allowed to enter the zone at any time.

Permits are issued to inhabitants and other authorized categories at a cost between €5 and €320. Whoever receives a permit needs to purchase a transponder that needs to be placed in the vehicle. When entering the zone, the responder is detected. When a vehicle enters the zone without a transponder, a camera system registers the license plate and automatically generates a fine which is then sent to the owner of the vehicle.

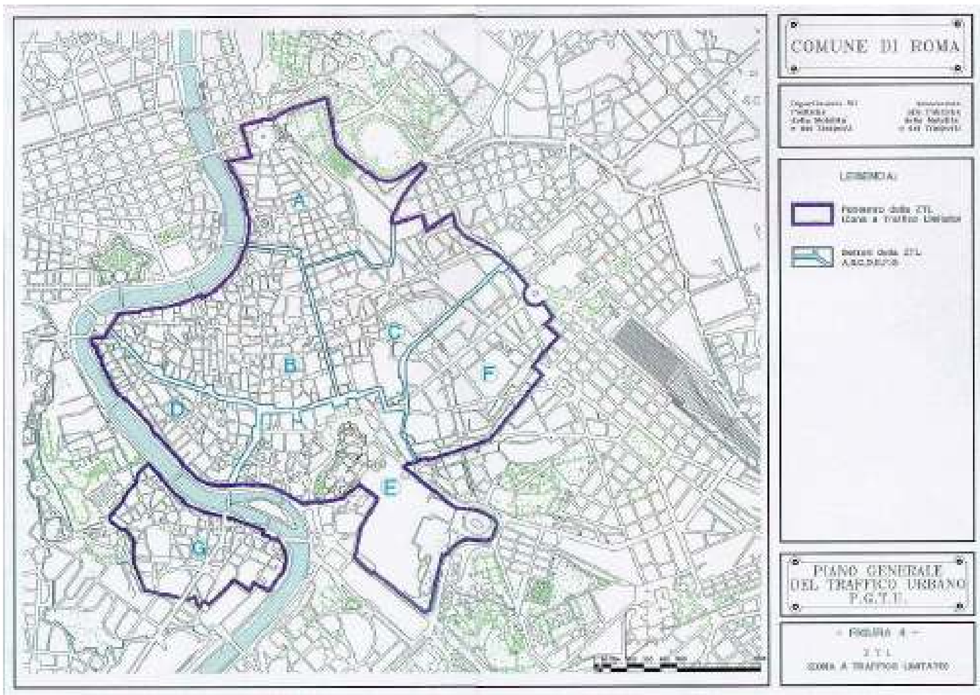

Figure 21. Zone with limited traffic in Rome, Italy (ATAC, 2007)

Definition clean vehicles

4-wheeled vehicles, 2-stroke motorcycles and mopeds may enter the low emission zone if they comply with at least the Euro 1 emission standard. However, they cannot enter the zone with limited traffic at certain times during the day and night.
Electrical vehicles can enter the defined zones at any time, as well as 4 stroke motorcycles and mopeds.

Impact analysis

Together with the implementation of parking fees, the restricted area led to a reduction in traffic volume of:

- 10% during the whole day
- 20% during the time frame in which the traffic is limited
- 15% during the morning rush hour

Outside of the zone, the traffic volume increased with 5% during the day, and 10 % in de morning rush hour. The average speed within the zone increased with 10% for cars and 5% for busses. The share of mopeds and motorcycles grew with 10%, and the share of public transport with 5% (Hoogma et al., 2003).
Costs of the restricted area are related to enforcement and infrastructure. Benefits other than the reduction in traffic volume and presumably better air quality is the income from fines.

10.1.1.2. Turin

Situation

Turin is a major city located in the north western part of Italy. Since 2004 a restricted area has been implemented with selective admittance policy. The area is divided in different zones, where different regulations are in place (see Figure 22).
During certain periods of the day, mostly rush hour, access to the city and the so called 'environmental zone' is limited to vehicles with certain environmental characteristics. In the other zones, traffic is forbidden for all vehicles during daytime, during the night, or during rush hour (Torino, 2007).

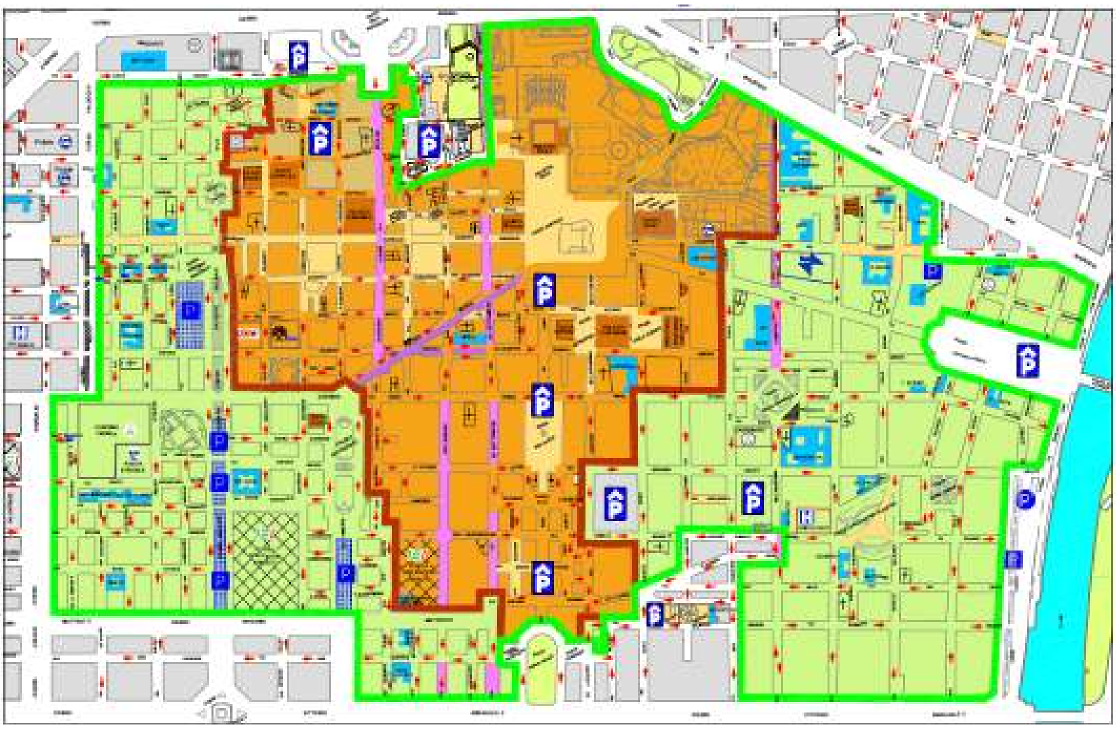

Figure 22. Zone with limited traffic in Turin, Italy. Environmental zone (green) and Central Zone (orange) (Torino, 2007)

Definition clean vehicles

The environmental characteristics to which vehicles must comply to be allowed access to the whole city or the zones, became more and more stringent over the years. This is the current status of the environmental definitions (Torino, 2007).

Whole city:
- Passenger cars complying with at least the Euro 1 emission standard (petrol) and Euro 2 (diesel)
- Delivery vans complying with at least the Euro 1 emission standard (petrol) and Euro 2 (diesel)

- Motorcycles and mopeds complying with at least the Euro 1 emission standard, or not older than 10 years
- Electrical vehicles and hybrid electrical vehicles
- Vehicles designed to use CNG or LPG as a motor fuel

Environmental zone:
- Passenger cars complying with at least the Euro 3 emission standard (petrol and diesel)
- Delivery vans complying with at least the Euro 3 emission standard
- Heavy duty complying with at least the Euro 1 emission standard
- Motorcycles and mopeds complying with at least the Euro 1 emission standard
- Electrical vehicles and hybrid electrical vehicles
- Vehicles designed to use CNG or LPG as a motor fuel

Central zone (extra permit needed):
- Passenger cars complying with at least the Euro 3 emission standard (petrol and diesel)
- Delivery vans complying with at least the Euro 3 emission standard
- Electrical vehicles and hybrid electrical vehicles
- Vehicles designed to use CNG or LPG as a motor fuel

Impact analysis

No information is available regarding impact of the measure.

10.1.1.3. Alba

Situation

In the city of Alba, which is located in the north western part of Italy in the same province as Turin, a restricted area has been implemented since the 1st of March 2005 (Alba, 2007). The access to the 'centro storico' or historic center (see Figure 23) is permanently forbidden for vehicles not complying with certain environmental criteria (see Definition clean vehicles).
The restricted area has been enlarged since 15th of January 2007 with a residential area called 'centro abitato'. Access to this additional area is not permanently forbidden: only during peak hours.

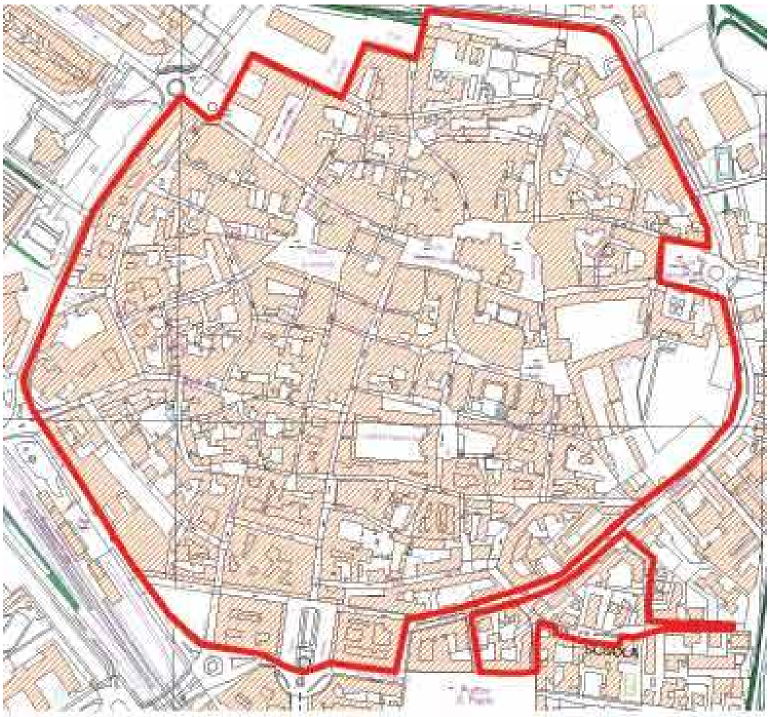

Figure 23. Zone with limited traffic in Alba, Italy (Alba, 2007)

Definition clean vehicles

- Petrol vehicles with a first registration date after 1st of January 1993 and complying with at least the Euro 1 emission standard.
- Diesel passenger cars with a first registration date after 1st of January 1997 and complying with at least the Euro 2 emission standard.
- Diesel delivery vans with a first registration date after 1st of October 1998 and complying with at least the Euro 2 emission standard.
- Diesel heavy duty vehicles with a first registration date after 1st of October 1996 and complying with at least the Euro 2 emission standard.
- 2-stroke motorcycles and mopeds with a first registration date after 1st of July 1999 and complying with at least the Euro 1 emission standard
- Electrical vehicles and hybrid electrical vehicles
- Vehicles designed to use CNG or LPG as a motor fuel

Impact analysis

No information is available regarding impact of the measure.

10.1.2. Germany

Situation

In Germany a regulation was approved, enabling cities and municipalities to limit access to certain areas to vehicles not complying with previously defined particle emission standards (Donner, 2006). A recently adopted national vehicle marking scheme facilitates the implementation of these restricted areas. Vehicle owners can obtain a sticker with a colour corresponding to the particle emission of their vehicle. The stickers are valid in the whole of Germany, cost around €5, and are obtainable at certified institutions for light as well as heavy duty vehicles.
Berlin, Stuttgart, Frankfurt, Munchen and Cologne are among the cities with plans to implement a restricted area, or 'Umweltzone'.

Under certain circumstances of problematic air quality conditions regarding particulate matter, the German national environmental administration can take traffic limiting measures based upon the stickers. Vehicles can be exempt from this measure if they have a sticker with a certain colour and thus emission level.

Definition clean vehicles

Vehicles are subdivided into four classes, from which three can obtain a corresponding sticker: green, yellow and red (see Figure 24). The forth class, the one with the highest emission of particulate matter, does noet receive a sticker (TÜV Hessen, 2007).
The three colours correspond to a certain emission level of particulate matter. This is defined according to the emission measured during the certification of the vehicle. The owner of a vehicle can determine the emission level by means of a code on a certificate they receive when registering their vehicle. When a vehicle is retrofitted with a particulate filter, the possibility exists to apply for a sticker with a different (better) colour.

- No sticker:
  - petrol vehicles not equipped with a catalysor, or in other words pre-Euro
  - diesel vehicles complying with the Euro 1 emission standard or worse.
- Red sticker:
  - diesel vehicles complying with the Euro 2 emission standard
  - diesel vehicles complying with the Euro 1 emission standard but retrofitted with a particulate filter.
- Yellow sticker:
  - diesel vehicles complying with the Euro 3 emission standard
  - diesel vehicles complying with the Euro 2 emission standard but retrofitted with a particulate filter.
- Green sticker:
  - diesel vehicles complying with the Euro 4 or 5 emission standard

- o diesel vehicles complying with the Euro 3 emission standard but (retro)fitted with a particulate filter
- o petrol vehicles equipped with a catalytic converter
- o vehicles designed to use alternative fuels (LPG, CNG, biofuels, hydrogen)
- o electrical vehicles

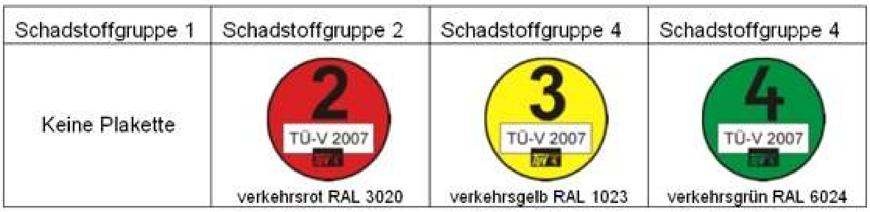

Figure 24. Stickers used in Germany as a national vehicle marking scheme

Impact analysis

No information is available regarding impact of traffic limiting measures based upon the stickers, taken exceptionally the German national environmental administration. The local measures (restricted areas) are discussed below.

10.1.2.1. Berlin

Situation

The limit values for fine particles (PM_{10}) and nitrogen dioxide (NO_2) set by the European Union are exceeded on many main roads in densely populated parts of Berlin's inner city (Berlin, 2007). Road traffic is the key source of these pollutants in Berlin, accounting for roughly 40% of the pollution caused by fine particles and 80% by nitrogen dioxide. This is one of the main reasons for starting with a restricted area in Berlin. It will come into force from 1st of January 2008. The area covers Berlin's inner city within the urban railway ring (see Figure 25). It is an area of approximately 88 km^2, which is densely populated. Approximately one million of Berlin's 3.4 million inhabitants live in this part of the city.

Figure 25. Restricted area, or 'Umweltzone', in Berlin, Germany (Berlin, 2007)

The traffic restrictions of the environmental zone will apply all day, and every day of the week. Also foreigners are affected by the measure, and need to obtain a sticker based on the year of first registration or the euro class indicated on an official document. The driving bans will apply regardless of the current air pollution. The environmental zone will be introduced in two stages, 2008 and 2010. As from 1st of January 2008, vehicles (light and heavy duty) must at least meet the requirements of the second class of the 4 defined classes. Therefore, vehicles with red, yellow and green stickers are allowed. As from 1st of January 2010, only vehicles with a green sticker can enter the city centre (Berlin, 2007).

Impact analysis

In Berlin, it was estimated that stage 2 of the restricted area will reduce the fine particle emissions from diesel exhausts by 50%. As a result of the environmental zone the number of residents affected by exceeded air quality limit values will decrease by approximately a quarter (Berlin, 2007).
When entering the restricted area without a sticker, a fine of €40 will be given.

10.1.2.2. Stuttgart

Situation

The city of Stuttgart was among the first cities in Germany to implement a selective admittance policy based on the colour of the sticker. As from the 1st of January 2008, vehicles without a sticker are not allowed to enter the city. This is extended to vehicles with a red sticker starting on 1st of January 2012 (Pressedienst Landeshauptstadt Stuttgart, 2006).

Impact analysis

A study performed on behalf of the city of Stuttgart indicated that of the 345.000 vehicles registered in Stuttgart, 53.700 vehicles will not receive a sticker and will thus not be able to enter the city as from 1st of January 2008 (PLS, 2006). 75% of these are old petrol vehicles. In the whole region of Stuttgart, some 300.000 vehicles would be affected by the measure. Considering the fact that Stuttgart has a fairly new vehicle park, the study calculated that on the national level about 20% of all vehicles would be affected.

10.1.3. London

Situation

London suffers from the worst air pollution of any UK city. However, it was estimated that in a large part of London the air quality targets set forth by the European Union will be met at the required dates. At the same time, there are considerable areas of London that will probably not meet the targets (AEA, 2003). To achieve the air quality targets, London approved plans for the implementation of a Low Emission Zone (LEZ) starting in February 2008. The scheme targets heavy duty vehicles (trucks, coaches and busses), and will be valid in so called Greater London (see Figure 26). Heavy duty vehicles have disproportionately high emissions per vehicle and targeting them produces greatest emissions reductions for least cost (AEA, 2003). However, as from 2010 vans are targeted as well.

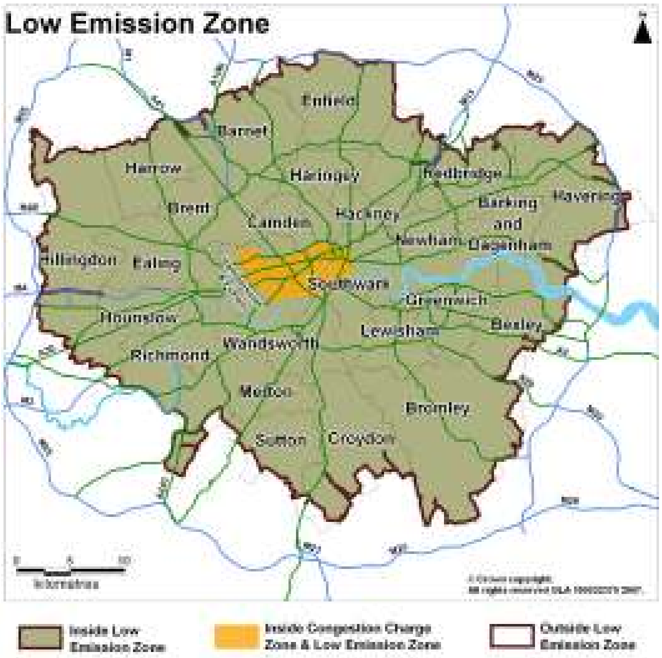

Figure 26. Low Emission Zone (green) in Greater London, OK. Congestion charge zone (orange) (TfL, 2007c).

The LEZ will operate using cameras to identify registration numbers of vehicles driving within Greater London. Different databases will be used to identify a vehicle's emissions standards, whether it was liable for a charge and if that charge has been paid (TfL, 2007c). A manually enforced scheme, targeting heavy vehicles only, would have enabled the quickest introduction of the LEZ (where offenders are pursued through the courts). However, automatic enforcement using cameras ensures higher compliance and so greater air quality benefits. Automatic enforcement required additional powers to decriminalize the offence and administer penalty charge notices through a civil process, but this provides a revenue stream that could help support the additional running costs. An automatic approach was also needed to include vans (in 2010), in order to ensure adequate detection rates.
Operators of affected heavy vehicles that do not meet the LEZ emission standards (unless exempt or entitled to a 100% discount) will need to pay a charge of £200 for each day they are driven in the zone (Dieselnet, 2007). The level of charge has been set in order to encourage operators to clean up their fleets.

Definition clean vehicles

The emission standards for the LEZ are based on Euro standards. Vehicles complying with Euro 3 can drive within the Zone at no charge. The emission standard of a pre-Euro 3 vehicle can be improved by retrofitting it with a particulate filter. In 2012, the limit for entering the zone without charge will probably be tightened to Euro 4.

From February 2008 the LEZ will apply to trucks over 12 tons. From July 2008 the LEZ will also apply to lighter trucks, buses and coaches between 3,5 and 12 tons. From 2010 the LEZ will include heavier diesel-engine light goods vehicles and minibuses between 1,205 and 3,5 tons.

Impact analysis

The costs of setting up and running a LEZ in London vary with the exact scheme and the types of vehicles included. A manually enforced scheme for trucks would have had the lowest cost to set-up (an estimated € 4,2 million to set-up, with running costs of around € 6 million each year). However, an automatic enforcement scheme was chosen. The existing Central London Congestion Charging Scheme (CCS) infrastructure, combined with the use of mobile ANPR cameras, and a small number of additional fixed cameras outside this area, is estimated to cost € 9 million to € 15 million to set-up, with running costs of around € 7,5 million to € 10,5 million each year, but might generate revenues of € 1,5 million to € 6 million per year (AEA, 2003). In a feasibility study of the LEZ, no schemes were found to be self-financing (AEA, 2003).

The number of vehicles affected by the LEZ is very high, as a large proportion of the national fleet operates in London at some point during each year. A LEZ therefore has a significant national impact. The cost to vehicle operators is likely to be significantly higher than the costs of setting up and operating the LEZ. For example, the costs of introducing the LEZ could have a cost to industry of € 96 million to € 202,5 million (the range reflects the number of vehicles that operate in London). The exact costs would depend on operator behaviour in response to the zone. Transport for London estimates that two thirds of all trucks and half of all buses and coaches driving in London would be compliant with the 2008 LEZ standards without any changes to current fleet management programs. The Zone is aimed at encouraging the clean-up of the remaining non-compliant vehicles.

The feasibility study indicated that the LEZ would improve the health of Londoners by reducing air pollution related impacts (AEA, 2003). It would also have small benefits in reducing noise. In later years, it could potentially lead to reduced emissions of the greenhouse gas CO_2. The economic benefits of these environmental improvements would more than offset any costs of introducing and operating the scheme, for example the estimated health benefits in London are estimated at €150 million. Moreover, these benefits are a sub-total, as they only include the air quality improvements in London - there would also be benefits outside London from cleaner vehicles traveling elsewhere. Calculating the health benefits using the EU Café system, results in over €375 million. The EU Café system takes into account a wide range of health effects from restricted activity days and respiratory symptoms to increased use of medicines, an total of €375 m of health benefits (TfL, 2007c).
Overall, the study concludes that the benefits of the schemes are likely to be broadly similar to the overall costs (including the costs to vehicle operators).

The London LEZ would have modest benefits in improving overall emission levels and absolute air quality concentrations in London, but it would make a larger contribution to reducing exceedences of the air quality targets. The recommended LEZ would have greatest impact in targeting PM_{10} emissions and air quality exceedences. It is estimated that by 2012 the Low Emission Zone will deliver emission reductions of around 16% in the area of London where the air quality does not meet European Union pollution objectives (TfL, 2007c).

10.2. Variable parking fees

Parking policies can be designed to target certain groups or types of vehicles. For example, single occupant vehicles, or commuters, or both, can be targeted by raising parking prices during peak hours, offering parking discounts for car or van pools. Another approach which is starting to become more and more prevalent, is differentiating parking fees on the basis of the environmental performance of vehicles. By doing so, cities and municipalities can contribute to improving the local air quality and the environment in general.

10.2.1. Research regarding variable parking fees

International research indicates that drivers are susceptible to price incentives such as higher parking fees, and seek alternatives to evade paying a higher price. A strengthening effect is the fact that parking fees have to be paid directly and are thus more confronting than e.g. a small increase in yearly car tax.
A Dutch study indicated that even relatively small price adjustments can generate a significant change in traffic patterns. Price elasticity related to parking is found to be around -0,1 and -0,3 (Blom et al ., 2006). This means that an increase of 10% in parking fees results in a decrease of traffic volume of around 1 and 3%. The effect also depends on factors such as traffic purpose, time of day, etc.
The environmental impact of differentiating parking fees seems to be higher when visiting persons are targeted as opposed to licensees. This is mainly due to the fact that they form a larger target group, and have more clean alternatives to enter the city, like public transport (Blom et al ., 2006).

The implementation of variable parking fees based on environmental performance of the vehicle requires some clear regulations to be defined (Moura, 2007).

- Ownership of the vehicle – private only or also public and companies;
- Allowance to take part on the benefit, based on use (residential, commercial, transport, etc), time of the day and days of the week that this is valid and size of the vehicles;
- Environmental performance of the vehicle (alternative fuels, emission standards, …).

International experience proved that the national policy on clean vehicles and specific supporting campaigns can significantly increase the environmental benefit of variable parking fees.

CIVITAS - Trendsetter

The European project CIVITAS - Trendsetter is one of the four demonstration projects within the CIVITAS I initiative. The Trendsetter project aims at improving mobility, air quality and quality of life while reducing noise pollution and traffic congestion by promoting, among others, integrated pricing strategies. One of the research topics concerned variable parking fees. The project's conclusions on this topic were (Trendsetter, 2005):

- Variable parking fees reduce emissions of air pollutants and of green house gases.
- Variable parking fees are strong economical incentives for car owners. Generally cheap and efficient measures. Loss of income due to free or reduced fee for clean cars is an economical barrier that might cause political problems.
- Reduced parking fees for "clean vehicles" and/or increased fees for "normal vehicles" - will force the shift toward "clean vehicles" and higher use of public transports.
- Depending on the definition of "clean vehicle" – reduced parking fees will give different results, such as: more use of renewable fuels and lower emissions of a specific pollutant component.
- It is important to find rational methods for registration of "clean vehicles".

The final report also made some recommendations towards local authorities:

- The lack of national definition of clean vehicles/less polluting vehicles can be a barrier. To get acceptance within a city might also be time consuming. The definition is needed to be able to implement fair incentives.
- Politicians need to see alternative costs for achieving a shift to other transport modes/clean vehicles.
- Changes in the parking legislation might be needed to be able to favour clean or less polluting vehicles.
- Information is needed to get both awareness and acceptance for the implemented measures.
- Support from the media is vital. Important to involve them early in the process.

10.2.2. Stockholm (Sweden)

Situation

For some years the city of Stockholm (Sweden) exempts electrical and hybrid electrical vehicles from paying parking fees. Since may 2005 this has been extended to vehicles using bioethanol and gaseous fuels other than LPG. Only inhabitants and companies from Stockholm can benefit from this measure. Private companies that use cars extensively within the city centre can apply for a special free parking permit for commercial clean vehicles (Blom et al., 2006; Trendsetter, 2007a).

The measure was heavily delayed due to lack of political agreement. Much effort has been spent on convincing concerned politicians and salaried employees in different city administrations to support the measure (Trendsetter, 2005).

Definition clean vehicles

Only vehicles designed to use bioethanol, or gaseous fuels other than LPG as motor fuel, and (hybrid) electrical vehicles can benefit from this measure. Recently small cars complying with euro 4 and running on petrol or diesel but not emitting more than 120 g CO_2/km are considered clean cars as well. These small diesel cars need to be equipped with a particulate filter (Sunnerstedt, 2007).

Impact analysis

This measure is difficult to asses on its own, while it is part of a larger package of policy measures aiming at stimulating the purchase and use of environmentally friendly vehicles in Stockholm. For example, clean vehicles are also exempt from paying congestion tax. On a national level, these vehicles can also benefit from lower car taxation. Since the introduction of free parking in 2005 and the exemption from congestion tax in 2006, 19% of all vehicles sold in Stockholm are clean vehicles. Nationwide, this figure is 13% (Blom et al ., 2006 ; Sunnerstedt, 2007).
Owners of clean vehicles in Stockholm receive a parking permit for free. This permit normally costs about 600 € per year. The special free parking permit for commercial clean vehicles of private companies regularly costs 850 € per year. From May until August 2005, 440 private and 390 company/commercial permits for clean vehicles were issued (Trendsetter, 2007a).
In December 2005, around 30% of the new Volvo's and 90% of the new Saab's were considered clean vehicles. The increase was realized especially in the region of Stockholm (Miljöforden, 2006b).

10.2.3. Göteborg

Situation

In the city of Göteborg, clean vehicles can benefit from reduced parking fees since 1998. Clean vehicles can park for free during 2 hours on parking places managed by the municipality. Additionally, parking permits for this type of vehicles are free. This measure is not solely for inhabitants of Göteborg (Blom et al ., 2006).

Definition clean vehicles

Only vehicles designed to use bioethanol, or gaseous fuels other than LPG as motor fuel, and (hybrid) electrical vehicles can benefit from this measure. Additionally, the municipality states that clean vehicles can not emit more than 190 g CO_2/km (Miljöforden, 2004c). This was added to exclude large hybrid SUV's from this measure.

Impact analysis

No information is available regarding the direct impact of the measure. However, there is a steady increase of sales of clean vehicles in Göteborg. During 2006 the number of clean vehicles in Göteborg increased by 87 %. In numbers, clean vehicles have increased from 4.001 to 7.464 and the clean vehicles now comprise more than 10 % of sales of new vehicles in Göteborg (Miljöforden, 2007b).

10.2.4. Norrköping

Situation

In the city of Norrköping (Sweden), since march 2005 clean vehicles can park 3 hours for free on parking places managed by the municipality. Owners of clean vehicles can obtain a special parking permit, allowing them to use these parking places. This measure is not solely for inhabitants of Norrköping.
Owners of clean vehicles who also have a local (Norrköping) parking permit, can park all day for free (Blom et al ., 2006).

Definition clean vehicles

Only vehicles designed to use bioethanol, or gaseous fuels other than LPG as motor fuel, and (hybrid) electrical vehicles can benefit from this measure.

Impact analysis

No information is available regarding impact of the measure.

10.2.5. Falun

Situation

The municipality of Falun (Sweden) is currently on its way to introduce free parking for clean vehicles. The administration fee will be €11 for a free pass to all the parking lots in the municipality. The free pass will be valid for three years. The proposal originated from the public and is on its way to be carried out. Already in 1999 the municipality decided on an annual fee of €44 for clean vehicles. But it is apparent that not many people have explored this possibility. Lowering the fee dramatically, would hopefully encourage the people of Falun to buy clean vehicles (Miljöforden, 2004b).

Definition clean vehicles

Only vehicles designed to use bioethanol, or gaseous fuels other than LPG as motor fuel, and (hybrid) electrical vehicles can benefit from this measure.

Impact analysis

Since the municipality of Falun is considering this measure, no information is available yet regarding impact of the measure.

10.2.6. Graz

Situation

The city of Graz (Austria) introduced a lower parking tariff for low emission cars (including cars like hybrids and electrical but also standard mass produced cars). The measure was introduced within the framework of a necessary tariff increase. The parking tariff for all ordinary vehicles was raised from € 1 per hour, to € 1,20. The tariff for low emission vehicles was lowered to € 0,80, or a reduction of 30% compared to ordinary vehicles. Owners of low emission cars can register their vehicle at the city council and get a so called "Umweltjeton" (see Figure 27), an environmental token and a special sticker. Parking ticket vending machines are equipped to recognise those tokens and deliver a lower tariff. The sticker is an official document, which is filled out by the city and includes the car number, type of car, colour of the car and an official seal of the city of Graz (Blom et al., 2006 ; CIVITAS, 2006).

Figure 27. "Umweltjeton", used in the city of Graz (Trendsetter, 2005).

Definition clean vehicles

Clean vehicles who benefit from a 30% reduction in parking tariff were defined as:

- euro 4 petrol powered vehicles emitting less than 140 g CO_2/km
- euro 4 diesel powered vehicles equipped with particle filters, and emitting less than 130 g CO_2/km
- euro 4 gas powered vehicles emitting less than 140 g CO_2/km

Electrical vehicles can park for free (Blom et al ., 2006).

Impact analysis

Costs for converting the parking ticket vending machines were quite low, due to the small adjustements needed. During the introduction in spring 2004, the interest of the general public was quite high. However, only 40 to 60 drivers of low-polluting vehicles were approved by the parking department until september 2005. The main reason is that only very few cars fulfil the set criteria. Mostly because they lack particle filters. Cars that fulfil the criteria are not promoted actively by producers and retailers. As more and more cars fulfilling the criteria become available, it is planned to carry out a special promotion together with the car retailers (Blom et al ., 2006 ; Trendsetter, 2007b).

10.2.7. Leeuwarden

Situation

The municipality of Leeuwarden (The Netherlands) offers one year of free parking to 40 owners of clean vehicles. Inhabitants from Leeuwarden as well as people working in Leeuwarden during at least 3 days a week can benefit from this measure (Gemeente Leeuwarden, 2007).

Definition clean vehicles

Vehicles running on natural gas, pure plant oil, bio-ethanol and hydrogen are considered to be clean vehicles.

Impact analysis

No information is available regarding impact of the measure.

10.2.8. The Netherlands

Situation

In the end of 2007 beginning of 2008, the Dutch government will probably adopt a proposal regarding parking policy. Municipal law will be altered in order to allow local authorities to adopt different parking fees for clean vehicles. This will probably be done for parking permits but also for local (short term) parking fees. When paying at a parking ticket vending machine, the owner will have to type in his license plate allowing the corresponding price to be determined according to the environmental impact of the vehicle. The city of Amsterdam, among others, has plans to adopt variable parking fees disencouraging environmentally unfriendly vehicles to enter the city.

Definition clean vehicles

This will probably be determined by the emission standard of the vehicle, the CO_2 emission and the presence of a particulate filter for diesel cars.

Impact analysis

No information is available regarding impact of the measure.

11. Conclusions

According to Gordon (2005), a package of sound fiscal policies, accompanied by a strong regulatory policy, is necessary to steer the market towards cleaner vehicles. While individual policy designs are important, comprehensive consideration of overall policy package impacts is even more important. A simultaneous top-down and bottom-up policymaking approach is necessary in this complex, dynamic sector. The bottom-up component entails developing fiscal policies based on sound principles – aligning prices with marginal social costs (establishing variable prices for fuels, vehicles, and roads that are related to energy consumption, pollution, congestion, and other socially harmful impacts). A top-down effort in fiscal transportation policymaking is equally as important as designing individual policies. This entails examining fiscal policies as a comprehensive package. Unfortunately this component often gets less attention than individual policy development. Any individual fiscal policy is only one part of the total set of prices faced by users.

A mix of policies which integrates carrots (incentives), sticks (disincentives) and regulations works best. This includes a mix of target audiences: steer industry and final consumers, both public and private. For private consumers, tax systems based on environmental performance are getting more and more common. No mandatory systems towards private fleet consumers exist today, voluntary systems are in place and the market starts offering green products. Company car taxation seems the appropriate instrument to influence that market. For public consumers, mandatory targets for clean vehicles seem to have an effect on the overall market and are a suitable instrument to open the market.

Monitoring and impact assessment results from different policy measures implemented are lacking most of the time. However, this is essential in the evaluation of how the market reacts on the different measures. Policy towards cleaner vehicles is dynamic so governments should be aware of the impact and redefine the measures whenever necessary.

The assessment of policy measures conducted in the CLEVER project is an update of the assessment performed in the ECOSCORE project in 2004. The main evolutions in 3 years time is that classic car taxation paid for ownership of a car are decreasing in favour of more place and time based road charges also depending on environmental performance of vehicles. Classic subsidy programmes are abolished because they are not in line with EU legislation on subsidies or the higher management costs of the system.

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CLEVER
Clean Vehicle Research

Consumer Behaviour for Purchasing Cars
Task 1.4

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Table of contents

1. Introduction

Two important factors have caused major evolutions and developments in the transportation and automotive sector and have stimulated the use of new technologies for our transportation modes: the availability of energy sources and the important negative effects of our transportation system on the environment (Van Mierlo et al., 2006). The dependence on fossil fuels and the environmental aspects related to our current transportation system, demand a fundamental revision of the energy supplies in general and of transport and mobility in specific. The ever more stringent emission standards for vehicles force the automotive industry to reduce the environmental impact of conventional diesel and petrol vehicles by using new technologies. Besides these improved conventional vehicles, vehicles with alternative fuels such as Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG), bio-fuels, biogas and hydrogen or drive trains such as hybrid, fuel cell and battery Electric Vehicles (EVs) can form an attractive solution. This report reviews the impact of the environmental friendliness of the car on the car purchase decision. In the next section, we will briefly discuss the alternative fuels and technologies that we consider in this report as environmentally friendly. A large scale market introduction of these environmental cars seems to be a great challenge. It depends not only on large-scale infrastructure costs, such as refueling/recharging facilities needed on the supply side, but it depends also on the acceptance by the end-users on the demand side. It is of great interest for transport planners, policy makers and car manufacturers to know if the strong concern for the environment that we observe nowadays, will be translated into a public acceptance of green cars. In this respect, sections 3 and 4 will set-up and present the results of a review of 26 scientific publications in order to assess the importance of the environmental friendliness in the car purchase decision. Still open research questions will be formulated in the conclusions.

2. Alternative Fuels and Technologies

Alternative Fuel Vehicles (AFVs) are vehicles that make use of LPG, natural gas, bio-fuels, biogas or hydrogen. LPG is the most common alternative fuel currently on the market. At atmospheric pressure LPG is a gas, but at a pressure of 4 bar it can be liquefied. Most of the LPG vehicles that currently exist are “retrofit” petrol vehicles, but there is a tendency towards the development of specific LPG vehicles. Natural gas mainly consists of methane (80 to 99 %). The vast majority of natural gas vehicles uses CNG, but Liquefied Natural Gas (LNG) also exists. Like LPG vehicles, CNG vehicles are usually adjusted petrol vehicles. They can also use biogas, which is produced by fermentation of manure and/or organic waste. Hydrogen can be used in a fuel cell (see further) or in a combustion engine. Through some adjustments, a petrol engine can be converted to hydrogen. Hydrogen can be produced through the oxidation of gas, which is the most common production method, or it can be produced from the electrolysis of water or from biomass. Bio-fuels are “supposed” renewable fuels, made from agricultural crops, wood or organic waste. The EU has set the target that 5.75% of the total amount of used transportation fuels have to be bio-fuels by the year 2010. To that extent, the EU counts on the short term on biodiesel, bio-ethanol and to a lesser extent on biogas and pure vegetable oil. On the mid-term they count on second generation bio-fuels, such as bio-methanol, produced by the gasification of biomass.

Vehicles with alternative propulsion systems are battery, fuel cell and hybrid EVs. Battery EVs are driven by an electric motor, which obtains its energy from a rechargeable battery. At standstill, the motor does not use energy and a part of the energy during braking can be recuperated to charge the battery. Due to their limited autonomy (80-120 km at full charge), battery EVs are suitable for use in the city or to travel short distances. Their autonomy is expected to increase strongly due to the use of new battery technologies, like lithium batteries. EVs can also be equipped with a fuel cell in stead of a battery. This fuel cell uses oxygen from the air and hydrogen from a tank to produce electricity. Currently only prototypes exist, but fuel cell vehicles are expected to be ready for the market in 10 to 20 years. The current prototypes display an autonomy of more or less 300 km, but in 10 to 20 years, 600 km should be possible. Finally, hybrid vehicles comprise a collection of vehicle technologies that use two (or more) drive trains or energy sources, but usually they have an internal combustion engine and an electric motor. Depending on whether only the electric motor or both the electric motor and the combustion engine drive the wheels, it is called a “series hybrid” or a “parallel hybrid” propulsion. A combination of both also exists (e.g. Toyota Prius).

3. Review of Consumer Preferences for Green Cars

According to Cooper (1989), a research review should be designed in a systematic, objective way. To this extent, the integrative research review contains five stages as main structure. The first stage is the formulation of the problem, which will guide the research (section 3.1). The second is the determination of the data collection strategy and a selection of multiple channels in order to avoid a bias in coverage (3.2). The third stage elaborated in 3.3 will give an evaluation and selection of the retrieved data. The fourth stage contains an analysis and interpretation of the reviewed literature (3.4). Finally, section 4 will give the presentation of the results (Bontekoning et al., 2002).

3.1 Formulation of the Problem

In order to assess the importance of the environmental awareness in the car purchase decision, it is necessary to get an insight into the process of purchasing itself. The consumer's decision to purchase a product is a multi-staged process. Kotler (2006) identifies that the consumer will go through five stages. Vehicle purchase behavior is fairly complex, as car purchase implies a high level of social and/or psychological involvement (Abramson and Desai, 1993). Therefore, the consumer will transit each stage of the purchase decision making process as presented in Figure 1.

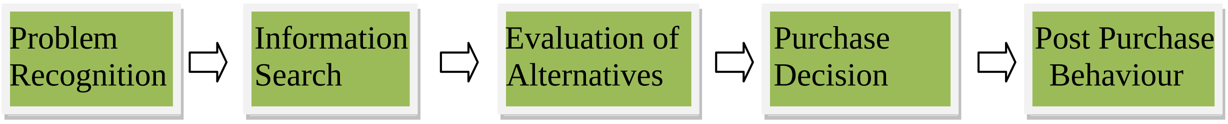

Figure 1. The purchase decision making process (Kotler, 2006)

3.1.1 Problem Recognition

The purchase decision of a new product is induced by problem recognition. This means that the buyer recognizes a discrepancy between the existing and the wanted situation (Kotler, 2006). In the case of car purchase, there can be several buying-triggers. A study of MU Consult (2000) identified several motives to purchase a new car. These motives can be, among others, reparation costs or a good exchange value for the old car.

3.1.2 Information Search

Following on from the problem recognition, the information search is the stage in which the consumer will inform himself about the product. The purchase of a car is a high involvement purchase which might mean that there will be an extensive information search. This information search may cover external or internal sources of information. An external search means gathering information from sources such as books and magazines, automobile articles, salespersons at dealerships, friends and test-drives. The consumer can also use his long-term memory or an internal information search (Punj and Staelin, 1983). Even before consumers actually consider buying a car, they are confronted with information out of advertising, television programs and articles. According to Abramson and Desai (1993), the purchase of a car is so important that the consumer attends to messages about cars continuously. As a result, at the time of actual search, the consumer does not pay extra attention to information about cars. Moreover, Abramson and Desai (1993) found out that, while car purchase is a high involvement action, the actual information search behavior is characterized by little effort.

3.1.3 Evaluation of Alternatives

Once sufficient information is gathered, the consumer moves on to the evaluation of the alternative solutions. The evaluation process of a car is complex. The consumer wants to make a well- reasoned purchase decision and will consider several car attributes when making his decision. In general, the consumer will assign different levels of importance to attributes. By use of a quantitative survey of 581 people who recently bought a car, OIVO (2004) found out that the three most important attributes consumers take into account when evaluating car alternatives are the purchase price, the operating cost and the quality of the car. Based on these attributes, consumers will select certain alternatives. Once these alternatives are selected, consumers will base their actual choice by the evaluation of other car attributes. According to Potoglou and Kanaroglou (2006a), the attributes of the car can be categorized into the monetary attributes, the non-monetary attributes, the socio-economical attributes and the environmental attributes.

Out of the monetary attributes, the purchase price is the first factor consumers take into account when purchasing a car (Cao and Mokhtarian, 2003; OIVO, 2004). Borgsteede and van Tatenhove (2004) state that consumers define in advance a certain price category to which the car of their choice has to belong. More specific, the consumer defines in advance a maximum price the purchase of a car cannot exceed. This maximum price determines which types of vehicles the consumer will choose from. The purchase price will only be irrelevant for those consumers who have a large income (Borgsteede and van Tatenhove, 2004). A second important criterion when choosing a car is the operating cost (Cao and Mokhtarian, 2003). The operating cost consists of the maintenance cost and the cost of fuel consumption. According to OIVO (2004), fuel consumption is a very important car attribute as they found that during the car purchase decision, the assessment of fuel consumption is based on the comparison of fuel consumption between vehicles of the same type, rather than on a specific analysis of the cost per kilometre. Importantly, the fuel consumption will only be taken into consideration because of the fuel costs, and not because of environmental issues (Clase, 2004; VITO, 2003).

Out of the non-monetary attributes, the quality (reliability and security) of the car is the third important car attribute (OIVO, 2004). Consumers want their car to be safe, moreover the car has to react how the consumer wants (e.g. in case of danger). However, the actual choice for a certain car is also induced by other intrinsic characteristics of the car, mentioned here after (Cao and Mokhtarian, 2003; OIVO, 2004; Borgsteede and van Tatenhove, 2004). Looks play an important role in the purchase of a car. Acceleration time, horsepower and the sound of engine are elements that are important for two reasons. First of all, certain consumers want their car to accelerate fast because they like to drive sportive. Secondly, these elements are important in terms of safety. Comfort, number of seats and luggage space play also a role in the car purchase process. A last important non-monetary attribute is brand loyalty (May, 1969; Newman and Werbel, 1973; Dowling and Uncles, 1997). According to these authors, consumers are likely to buy a car of the same brand as their previously owned car, based on their experiences with that brand.

Socio – economic attributes play an important role too as a car has for many people an important image-function and carries a certain status. Consumers are inclined to choose products that communicate their role and status in society (Kotler, 2006). As consumers buy products that reflect their personality, lifestyle and the social class to which they belong, personal, social and cultural factors will have an important influence on the decision-making process. Moreover, Choo and Mokhtarian (2002) state that travel attitude, and demographic characteristics such as age and gender play an important role too in the vehicle type choice. According to the travel attitude, workaholics or people who do not enjoy personal vehicle travel for short distance are more likely to choose large cars; people who tend to be organizers are more likely to choose mid-sized cars; people who tend to be status seeking and who travel a lot by airplane are more likely to drive luxury cars; sports cars are more frequently bought by younger, status seeking people who are not workaholics and calm people are more likely to drive minivans. Out of the demographic characteristics, the consumer's age is found negatively associated with driving small or sports cars and Service Utility Vehicles (SUV). What gender is concerned, Choo and Mokhtarian (2002) found out that females are less likely to drive pickups than other vehicle types. Males, on the other hand, are more likely to buy bigger cars (Miller, 2003). Finally, car purchase is also influenced by household characteristics. Kurani et al. (1996) state that households are the fundamental unit for decisions on vehicle purchase. This is confirmed by Kotler (2006), who says that the family of procreation (one's spouse and children) has the most direct impact on the buying behavior. As a consequence, the importance of car attributes such as number of seats, luggage space, and size will depend on the need of the household (Kurani, Turrentine and Sperling, 1996). According to Beggs and Cardell (1980), the choice of the vehicle's size depends on household size, income level and the type of vehicle which the smallest car complements in the household fleet. The larger the household's income, the more likely the household will buy luxury cars and SUV's. When the household already has a large car, it will be more likely that the second car in the household fleet will be a smaller one. Kurani and Turrentine (1995) state that households that own two or more cars can be potential buyers of environmentally friendly cars for the second or third car in the household fleet. These households are referred to in the literature as "hybrid households" (Kurani and Turrentine, 1995).

The fourth kind of attributes Potoglou and Kanaroglou (2006) defined, are environmental attributes. The question is if the consumers will take these attributes into account when purchasing a vehicle.

3.1.4 Purchase Decision

After the evaluation of several alternatives on the basis of the set of car attributes, the consumer will form his purchase intention that will result in the actual purchase decision. However, there are still two factors that can come between the purchase intention and the purchase decision. First of all, the attitude of others such as family members: the stronger their opinion and the closer related to the purchaser, the greater their influence on the purchase decision. Secondly, the purchase intention can be influenced by unexpected situational factors (Kotler, 2006).

3.1.5 Post Purchase Behaviour

The last stage within the decision making process, is the evaluation of the purchased product. The level of satisfaction will depend on the relationship between the expectations about the product and the perception of the product performance (Kotler, 2006).

3.2 Determination of the Data Collection Strategy

For the data collection, a computerized search was used. The use of electronic sources may involve a risk of having a bias in the data coverage towards more recent articles. Literature from the early ’80s is often not accessible from electronic resources. Due to this inconvenience, the review could only treat 3 papers from the early ’80s. Nevertheless, the short period of coverage will not produce a significant coverage bias in this review, as we presume that the majority of the papers involving the demand for environmentally friendly vehicles were published in the ’90s. The review covers the period 1980-2007 as much as possible. The articles were mainly retrieved by tracking cited references and by tracking e-catalogues. Several sources were used in the search for literature in order to avoid a bias in coverage. This includes the web-based search tools (V-spaces, article database; “web of science” and other e-sources) and the VUBIS library e-catalogue from the university library of the Vrije Universiteit Brussel (VUB). Also ordinary web-search robots such as google were used to track cited references and to find publication titles. The search was conducted during May 2007, using the general search terms such as “alternative fuel vehicles” “environment” and “purchase behaviour”.

3.3 Evaluation of the Retrieved Data

By using the above described methodology, 26 publications were collected. The reviewed articles show first of all divergences in the treated research field according to the research period. Studies in the ‘80s and ‘90s focused mainly on the potential demand for battery EVs (Beggs and Cardell, 1980; Beggs et al., 1981; Segal, 1995; Kurani and Turrentine, 1995; Kurani et al., 1996; Chéron and Zins, 1997; Gould and Golob, 1998a,b), while more recent studies rather focused on cars with alternative fuels (Bunch et al., 1993; Brownstone et al., 1994; Sperling et al., 1995; Brownstone et al., 1996; Bunch et al., 1996; Brownstone et al., 1997; Ewing and Sarigöllü, 1998; Tompkins et al., 1999; Ewing and Sarigöllü, 2000; Dagsvik et al., 2002; Mourato et al., 2004; Potoglou and Kanaroglou, 2006a,b; Lundquist et al., 2006). There was only one article (Mourato et al., 2004) that assessed the potential demand for fuel cell EVs.

Secondly, most literature on the demand for environmentally friendly vehicles is carried out in America. Out of the 26 reviewed articles, 14 were carried out in California, 5 were elaborated in Canada and 4 in other States of the US. In contrast, Europe was represented with only 2 papers and Asia with only 1. The bias towards California as the geographical focus of attention in most of the publications may be explained on the one hand by the heightened awareness of air pollution due to local conditions and the press attention (Glazer et al, 1995). On the other hand, it can be explained by the Californian regulations and state programs that not only require semi-annual vehicle emission checks, but also the instauration of emission packages when a new car is bought in the state (Gould and Golob, 1998a).

Thirdly, the reviewed studies differed in their applied research methodology[1] in order to assess the consumer preferences for green cars. In the ‘80s, attitudinal surveys were a common used research methodology to assess the consumer preferences for green cars. As a result of the use of electronic sources, the risk of a bias in the data coverage towards more recent articles is illustrated by the fact that only 2 publications out of the 26 made solely use of an attitudinal survey. This minor representation can also be explained by the fact that

[1] For a description of the applied research methodologies, see section 4.

attitudinal surveys, widely used by the car industry to understand environmentally conscious purchase behavior, are often not publicly available (e.g. the Dohring Company (1994), Kirchman (1993), Buist D.R. (1993)). Nowadays, we see a tendency towards the use of experimental design, representing 6 out of the 26 publications, and especially towards the use of preference valuation techniques, representing 18 out of the 26 publications. However, there must be said that within these studies, attitudinal surveys are often used in a first phase in order to develop the survey instrument or to obtain in-depth qualitative information about the consumer's attitudes on environmental issues.

3.4 Analysis and Interpretation of the Literature

Based on the criteria such as the title, abstract, keywords and the type of media, a pre-selection of the articles was made. Starting from this pre-selection, the publications were first divided according to the publication year in order to have a good representation of the different research periods and the resulting research field. Secondly, the publications were classified according to the used research methodology.

4. Presentation of the Results

In this section, the findings of the publications will be presented in order to give an answer to the central question of this review: will the environmental friendliness of the car play a role in the car purchase decision? As explained in section 3.3, we can make a classification according to the research methodology that has been used. The overview of publications in this section is given according to these different research methodologies, namely attitudinal surveys, experimental analysis and preference valuation techniques or a combination of all three. First, a brief definition of the methods will be given, followed by an overview of the findings giving an answer on the previously formulated question. An overview of common cited critics on the research method will close each section by highlighting their limitations.

4.1 Attitudinal Surveys

4.1.1 Definition

Although there are many definitions of attitude, we will use in this paper the definition suggested by Eagly and Chaiken (1993). Attitudes are “tendencies to evaluate an entity with some degree of favor or disfavor, ordinarily expressed in *cognitive*, *affective*, and *behavioural* responses”. In transportation studies, cognitive attitudes are related to information and understanding, e.g. sensitivities to transportation costs. Affective attitudes are related to feelings and concerns, e.g. sensitivity to the environment, while behavioural variables reveal tendencies towards different situations, e.g. “will you buy a green car to help the environment?” (Parkany et al., 2003). Attitudinal surveys will evaluate consumer preferences for green cars by using new utility demonstrations or hypothetical constructs. The latter will measure the attitude through indirect indicators such as verbal expression or overt behavior (Zikmund, 2003).

4.1.2 Overview of the Results

Tedeschi et al. (1982) elaborated a study to clarify the relationship between variables -such as knowledge on environmental issues, environmental concern, perceptions of personal or environmental control and self-interest - and the actual environmental behavior. A sample of 106 American drivers, of which 43 persons participated voluntarily in an inspection of their cars for excessive exhaust emissions, was presented a survey on environmental problems. Overall, the drivers who attended the voluntary car emissions inspection were found not to differ from the non-participants according to their levels of knowledge or in their attitudes regarding air pollution. In order to enhance the individual responsibility for pollution control, Tedeschi et al. believe that heightening the awareness of the direct effects of pollution on people’s lives may be effective. A recent study by Wang et al. (2007) conducted an attitudinal survey amongst thousand Chinese citizens to investigate the potential consumers’ attitude towards micro battery EVs. These micro EVs are characterized by a driving range of maximum 100 km, a vehicle speed of 30-50 km/h and a considerable low purchase price of on average 2925 euro. It was found that 75% of the investigated people would purchase this competitively priced micro EV, and use it especially for driving short distances. This EV purchase decision is, according to Wang et al. (2007), also influenced by the age, education, environmental attitude and the living area (such as local traffic conditions, regulations) of the consumer.

4.1.3 Critics on Attitudinal Surveys

Attitudinal surveys often have mixed success in predicting the purchase of green cars. Due to the fact that many people do not have any familiarity with the new technologies, those studies rather reflect consumer ideals for socially desirable values (e.g. environmental benefits) than their real purchase intentions. As a result of the “feel good” answers for the green and progressive technologies, these studies tend to overstate the demand for environmentally friendly vehicles (Gould and Golob, 1998a; Kurani et al., 1996). In order to avoid these social desirable answers, one can measure the implicit attitudes of respondents towards green cars. Implicite attitudes are attitudes of which the consumers are not aware of, but nevertheless influence the behaviour and choices of the consumer. Implicit attitudes can be measured by the Implicit Association Test (IAT) (Greenwald et al., 1998). This will be investigated in more detail during the following work packages.

4.2 Experimental and Quasi- Experimental Studies

4.2.1 Definition

Experimental research is defined by Zikmund (2003) as a research method in which conditions are controlled so that causal relationships among variables can be evaluated while all other variables are eliminated or controlled. The essence of experimental and quasi-experimental designs is to put individuals (experimental group) in a natural setting -field experiment- or in an artificial setting -a laboratory experiment- and to observe their reaction that will be measured against a group of individuals not exposed to the experimental treatment (control group).

4.2.2 Overview of the Results

Turrentine et al. (1992) predicted the potential demand for green cars by executing AFV test-drives for 236 Californian drivers and by using several methods such as pre- and post-test surveys, focus groups and structured interviews. They found out that people who belong to environmental organizations do not have higher purchase intentions for green cars. Further research of Kurani and Turrentine (1995) extended this research and focused on electric vehicles. A large amount of information such as travel diaries, maps and informational material were provided. Although they found a strong association between the idea of “moral choosing” and the likeliness of purchasing EVs, there was little evidence that households were willing to pay more for them. They did find a greater Willingness To Pay (WTP) for EVs displayed by households that own two or more cars. This gives an indication that in a hypothetical two-vehicle household, they will combine the EV and gasoline vehicle in their stock to satisfy the different travel needs of the various household members. Subsequently, Kurani et al., (1996) confirmed previous findings and found that although environmental awareness may not lead to the purchase of an EV, it may encourage households to seek out and evaluate EVs for purchase consideration. Gould and Golob (1998a, b) made use of personal vehicle trials in California to overcome the problem of consumer’s lack of frame-of-reference for the evaluation of EVs. The experimental design consisted of an inboard travel logger, a fill-in travel diary and pre- and post-trial attitudinal questionnaires. Although the opinions about the environmental efficacy showed improvement after the trial of the EV, the participants mentioned that they are likely to select an EV on the basis of other factors (e.g. technology) than the environmental benefit

A quasi-experimental study was elaborated in Los Angeles by Urban et al. (1994). In this study, a multi-media workshop was organized where the consumers were placed in a virtual buying environment. The experimental design simulated the types of information available to the consumer at the time a purchase of an EV is made. One of the preconditions was that the participants accepted the idea of an environmentally friendly car. Although the EVs were rated highly in terms of environmental attributes, the concern about the environment was the lowest rated issue when purchasing a vehicle. This supports the conclusion that consumers do not want to give up other car attributes for environmental benefits.

4.2.3 Critics on Experimental Studies

Experimental designs such as vehicle trials may impose some limitations. First of all, trials may evoke the "Hawthorne" effect, indicating that people will produce upward biased estimates of interest in green cars since they receive special attention. As a result, fewer people than those who expressed a purchase intention are likely to purchase a green car. Secondly, there may arise several measurement problems related to the duration and length of time of the trial. According to the duration of the trial, more regular patterns will arise over time as the novelty factor declines. Due to the limited length of trials, the consumers' experience of the technology is truncated, vis-à-vis everyday use. Finally, trials may provide reactions to a specific category of product because of the opportunity that the participants have to experience competing technologies (e.g. conventional gasoline cars) (Gould and Golob, 1998a, b).

4.3 Preference Valuation Techniques

4.3.1 Definition

Preference valuation studies are often used by economists to analyze the potential demand for a product or service by measuring the consumer preferences for those products/services. The reviewed papers used two methodologies in the assessment of consumer preferences for green cars: stated and revealed preference techniques.

The Stated Preference (SP) technique is a survey-based technique that allows researchers to uncover how people value different product/service attributes. The most common SP techniques used in transport studies are the Choice Modeling (CM) method and the Contingent Valuation Method (CVM). CM originates from the conjoint analysis. It uses a choice experiment, where consumers are asked to express their preferences for hypothetical vehicles described by specific attributes. Subsequently, via statistical techniques, the analysis will derive a value for each of these attributes and thus express the relative preferences among vehicle attributes (Segal, 1995; Dagsvik et al., 2002). CVM asks respondents their maximum WTP for an increase or their minimum Willingness To Accept (WTA) for a decrease in environmental quality. In the dichotomous CVM design (yes/no answers), respondents accept or refuse a payment for a change in the quality or the quantity of a good at a given cost (Mogas et al., 2006). In contrast to the SP technique, the Revealed Preference (RP) technique uses real market data from observations on actual choices in order to measure the consumer preferences.

4.3.2 Overview of the Results

Within the reviewed papers, most preference valuation techniques have been used for the valuation of non-environmental attributes (e.g. driving range, recharging time) while there has been little work on the valuation of the environmental attributes of cars (e.g. less emission, zero noise). Therefore, a distinction will be made across the studies that did not include an environmental attribute in their design, and the studies that did include one.

Out of the publications that excluded the environmental attribute in their design, Beggs and Cardell (1980) and Beggs et al. (1981) assessed the potential demand for battery EVs amongst multi-vehicle households in the Baltimore area. They assumed that EVs could become a niche market for small car buyers in multiple vehicle households. An ordered logit model was applied to the data gathered from an SP survey in which the participants were asked to provide rank orderings for 16 car designs which differed over 9 attributes such as price, operating cost, range, recharging time, performance, size and air conditioning. The findings show a small market share for EVs as a result of the high negative valuation of the limited range and the long recharging times. Similar results have been found by Segal (1995), who used a conjoint analysis for the prediction of a potential market for battery EVs in California. The contingent rating questions included each 7 attributes such as recharging/refueling attributes, range, fuel attributes and cost of the vehicle. The main finding of this study is the prediction of a very low market share for battery EVs as a result of the high purchase price and the inconvenience associated with the EV ownership after sale. The greatest WTP for the EVs was expressed by the multi-vehicle Californian households. Also, Chéron and Zins (1997) made use of the conjoint forecasting method to identify the most determining factors in blocking a viable market for battery EVs in Montreal. The conjoint analysis consisted of an experimental design combining the following attributes: range, maximum speed, recharging time and cost and delay in case of a dead battery. The study concludes that an EV will not be accepted by the market because of the concern over battery charge duration. So, unless the driving range and the recharging time are comparable to conventional gasoline vehicles, there will be no market potential for EVs. Moreover, Chéron and Zins doubt that that these factors can hardly be compensated by the greater cleanliness of EVs. Finally, Dagsvik et al. (2002) made an assessment of the potential Norwegian household demand for AFVs by using several alternative structural demand models based on the obtained SP data. The included attributes were the purchase price, driving range between refueling/recharging, top speed and fuel consumption while attributes such as refueling/recharging time and availability, emission level and size of vehicle were not taken into account in the choice sets. Their results confirm the findings of Chéron and Zins (1997) by stating that there will be an low WTP for AFVs unless their attributes - especially the purchase price and the driving range- become fully competitive compared to conventional gasoline vehicles.

Out of the publications that included an environmental attribute in their design, Bunch et al. (1993) and Golob et al. (1993) made use of multinomial logit models applied to SP vehicle choice data to predict the market penetration of AFVs in California. The vehicle attributes included in the SP design were purchase price, fuel cost, range, performance, fuel availability and vehicle emissions. The main finding is that consumers are willing to pay $9000 or 6074€ more for a vehicle with reduced emission levels of up to 90%. Brownstone et al. (1994) and Brownstone et al. (1996) forecasted the demand for AFVs in California by applying a vehicle transaction choice model based on SP data conditional on the vehicles currently held by the household. They discovered that households with children attached a greater value to emission reduction than households without children. Moreover, 2-vehicle households with children under 21 years expose the greatest WTP for a reduction in emissions. Sperling et al.

(1995) made an assessment of the potential target market for methanol in the household sector of New York and California. The dichotomous CVM was used to measure their WTP for the typical attributes -less pollution and more power- of methanol. They found a great WTP for cleaner fuels across all socioeconomic groups indicating that income is not a determining factor in the purchase of clean fuels. Especially Californians and female drivers were found to express a greater WTP for clean fuels than New Yorkers and male drivers respectively. Tompkins et al. (1999) investigated determinants of the AFV choice by the application of multinomial logit models based on data from a SP survey for the Continental US. A relative emissions variable was included in the SP design next to other non-environmental attributes such as price, range, fuel cost, and fuel efficiency. As in Sperling et al. (1995), only the Californians expressed a WTP for AFVs. Mourato et al. (2004) made use of the CVM to assess the preferences of London taxi drivers for fuel cell taxis. Within the CVM questionnaire, a section concerning attitudes to general environmental and transport issues (e.g. congestion, noise or exposure to air pollution) as well as a valuation section where the taxi drivers' WTP for participation in a fuel cell taxi pilot project was included. Despite the environmental concerns and a supportive attitude towards green cars, the WTP in the short term to participate in the pilot project was mainly determined by financial considerations (i.e. reduced running costs). However, environmental considerations are found to affect the vehicle purchasing decisions in the longer term as the taxi drivers state that they are willing to invest in a greener car fleet. Ewing and Sarigöllü (1998) carried out a survey over 1500 commuter households in Montreal. The survey included choice experiments, in which emission levels were included to examine the role of the environmental concern on the vehicle choice. The main conclusion was that there might be a large market potential for AFVs if these can compete with conventional vehicles in price and performance. These results were extended and supported by Ewing and Sarigöllü (2000), who assessed the consumer preferences for AFVs, including low-emission vehicles and zero-emission vehicles, by a combination of an SP choice experiment for the vehicle-specific attributes (purchase price, repair and maintenance cost, cruising range, refueling time, acceleration and polluting emissions) and a separate assessment of attitudes towards the environment and technology. Although a strong preference was found for AFVs, the vehicle performance characteristics are, according to the authors, critical for their acceptance. A more recent study by Potoglou and Kanaroglou (2006a, b) used a nested logit model based on a SP internet survey to asses the household demand and the WTP for alternative fuelled vehicles by inhabitants of Montreal. The SP design consisted of 8 choice sets with each 3 kinds of attributes: the monetary, the non-monetary and the environmental attributes, where the pollution level was introduced to assess the perceived vehicle cleanliness. They pointed out that consumers are sensitive to incentives such as paying no tax and to significantly reduced pollution levels of vehicles. However, the personal and household characteristics as well as the cost and performance characteristics of the vehicle seem to be crucial in the selection of a certain vehicle technology. Finally, Lundquist et al. (2006) developed a theoretical and empirical framework by use of a vehicle choice experiment in Maine to model vehicle choice decisions under eco-labeled conditions and to evaluate the effectiveness of eco-information in altering consumers' attitudes towards environmentally friendly vehicles. The authors believe that the understanding of individual perceptions and social standards is essential to understand the success of environmentally friendly initiatives. They conclude that consumers will consider eco-information, when provided, in their purchase decision but that the consumers' reaction to eco-labeling will be differently due to their personal characteristics.

4.3.3 Critics on Preference Valuation Techniques

Economists have been sceptical towards the use of SP data. One possible problem with hypothetical choices is that this may not reflect the real purchase intentions of the respondents (Brownstone et al., 1994). Another criticism is that consumers can not have preferences for attributes that they have not directly experienced and therefore they do not have constructed preferences for them (Gould and Golob, 1998). Moreover, respondents tend to give socially desirable responses, such as “feel good” responses for environmental benefits or they may provide in contrast anti-environmental survey responses (Kurani et al., 1996). As a result, they may signal their preference for provision of less pollution, although in reality they would not spend any extra money on purchasing an AFV. Also Ewing and Sarigöllü (2000) mentioned that people who are highly concerned about the environment may have a higher motivation to return the surveys. Finally, Kurani et al. (1996) state that surveys usually question one person from a household, while vehicle purchases are often made jointly by the whole household.

In contrast, RP data or market data do not have the possibility for confusion or unstated assumptions. But the main problem in predicting a market for green cars by using RP data is the absence of actual choice observations since only a small market share of hybrid andAFVs is currently available (Potoglou and Kanaroglou, 2006a, b). Furthermore, using RP data makes it difficult to observe the effect of large variations in the variables of interest. Finally, RP data may often produce strong correlations between the variables (multicollinearity) and may evoke difficulties in measuring the vehicle attributes (Abley, 2000).

5. Conclusions

To understand the public acceptance of the new green vehicle technologies, it was first of all important to come to a definition of environmental cars, as given in section 2. Section 3 considered the design of the review. In order to investigate the importance of the environmental awareness in the car purchase decision, it was useful to get an insight into the process of car decision making itself. The overview of the different car attributes in the evaluation of vehicle types showed that the purchase price, followed by the operating cost (maintenance and fuel cost) and the quality (reliability and security) of the car are the first factors consumers take into account when purchasing a vehicle. Based on these attributes, consumers will already select certain alternatives. In this respect, it can be useful to focus in further research on the Life Cycle Cost (LCC) of the conventional as well as the green cars. From a consumer's point of view, the LCC of a car is the total cost related to the life cycle of a car. This LCC includes the purchase price, the fuel costs, the insurance costs, several taxes and the maintenance cost. As the purchase price is found to be the prime attribute in the assessment of a new car, a transition towards mass production and cheaper materials could lower the purchase price and thus increase the consideration of green cars in the car purchase decision. The results of Wang et al. (2007) confirm this hypothesis as they found out that a large number of consumers would purchase a micro battery EV as a result of its considerable low purchase price. The final choice will be made by the evaluation of other attributes of the car such as the intrinsic characteristics of the car -looks, acceleration time, horsepower, comfort, number of seats, luggage space and brand loyalty- and the socio-economical attributes like personal, social, cultural factors and household characteristics.

Section 4 presented the results of the review in order to answer the central question: will the environmental attributes of a car be taken into account when purchasing a vehicle? The answers to that question are presented according to the 3 used research methodologies. According to Tedeshi et al. (1982) who made use of an attitudinal survey, the Americans are concerned about the quality of the environment, but are unwilling to accept the individual responsibility for pollution and thus unwilling to undertake individual action such as purchasing a green car. The attitudinal survey elaborated by Wang et al. (2007) showed in contrast a high acceptance of the micro battery EV, especially due to its low purchase price. This finding shows that the limited driving range and the recharging at home can be acceptable, especially when considering the case of a second car in a two-vehicle household.

Out of the publications that made use of experimental designs, most studies (Turrentine et al., 1992; Kurani and Turrentine, 1995; Kurani et al., 1996; Gould and Golob, 1998a,b; Urban et al. 1996) shared the opinion that there exists a strong concern for the environment and a strong belief that lifestyle changes are need to solve environmental problems. However, they also discovered that the environment was the lowest rated issue when purchasing a vehicle. Even people who belong to environmental organizations do not express higher purchase intentions for green cars (Turrentine et al., 1992). The greatest WTP for EVs was expressed by the households with 2 or more vehicles (Kurani and Turrentine, 1995).

Within the articles that made use of preference valuation techniques, a distinction was made between the publications that included an environmental attribute in their survey design and the ones that did not. Out of the studies where the environmental attribute was excluded, the focus was set on the potential market for EVs. The main finding of these studies is that there will be no viable market for EVs unless their attributes such as the limited range and the long recharging times (Beggs et al., 1981; Chéron and Zins, 1997), the high purchase price and the inconvenience after sale (Segal, 1995) become fully competitive compared to conventional gasoline vehicles. Moreover, Chéron and Zins (1997) state that these factors can hardly be compensated by the greater cleanliness of EVs. However, Beggs and Cardell (1980); Beggs et al. (1981) and Segal (1995) found out that an EV could be attractive as a second household car in multi-vehicle households. Out of the publications that included an environmental attribute, the WTP for cars with reduced emission levels was especially expressed by 2-vehicle households with children under 21 years (Brownstone et al., 1994-1996), by Californians (Sperling et al., 1995; Tompkins et al., 1999) and by female drivers (Sperling et al., 1995). However, these studies also pointed out that this WTP will highly depend on the vehicle performance and price characteristics of green cars to be fully competitive with conventional vehicles (Ewing and Särigöllü, 1998-2000; Potoglou and Kanaroglou, 2006a-b) next to the personal and household characteristics of the consumers (Brownstone et al. 1994-1996; Tompkins et al., 1999; Potoglou and Kanaroglou, 2006a-b; Lundquist et al., 2006; Sperling et al., 1995 and Mourato et al., 2004).

A last interesting result found in the review is the fact that Californians express a higher WTP for green cars than other households, even within the USA. We stated first of all that this result may be due to the state programs of California that not only require semi-annual emission checks, but also the instauration of emission packages when a new car is bought (Gould and Golob, 1998a). Regulations or legislations, and especially pricing measures like subsidies or car taxation, seem to have a great influence on the purchase intentions for cars (Potoglou and Kanaroglou, 2006; Clase, 2004). People will undertake individual action such as a paying more for a greener car when everyone is subject to the legislation and the “polluter pays principle” is respected (CRIOC, 2004). Secondly, the heightened awareness of air pollution due to local conditions and the press attention for environmental issues may also have a great contribution to that result (Glazer et al., 1995). This underlines the important impact of information and environmental consciousness on the car purchase decision (Mourato et al, 2003; Kurani et al., 1996). The purchase intentions for green cars will not only be influenced when an amount of (eco-) information is provided (Lundquist et al., 2006; Urban et al., 1996), but will also differ according to the consulted information sources (Gould and Golob, 1998a). Gould and Golob (1998a) found out that people informed by mass media and conversations are less likely to purchase an EV, than when they are informed by business- and auto magazines and newspapers. Also, the environmental awareness may encourage households to seek out and evaluate green cars for purchase consideration (Mourato et al, 2003; Kurani et al., 1996; CRIOC, 2003). Therefore, it is of great interest to investigate the influence of the recent film “An inconvenient truth” on the environmental concern and car purchase behavior in Europe.

6. Reference List

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