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STUDY

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Economic and Scientific Policy

CO^2 REDUCTIONS FROM PASSENGER CARS

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Executive Summary

Introduction

After power generation, road transport is the second biggest source of greenhouse gas emissions in the EU. It contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas. Road transport is one of the few sectors where emissions are still rising rapidly, so at present it is undermining rather than helping the EU's efforts to tackle climate change. Passenger cars alone are responsible for around 12% of EU CO_2 emissions. Although there have been significant improvements over recent years in vehicle technology - particularly in fuel efficiency, which translates into lower CO_2 emissions – these have not been enough to neutralise the effect of increases in traffic and car size. CO_2 emissions from road transport rose by 26% between 1990 and 2004. This increase acted as a brake on the EU's progress in cutting overall emissions of greenhouse gases, which fell by just under 5% in the EU-25.

Problem definition

The existing strategy to reduce CO_2 emissions from passenger cars in the European Union will most probably not reach the target of 120 g CO_2/km in 2012. Because of this the Commission proposed a revised strategy in which additional measures are formulated.

The Communication setting out the Commission's proposal for a revised strategy is addressed to the Council of Ministers and European Parliament. The Commission will await their responses and based on these will proceed to implement the strategy. The legislative proposal is already foreseen in the Commission's 2007 Legislative and Work Programme but preparatory work may take until mid-2008.

The committee of Environment, Public Health and Food Safety of the European Parliament requested Tauw to give an independent assessment on the issue: what CO_2 reduction targets are feasible to demand of car manufacturers for passenger cars in terms of engine, vehicle design technology and costs? In the assessment a view should be presented on the potential cost savings for consumers due to lower fuel consumption and of environmental benefits due to less CO_2 emissions.

Approach

The short feasibility study done by Tauw consisted of three elements:

- A summary of relevant research on the issue
- An overview of the points of view of stakeholders
- An independent view based upon existing research and new insights. In doing so Tauw used the following criteria: technical, financial, psychological, environmental and practical

Conclusions

Given the state of the art of today’s car technology, it is possible to meet the target of 120 g CO_2/km. For small cars this target is possible by optimisation of the engine, for larger cars hybridisation is necessary. An interesting development is in cars that use light materials to bring down the weight of the car. This can lead to an emission factor far below 120 g CO_2/km. The use of biofuels can be an interesting option for further reduction of the emission factor, but will unlikely be able to have a significant contribution in the short run (2010 - 2015). A significant use of biofuels (10 - 20 %) might be possible in 2020 - 2030.

The switch to cars that meet the 120 g CO_2/km target will work out more or less cost neutral for car buyers. The average increase in the retail price of cars will be compensated by the savings on fuel costs.

To reach the 120g/km target for the entire European car fleet as a whole, more car drivers should switch to buying cleaner cars. Awareness campaigns can help to make the necessary change of mentality. There are some signals that indicate that a spirit of change is in the air. Recent years can be characterised as car drivers buying large high emission cars, but this might change rapidly because of the attention the CO_2/climate issue already has under the general public.

It will be clear that the major environmental benefit of the proposed legislation is a slowing down of both climate change and of the depletion of fossil fuel reservoirs. Both problems were the main reason for the European Commission to propose the revised strategy. However, there are some other environmental issues related to the strategy as well. The most important issue is related to the sustainability of the large-scale application of biofuels. There should be a clear definition of the sustainability criteria for biofuels before massive production takes place. Most important criteria are the following: Green House Gas balance, competition with food production, biodiversity & deforestation.

Although in our view implementation of the revised strategy to reach the 120 g/km target is possible both technically as financially, there are practical problems in reaching the target.

- When can the 120 g/km target be met: in 2012, in 2015 or later? 2015 might be possible, 2012 is unlikely given the slow progress of reaching the 140 g/km target in 2008/2009 and the time needed to develop new cars and change mass production lines.
- In addition it deserves attention to provide clarity about the targets quickly, to save time. It also is recommended to provide clarity about emission reduction targets for the longer term, to enable car manufacturers to develop their investment strategies and also to focus research efforts.
- How will the necessary effort be divided amongst car manufacturers? In our view the 120 g/km should be one for the entire European new car fleet. This gives individual car manufacturers the possibility not to give up their own identity while at the same time they can support other manufacturers to make the target possible.
- What will happen when the average European new car fleet does not meet the 120 g/km target? Should there be sanctions for car manufacturers? The main driving force should be the behaviour of both consumers and manufacturers. Consumer behaviour can be influenced by financial benefits and other benefits given to them to member states of the European Union. This will lead to a switch towards the buying of more clean cars and in the end to a switch of car manufacturers to focus on the production of cleaner cars.

Contents

1. Introduction

After power generation, road transport is the second biggest source of greenhouse gas emissions in the EU. It contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas. Road transport is one of the few sectors where emissions are still rising rapidly, so at present it is undermining rather than helping the EU's efforts to tackle climate change. Passenger cars alone are responsible for around 12% of EU CO_2 emissions. Although there have been significant improvements over recent years in vehicle technology - particularly in fuel efficiency, which translates into lower CO_2 emissions – these have not been enough to neutralise the effect of increases in traffic and car size. CO_2 emissions from road transport rose by 26% between 1990 and 2004. This increase acted as a brake on the EU's progress in cutting overall emissions of greenhouse gases, which fell by just under 5% in the EU-25.

To help reduce greenhouse gas emissions and meet its Kyoto Protocol targets, the EU has agreed that average CO_2 emissions from new passenger cars should not exceed 120 g CO_2 per km by 2012[1]. This target was reconfirmed most recently at last June's (2006) meeting of the European Council, when EU leaders revised the EU Sustainable Development Strategy. The target compares with an average emissions level of 186 g CO_2 per km in 1995. Achievement of this target will help Member States in the delivery of the reductions needed to respect of the Kyoto protocol.

On 7 February 2007, the European Commission adopted the Communication (COM(2007) 19) outlining a comprehensive new strategy to reduce carbon dioxide emissions from new cars and vans sold in the European Union. The new strategy, together with a revision of EU fuel quality standards proposed on 31 January 2007, further underlines the Commission's determination to ensure the EU meets its greenhouse gas emission targets under the Kyoto Protocol and beyond. The strategy will enable the EU to reach its long-established objective of limiting average CO_2 emissions from new cars to 120 grams per km by 2012 - a reduction of around 25% from current levels. By improving fuel efficiency, the revised strategy will deliver substantial fuel savings for drivers. To encourage the car industry to compete on the basis of fuel efficiency instead of size and power, the Commission is also inviting manufacturers to sign an EU code of good practice on car marketing and advertising.

[1] This corresponds to fuel consumption of 4.5 litres per 100 km for diesel cars and 51/100 km for petrol cars

2. Problem definition

2.1 Introduction

The existing strategy to reduce CO_2 emissions from light duty vehicles in the European Union will most probably not reach the target of 120 g CO_2/km in 2012. Because of this the Commission proposed a revised strategy in which additional measures have been formulated.

The Communication setting out the Commission's proposal for a revised strategy is addressed to the Council of Ministers and European Parliament. The Commission will await their responses and based on these will proceed to implement the strategy. The legislative proposal is already foreseen in the Commission's 2007 Legislative and Work Programme but preparatory work may take until mid-2008.

The committee of Environment, Public Health and Food Safety of the European Parliament requested Tauw to give an independent assessment on the issue: what CO_2 reduction targets are feasible (2012 -2015) to demand of car manufacturers for passenger cars in terms of engine, vehicle design technology and costs? In the assessment account should also be taken of potential cost savings for consumers due to lower fuel consumption and of environmental benefits due to less CO_2 emissions.

2.2 Existing strategy

As proposed by the Commission in 1995, and supported by the Council and European Parliament, the existing strategy has three pillars.

1. The first consists of voluntary commitments by the European, Japanese and Korean car industries to reduce CO_2 emissions from their new cars sold in the EU to an average of 140g/km by 2008 (for European manufacturers) or 2009 (for Japanese and Korean manufacturers).
2. The second pillar involves raising awareness among consumers. An EU directive[2] requires the display on each new car of a label showing its fuel consumption and CO_2 emissions, as well as publication of fuel efficiency information in other formats, including in printed advertisements.
3. The third pillar aims to promote fuel-efficient cars through fiscal measures. Several Member States have done this, and the Commission has proposed EU legislation[3] aimed at including a CO_2 element in national car taxes.

2.3 Achievements

The existing strategy has brought only limited progress towards achieving the target of 120g CO_2/km by 2012. Between 1995 and 2004 average emissions from new cars sold in the EU-15 fell by 12.4%, from 186g CO_2/km to 163g CO_2/km. Over the same period new cars sold in the EU became significantly bigger and more powerful.

[2] Directive 1999/94/EC
[3] COM(2005)261 final

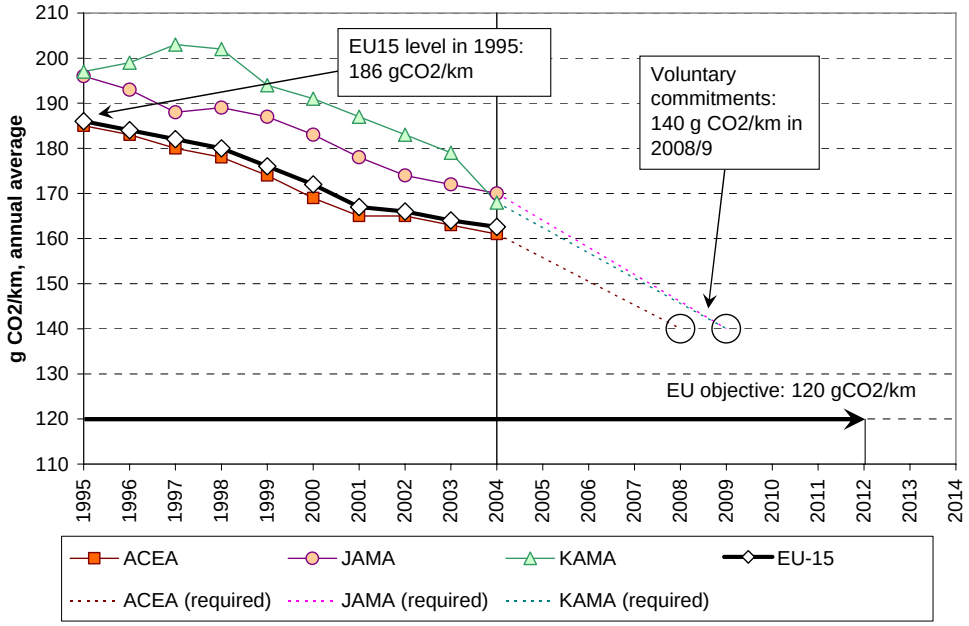

Figure 2.1 EU 15 average new car fleet CO_2 emissions between 1995 and 2004 (European Commission, 2007)

ACEA: European Automobile Manufacturers Association

JAMA: Japan Automobile Manufacturers Association

KAMA: Korea Automobile Manufacturers Association

2.4 Revised strategy

The revised strategy as communicated on February 7, 2007 is based on a comprehensive set of measures to influence both the supply and demand sides of the EU market for cars and vans. The overall effect of these is to promote affordable fuel efficiency improvements and reductions in CO_2 emissions, as well as substantial fuel savings for car and van drivers. Together with the recent proposal to update the fuel quality directive, which will reduce greenhouse gas emissions from transport fuels by 10% between 2010 and 2020, the strategy represents the first concrete implementation of the Commission's recent Energy Efficiency Action Plan and of the 10 January Energy and Climate Change package.

The main measures of the revised strategy are as follows:

- EU legislation to reduce CO_2 emissions from new cars and vans will be proposed by the Commission by the end of this year or at the latest by mid 2008.
- Average emissions from new cars sold in the EU-27 would have to reach the 120 g CO_2/km target by 2012. Improvements in motor technology would have to reduce average emissions to no more than 130 g/km, while complementary measures would contribute a further emissions cut of up to 10 g/km, thus reducing overall emissions to 120 g/km. These complementary measures include efficiency improvements for car components with the highest impact on fuel consumption, such as tyres and air conditioning systems, and a gradual reduction in the carbon content of road fuels, notably through greater use of biofuels. Efficiency requirements will be introduced for these car components.
- For vans, the fleet average objectives would be 175 g by 2012 and 160 g by 2015, compared with 201 g in 2002.

- Support for research efforts aimed at further reducing emissions from new cars to an average of 95 g CO_2/km by 2020.
- Measures to promote the purchase of fuel efficient vehicles, notably through an amendment to the car labelling directive to make it more effective and by encouraging Member States that levy road tax to base it on cars' CO_2 emissions. The Council will be encouraged to adopt the Commission's proposal on road taxes without further delay.
- An EU code of good practice on car marketing and advertising to promote more sustainable consumption patterns. The Commission is inviting car manufacturers to develop this and sign up to it by mid-2007.

3. Approach

The short feasibility study done by Tauw consisted in three elements:

A summary of relevant research on the issue

Already a lot of research has been done about the reduction of CO_2 emissions from passenger cars. Tauw performed a desk study on this and summarizes the most important results in this report.

An overview of the points of view of stakeholders

The most important stakeholders are car manufacturers, environmental organisations and the general public. Car manufacturers and environmental organisations have given their opinion about the feasibility of the proposed legislation in reports and press releases. The general public was consulted on the review of the EU strategy to reduce CO_2 emissions from cars. An overview of the points of view of the stakeholders is presented in this report.

An independent view based upon existing research and new insights.

Based upon existing research and new insights gathered in the short study an independent view on the feasibility of the proposed target is given in this report. In doing so we used the following criteria:

- Technical: improvements in motor technology plus complementary measures (efficiency improvements for tyres, air conditioning systems, gear shift indicators, reduction of carbon content of road fuels (increased use of biofuels));
- Financial: increase in prices of cars, fuel savings, fiscal measures;
- Psychological: people tend to buy larger cars, this leads to an increase of CO_2 emissions: to what extent is a change of mentality necessary to achieve the proposed target? How can consumers be influenced to buy low emission cars?
- Environmental: what is the environmental impact of the proposed legislation. What are possible environmental side effects that have to be taken into consideration?
- Practical: what are relevant practical issues when judging the feasibility of the proposed target? What problems are accompanying the implementation of the proposed legislation?

4. Results

4.1. Relevant research

In order to support the development of the strategy concerning CO_2 emissions from passenger transports, a lot of research has been carried out. The Impact Assessment that was published on February 7, 2007 was a summary of this research.

The most relevant findings to judge the feasibility of the proposed target of 120 g/km in 2012 can be found in the study *"Review and analysis of the reduction potential and costs of technological and other measures to reduce CO_2-emissions from passenger cars"* (October 31, 2006), which has been carried out by TNO, IEEP and LAT on behalf of the European Commission (DG-ENTR).

The most important conclusions of this study are:

- The costs of reaching an average CO_2 -emission of new vehicles of 140 g/km in 2008 will involve additional manufacturer costs of €832 per vehicle compared to the 2002 baseline. This translates into an additional retail price of €1200 per vehicle.
- For most target-measure combinations the manufacturer costs for reaching a 2012 target of 120 g/km are around €1700 per vehicle compared to average costs of the 2008/9 baseline vehicle emitting 140 g/km. This translates into an additional retail price of €2450 per vehicle.
- In general it can be concluded that, regardless of the type of policy measure that is chosen, reaching a new vehicle sales average TA CO_2 -emission of 120 g/km requires the introduction of hybrid vehicles in the segments of small, medium ad large petrol cars and of large diesel cars. For small diesel cars the necessity for hybridisation depends on the policy measure, while for medium size diesel cars hybridisation is necessary for none of the policy measures.

We also like to mention here the findings of UBA, the German Umwelt Bundes Ambt. In verbal communication with representatives of UBA we learned that an UBA publication is nearly finished in which will very likely be stated that a reduction of CO_2 -emissions by 20% will lead to a considerably lower increase of retail prices. More details have been presented in 4.3.3.

4.2. Points of view of stakeholders

The most important stakeholders are car manufacturers, environmental organisations and the general public. Car manufactures and environmental organisations have given their opinion about the feasibility of the proposed legislation in reports and press releases. The general public was consulted on the review of the EU strategy to reduce CO_2 emissions from cars. An overview of the points of view of the stakeholders is presented here.

4.2.1 Car manufacturers

The European Automobile Manufacturers Association (ACEA) made their point of view clear in their press release of 26 January 2007. Their key message is the following:

Reducing further CO_2 emissions through vehicle technology only is the most expensive and least cost-effective option for society. The prohibitive rise in production and retail costs will lead to a loss of jobs and relocation of production outside Europe. More can be done for the environment, at lower costs.

ACEA refers to the Task A study done by TNO. They point out that other measures like an increased use of biofuels and eco-driving are more cost-effective in reducing CO_2 emissions. Besides that, they are disappointed that infrastructural measures are not part of the revised strategy of the Commission. A summary of the results of the TNO study is given in the ACEA press release:

Within the European Climate Change Programme (ECCP), a consultant for the Commission, the independent scientific research institute TNO, assessed costs and reduction potential of different measures (Task A). The final report (TNO, 2006) was published on 31 October 2006.

Vehicle technology

ECCP concludes that costs of lowering average CO_2 emissions from 140 g/km to 120 g/km through vehicle technology would translate into a retail price increase of € 2450 per vehicle. This is in addition to a retail price increase of € 1200 from reaching 140 g/km in 2008. The consultant

calculated societal costs, which include cost of technology but also savings from fuel-efficiency, of € 132 - € 233/tCO_2 abated for going from 140 g/km to 120 g/km. This figure is far higher than many other measures assessed.

Biofuels

The results on cost-effectiveness of biofuels differ strongly depending on production pathways. Some biofuels are highly cost-effective, as is shown by TNO. As a 1% increase in biofuels leads to annual CO_2 savings of 3.1 - 4 Mt per year in 2012, an increase of 5% would lead to

savings of 15.5 – 20 Mt per year. This is a larger reduction than could be achieved by putting all the burden of reaching 120 g/km on vehicle technology (14.4 Mt per year, going to 120 g/km).

Eco-driving

ECCP data shows that eco-driving is very cost-effective compared to other transport measures – it actually leads to cost savings to society (in all scenarios studied). Measures aimed at existing and new drivers could lead to annual CO_2 savings of 7.8 Mt – more than half of what could be achieved by putting all the burden of reaching 120 g/km on vehicle technology.

Infrastructure measures

Infrastructure measures have not been considered within ECCP. This is disappointing, because the potential reductions are large. Japan, for example, counts CO_2 savings through infrastructure measures of 28.3 Mt in their Kyoto implementation plan.

The Japanese Automobile Manufacturers Association (JAMA) also expresses concern over the focus on vehicle technology in their reaction to the proposed revised strategy of the Commission. They also see the limited time frame as a problem (Jama, 2007):

JAMA members are making every effort to meet the interim target of 140 g CO_2/km by 2009. If JAMA members are to meet the Commission's new target of 120 g/km by 2012, the CO_2 emissions rate will have to be cut by a further 20 g/km in only 3 years. JAMA therefore does not believe that it will be possible to meet the ambitious 2012 target in such a limited time frame

4.2.2 Environmental organisations

Green10 opinion

The European Federation for Transport and Environment (T&E) gave their reaction on the forthcoming legislation in a letter addressed at the European Commission (23 January 2007). The letter represents the point of view of the Green10 (a group of environmental NGO's active at EU level of which T&E is a member).

The most important conclusions of the Green10 are the following:

The voluntary agreement is failing

The Commission's own assessment, based on 2004 data, was that 'the situation is not satisfactory'. Data for 2005 showed that progress was just a 1 per cent reduction compared with 2004. Fleet average CO_2 emissions of cars sold in 2005 stood at 162 g/km. In other words, the manufacturers are not sufficiently committed to voluntarily achieving their 140 g/km target.

Emissions trading and biofuels no substitute for fuel efficient cars

Including road transport in the emissions trading system or biofuels are NOT alternatives for making cars more fuel-efficient. Such an integration would come down to a modest rise – a few cents- in the price of petrol and diesel. It would hence not provide meaningful new incentives to car makers to improve the energy efficiency of their products. Biofuels are also a scarce resource and are not a substitute for energy efficiency.

'120' target is feasible

The 120 g/km target is feasible. It is a fleet-average target that can be met through instruments that require neither individual car makers nor individual cars to meet it. It is not just about deploying complicated and advanced new technologies, it is just as much about using existing technologies and stopping or reversing the trend towards ever-more powerful and faster cars (for example fitting cars with smaller engines is a very effective and cost effective measure).

Longer term targets needed

Finally, both climate policy and the car industry need clear and ambitious long-term goals. The year 2012 is only five years away. Strong targets for 2016 and 2020, and beyond, are needed. Doubling fuel efficiency over the next decade is a feasible target and would fit with the strategy to protect the climate by reducing the EU's emissions by 30% by 2020.

T&E-study

We also mention here a study done by T&E: *How Clean is Your Car Brand? The car industry's commitment to the EU to reduce CO_2 emissions: a brand-by-brand progress report* (October 2006). This report presents an overview of the progress of individual car brands in reducing CO_2 emissions under the terms of the voluntary commitment made by the car industry to the EU in 1998 (European car manufacturers) and 1999 (Japanese and Korean car manufacturers).

T&E concludes that three-quarters of the 20 major car brands sold in Europe in 2005 have failed to improve fuel efficiency at the rate needed to meet the target of 140 g CO_2/km in 2008 (European car manufacturers) and 2009 (Japanese and Korean car manufacturers).

Aat Peterse of T&E: *"Renault is on track while Volkswagen is way off even though Renault started with higher emissions in 1997. Clearly the target is achievable, but as long as seventy-five percent of carmakers go unpunished for their failure, we will never make the necessary progress. Europe must kiss its voluntary targets goodbye and waste no more time in coming up with legally-binding measures to double fuel-efficiency in the next decade. Individual carmakers must be held responsible and punished if they fail."*

Appendix 2 gives an overview of the performance of individual car brands.

4.2.3 The general public

A public consultation on the review of the EU strategy to reduce CO_2 emissions and improve fuel efficiency from cars was held from 12 June to 21 August 2006 in preparation for the Communication from the Commission to the Council and European Parliament. An online questionnaire available in English, French and German was designed to gather the anonymous views and opinions of the general public on passenger road transport's contributions to climate change and possible future ways to reduce it. The standard Commission internet tool for Interactive Policy Making was used. The objective was to allow as many as possible to express their views, but since the consultation was based on self-selection of those who wished to respond to the questionnaire, the views expressed by respondents cannot be regarded as representative of the views held by the EU population.

A total of 1215 responses were received, with a 2:1 male/female respondents' ratio. The largest number of respondents lived in the UK, followed by France and Germany. 77% of respondents owned a car and 23% did not. From the responses, these cars seem to be fairly consistent with the average EU fleet in terms of their size distribution and fuel consumption. However, there are indications that the sample of respondents may be more informed/concerned about environmental issues than the average citizen.

The most important result of the consultation is the following (European Commission, 2007):

In exchange for an annual fuel cost reduction of €150, some 70% of the respondents would be willing to pay more for the vehicle; half of these by no more than €1,000, another 22% by €1,000 to €1,500, with almost 20% above €1,500.

4.3 An independent view

In this part of the report Tauw gives an independent view about the feasibility of achieving the proposed target of 120 g CO_2/km in 2012/2015. By doing so we use five criteria: technical, financial, psychological, environmental and practical. First we will make some remarks about the composition of considered measures in the revised strategy.

4.3.1 The composition of measures in the revised strategy

In the revised strategy the 'package' of measures proposed can be subdivided in the following components:

- Requirements to car manufacturers on improvements in motor technology leading to reduction of CO_2 emissions.
- Requirements on efficiency improvements for car components.
- Increased use of biofuels.
- Influencing consumption patterns.
- Supporting research efforts.

The last item will need to be an attention point for both the shorter and longer term. Influencing the consumption pattern can be considered as a very important item as well, and we will discuss this under Psychological. It is however an item that falls under the category of influence and is not an issue that can be implemented through requirements and subsequently be enforced.

The requirements on efficiency improvements for car components, is a category that will also need attention if it needs to be used as requirements. One of the important attention points would have to be the way in which car manufacturers conduct the measurements of the CO_2 emissions of their cars. In the protocols of the test conditions (drive cycle tests, in Europe NEDC) it is now prescribed that tyres pressures are optimal, that the tyres comply with certain specifications, and that air conditioning is not functioning. It can be assumed that the drivers will aim at optimising gear shift during the test drives.

In COM 2007 19 the set of efficiency improvements includes minimum efficiency requirements for air conditioning systems, pressure monitoring systems, maximum tyre rolling resistance limits and gear shift indicators. The whole set is characterised as measurable, monitorable and accountable.

In principle this is true for the measures for which it can be assessed whether the minimum or maximum requirements are met or whether devices have been implemented in cars, but one factor cannot be ensured and that is the actual driving behaviour of the car owners, and the way indicators will lead to a more desired driving behaviour. Therefore the real world situation will deviate from the test situation.

Another point here is that additional test protocols will have to be implemented which will then take into account the consequences of the components for which the requirements will apply, such as the air conditioning systems.

From this we conclude that the major components necessary for achieving CO_2 reductions from passenger cars are the requirements on improvements in motor technology and the increased use of biofuels. Therefore these factors receive the most attention in our analysis.

4.3.2 Technical

Favourable examples

In our view it is clear that the technical possibilities to meet a target of 130 g/km or even the overall target of 120 g/km are available at this moment. Car manufacturers have already produced cars (petrol and diesel) with emissions below the target. Some examples: Smart 450 (diesel, 101 g/km), VW Polo Blue Motion (diesel, 102 g/km),Toyota Prius (petrol, 104 g/km), Citroën C1 (petrol,109 g/km) Daihatsu Cuore (petrol, 109 g/km), Honda Civic (petrol,109 g/km), Peugeot 107 (petrol, 109 g/km) and the Toyota Aygo (petrol, 109 g/km).

Car weight and hybridisation

The most determining factor in car fuel consumption and CO_2 emissions is the weight of the car. For small cars it is not a problem to reach the target of 120 g/km. The cars that are on the market today with emissions lower than 120 g/km are in general small cars, like the cars mentioned above. For larger cars hybridisation (a combination of fuel powered and electric propulsion) of the car is necessary to meet the target (for instance the Toyota Prius, a 1275 kg car with an emission factor of 104 g CO_2/km).

Figure 4.1 Toyota Prius: Hybrid, 1275 kg, 104 g CO_2/km, in production since 1997

The TNO study (TNO, 2006) came to the same conclusion: the target can be met technically, even for large cars (TNO classified the cars into three categories: small, medium and large). By optimising the engine a significant reduction of CO_2 reductions can be achieved. For petrol cars measures like downsizing with turbo-charging (up tot 10% CO_2 reduction), variable valve control (7% reduction) and DI / stratified charge (10% reduction) give considerable reductions considering the required reduction (The proposed target of 120 g/km equals to a reduction of 26% compared to the emission factor in 2004: 163 g /km). A complete overview of the several specific measures to reduce CO_2 emissions as studied by TNO can be found in appendix 1. Please note that the CO_2 reductions of individual measures cannot simply be totalled: one certain measure might exclude other measures, or decrease the reduction potential of other measures. Because of this, TNO concluded that some degree of hybridisation is in general necessary to meet the target of 120 g/km. With hybridisation it is always possible to meet the target, even for large cars.

Hybridisation and performance

We'd like to point out here that a lot of car manufacturers are working on hybrid cars and that more and more hybrid cars are entering the market. Some cars have been on the market already for quite a time (like the Toyota Prius, on the market since 1997). An often heard complaint from car drivers is that hybrid cars would not be able to show the same performance as conventional cars. Recent developments however show that a new generation of hybrid cars is about to come on the market that show very good performance. An example is the Chevrolet Volt, a concept car developed by General Motors and presented at the North American International Auto Show of January 2007. The Chevrolet Volt is a robust looking 1600 kg car with sports car performance designed to produce 190 km/hr and an acceleration of 0 - 100 km/hr in 8 seconds.

Figure 4.2 Chevrolet Volt: Plug-in hybrid, 1600 kg, 111 g CO_2/km, on the market in 2010

The car is a so-called plug-in hybrid: a hybrid car with onboard energy storage that can be recharged by connecting a plug to an electrical power source. The Chevrolet Volt is designed to run purely on electricity from on-board batteries for short trips up to 65 km. With use of a small internal combustion engine connected to a generator to re-supply the batteries, the vehicle's range is potentially increased to 1030 km. In this mode the gasoline economy of the car amounts to 21 km/litre, which equals to a CO_2 emission of 111 g/km. GM has set an internal target of production of the Chevrolet Volt for 2010. (sources: http://www.chevrolet.com/electriccar/and http://www.autoweek.nl/newsdisp.php?ID=5799&cache=no)

Weight reduction and CO_2 emission reduction

As mentioned before the weight of the car is crucial when it comes to fuel consumption and CO_2 emissions. TNO calculated that a 30% reduction of the Body In White (BIW[4]) weight (which equals to more or less 9% of the total car weight) leads to 5.5% CO_2 reduction. In the SuperLIGHT-CAR programme (a collaborative Research & Development project co-funded by the European Commission that started in 2005) a goal is set of 30% BIW weight reduction in the year 2009.

Far more can be achieved however by focussing on smaller (and therefore lighter) cars. Roughly one can say that a 10 % weight increase equals a 5 % CO_2 increase (JAMA, 2007). TNO says about the same: a 10 % weight increase equals a 6.5% CO_2 increase (TNO, 2006). In the TNO study the following definitions for small and large cars are used: Petrol: small: 957 kg, large: 1500 kg, Diesel: small: 1028 kg, large:1690 kg. So roughly one could say that an average large car is about 50% heavier than an average small car. This weight increase of 50% leads to a CO_2 increase of 25 to 33%. As mentioned above there are several cars that have CO_2 emissions below 120 g/km, even without hybridisation. These are all small cars. One of the main reasons of the fact that the voluntary target of 140 kg/m will not be met in 2008/2009 is because of the recent trend of people buying larger cars. There is no doubt about it that when this trend is broken, the target of 120 g/km can easily be met.

[4] Body in White or BIW refers to the stage in automotive design or automobile manufacturing in which the car body sheet metal (including doors, hoods, and deck lids) has been assembled or designed but before the components (chassis, motor) and trim (windshields, seats, upholstery, electronics, etc.) have been added.

But note that not only downsizing of the car can lead to weight reduction: also the use of lighter materials can be very efficient in that respect. A revolutionary development is the Loremo (www.loremo.com), a new car that will be for sale in Europa in 2009. The weight of the Loremo is only 450 kg, due to the use of light materials. The chassis of the car is made of ultra light steel, which leads to a weight of only 95 kg, three times less than the weight of a conventional chassis. The body is made of a composite of polymers, not only a very light material but also a very safe material.

Figure 4.3 Loremo: Low resistance mobile, 450 kg, 50 g CO_2/km, for sale in Europe in 2009

Aerodynamic design gives the car low air resistance. Both factors (small weight and aerodynamic design) lead to a diesel consumption of only 1 liter/70 km. The accompanying CO_2 emission amounts to only 50 g/km. The price of the car will be less than 12,000 euros. Top speed of the car is 160 km/hr, the car needs 16 seconds to go from 0 - 100 km/hr. In our view this car is the living proof that high performance and low CO_2 emission can go hand in hand against a very reasonable price.

Biofuels

Concerning the use of biofuels, we'd like to say that we see this as an important option to bring down the CO_2 emission factor. especially for the longer term when emission reduction targets may become more strict, an increased use of biofuels is a very interesting option to bring down CO_2 emission, because it creates short term carbon cycles. The problem for the short term however is that biofuel production is only getting started.

In 2000 the contribution of biofuels in the total mix of transportation fuels was only about 0.3%. In 2003 the Biofuels Directive on the promotion of the use of biofuels and other renewable fuels for transport, set out indicative targets for Member States. To help meet the 2010 target – a 5.75% market share for biofuels in the overall transport fuel supply – the European Commission has adopted an EU Strategy for Biofuels.

On 31 January 2007 the European Commission proposed new standards for transport fuels that will reduce their contribution to climate change and air pollution, which include increased use of biofuels. The proposed changes to Directive 98/70 underscore the Commission's commitment to ensure that the EU combats climate change and air pollution effectively.

The new standards will not only make petrol, diesel and gasoil 'cleaner' but will also allow the introduction of vehicles and machinery that pollute less. A key measure is that, to encourage the development of lower-carbon fuels and biofuels, suppliers will have to reduce the greenhouse gas emissions caused by the production, transport and use of their fuels by 10% between 2011 and 2020. This will cut emissions by a cumulative total of 500 million tonnes of carbon dioxide by 2020.

The European Commission-supported project "Clear Views on Clean Fuels (NNE5-2001-00619), or in short, VIEWLS (VIEWLS, 2005) researched the biomass production potential in the Central and Eastern European region, and the possible biofuel trade chains that may develop from this within Europe. One of the conclusions of the project was that the agricultural area in Europe need not be a limiting factor, provided that it starts to prepare for intensifying the agricultural sector in Central and Eastern Europe. Under these conditions the production of food crops, wood production and raw materials for bio-energy are all possible. The year 2030 could see biofuels taking a 20% share of the transport fuel market, based on the amount of land available. This conclusion strengthens our view that biofuels are an interesting option in the long run (2020 - 2030). A significant use of biofuels (10 - 20 %) would be possible in 2020 - 2030.

General conclusion (technical):

Given the state of the art of today's car technology, it is possible to meet the target of 120 g CO_2/km. For small cars this target is possible by optimisation of the engine, for larger cars hybridisation is necessary. An interesting development is in cars that use light materials to bring down the weight of the car. This can lead to an emission factor far below 120 g CO_2/km. The use of biofuels can be an interesting option for further reduction of the emission factor, but will unlikely be able to have a significant contribution in the short run (2010 - 2015). A significant use of biofuels (10 - 20 %) might be possible in 2020 - 2030.

4.3.3 Financial

Optimising cars to make them more fuel efficient in general leads to increased retail prices. The height of the increase is debatable. In the next two paragraphs we introduce two studies that reflect the expected upper and lower boundary of the increase in retail prices. In the last paragraph we give a short outline of the costs and savings, which a car buyer will encounter when buying a new car.

TNO study: Review and analysis of the reduction potential and costs of technological and other measures to reduce CO2-emissions from passenger cars

TNO, IEEP and LAT performed this study for the European commission. TNO (TNO, 2006) concluded that:

- *The costs of reaching an average CO_2-emission of new vehicles of 140 g/km in 2008 will involve additional manufacturer costs of €832 per vehicle compared to the 2002 baseline. This translates into an additional retail price of €1200 per vehicle.*
- *For most target-measure combinations the additional manufacturer costs for reaching a 2012 target of 120 g/km are around €1700 per vehicle compared to average costs of the 2008/9 baseline vehicle emitting 140 g/km. This translates into an additional retail price of €2450 per vehicle.*
- *For most target-measure combinations the additional manufacturer costs for reaching a 2012 target of 130 g/km are around €900 per vehicle compared to average costs of the 2008/9 baseline vehicle emitting 140 g/km. This translates into an additional retail price of €1250 per vehicle.*

These figures are averages for the whole car fleet (small, medium, large). Small cars however have lower CO_2 emission due to their lower weight. For these cars the increase in retail price will be significantly smaller due to the lesser effort needed to reach the target of 120 g/km. For small cars in general only some optimisation of the engine is needed to reach the target. This is significantly less expensive than hybridisation of the car. Large cars in general need some degree of hybridisation to meet the target, optimisation of the engine alone will not do for large cars.

Remarks on the study

The study is in our opinion very thorough and gives insight into many aspects of the CO_2 issue. However, the data on which the report is based was collected and made available by the members of ACEA. Although this gives direct insight in the production costs, it is uncertain what the influence of this information source has been. We regard the prices in this study as the upper limit.

UBA study: Kosten der CO2-Minderung bei PkW

This study calculates the costs of reducing the CO_2 emissions from passenger cars by 20%. This amounts to a reduction from the present CO_2 emissions per driven kilometre to an emission of 130 g CO_2/km. The report is not public yet, we received the information in a conversation with the author. This study discerns three car sizes which are approximately comparable to the three car sizes in the TNO report. The costs for the 20% CO2 emission reduction are calculated for each of these cars. This was done for diesel and petrol vehicles. The resulting figures are summarized below.

Table 0.1 Costs for a 20% CO_2 reduction according to UBA

	Diesel			**Petrol**		
	Small	Medium	Large	Small	Medium	Large
Additional Manufacturing cost	160	190	250	180	200	220
Additional retail price*	230	274	360	259	288	317

* The additional retail price was calculated by multiplying the manufacturing cost by 1.44 as was done in (TNO, 2006, page 30).

Remarks on the study

The study was a short study and is not as thorough as the TNO study. The data used for the calculation of the additional manufacturing costs are taken from other studies which seem to be more independent than costs taken directly from car manufacturers. We regard the prices in this study as the lower limit.

Consumer costs and benefits

Against the increase in retail price stand the savings of fuel costs due to the higher fuel efficiency. Tauw calculated roughly how this works out for the situation in which the average CO_2 reduction goes down from 140 g/km to 130 and 120 g/km respectively. In our calculations we used the following assumptions:

- Annual mileage: 16.000 km/year (TNO, 2006)
- Car lifetime: 13 years (TNO, 2006)
- The use of 1 g fuel (petrol, diesel) leads to an emission of 3.15 g CO_2 (TNO, 2006)

- Petrol price: 1.22 euro/litre (petrol), 1.09 euro/litre (diesel) (European average, April 2007)

We calculated annual fuel savings of:

- 137 litre of petrol and 120 litre of diesel which corresponds to 167 euros for petrol and 130 euros for diesel for the target of 120 g/km.
- 68,5 litre of petrol and 60 litre of diesel which corresponds to 84 euros for petrol and 65 euros for diesel for the target of 130 g/km.

Over the car lifetime of 13 years the savings are 2171 euros (petrol)/1937 euros (diesel) for the target of 120 g/km and 1085 euros (petrol)/969 euros (diesel) for the target of 130 g//km. The net present value of the cost savings will be lower. These savings should be compared to the average additional retail price of a vehicle. The additional retail price per vehicle for a CO_2 emission reduction to 120 g CO_2/km is up to 2450 (a lower limit was not found) and 230-360 to 1250 euros per vehicle for a CO_2 emission reduction to 130 g CO_2/km. Please note that an increase of fuel prices during the car lifetime of 13 years was not considered in our calculations. The most likely scenarios predict strong increases in fuel prices, which lead to larger savings. Therefore one could say that from a consumers point of view switching to a car that meets the 120 g/km target can be done more or less cost neutral. Most likely it does not lead to extra costs, because the increased retail price will be compensated more or less by the savings on fuel costs.

Fiscal instruments like a CO_2 based tax or financial benefits for low emission car buyers can stimulate consumers to buy low emission cars. In that situation they will have a financial benefit.

General conclusion (financial):

The switch to cars that meet the 120 g CO_2/km target will work out more or less cost neutral for car buyers. The average increase in the retail price of cars will be compensated by the savings on fuel costs.

4.3.4 Psychological

The main reasons of the rise of 26% of the total amount of CO_2 emissions of road transport between 1990 and 2004 are the increases in both traffic and car size. There is a clear tendency of people buying larger cars. As stated before, the weight of a car is the determining factor for its CO_2 emission. Although we pointed out that the 120 g/km target is feasible both from a technical and financial point of view, we still think that there should be some kind of mentality change among car drivers. Without this a great part of the car owners might continue to buy high emission cars. To meet the 120 g /km for the entire European car fleet as a whole more car owners should shift to cleaner cars. One way to do this is by raising their awareness, and that might certainly work out the right way. The CO_2/climate issue is high on the agenda these days, people are becoming more aware of the threat that climate change may cause to them. Some kind of awareness campaign might lead to the desired mentality change, where people will be proud to own a low emission car instead of the other way around as seems to be the case now. As we pointed out above, low emissions cars do not necessarily need to have a lower performance than conventional cars. This might speed up the switch to cleaner cars even more.

We like to mention here the great popularity of the Loremo. Although the car is not in production yet (it will be for sale in 2009) already a lot of people made clear that they want to buy it. In our view this is an indication that there is some kind of change taking place. We see this as a signal that car manufactures should pick up. For them it might become more and more interesting to switch to cleaner cars.

Not only does it provide a more environmental friendly profile, but it might also become interesting from an economical point of view. When car drivers like to switch to cleaner cars for ideological reasons or for economic reasons (e.g. when fuel prices go up fast, and fuel savings might exceed extra retail costs) car manufacturers should be ready for it.

General conclusion (psychological):

To reach the 120 g/km target for the entire European car fleet as a whole, more car owners should switch to buying cleaner cars. Awareness campaigns can help to make the necessary change in mentality. There are some signals that indicate that a spirit of change is in the air. Recent years can be characterised as car owners buying large high emission cars, but this might change rapidly because of the attention the CO_2/climate issue already has under the general public.

4.3.5 Environmental

It will be clear that the major environmental benefit of the proposed legislation is a slowing down of both climate change and of the depletion of fossil fuel reservoirs. Both problems were the main reason for the European Commission to propose the revised strategy.

There are some other environmental issues related to the strategy as well. The most important issue is related to the sustainability of the use of biofuels. One of the ways to reach the 120 g/km target in the revised strategy is an increased use of biofuels (for the step from 130 g/km to 120 g/km). We should point out however that in our view there should be a clear definition of the sustainability criteria for biofuels before massive production takes place. We mention the most important criteria here:

- Green House Gas balance: biofuels are CO_2 neutral but not for 100%; production (including the use of fertilisers) and transport lower the climate neutrality. In the Netherlands and the UK studies on this subject have lead to criteria that require a certain minimum of CO_2 efficiency for the changes to biofuels compared with fossil fuels.
- Competition with food production: it should be avoided that the cultivation of energy crops leads to a decrease of the cultivation of food crops.
- Biodiversity & deforestation: it should be avoided that ecosystems and the species living in them disappear because of an increased use of land for the cultivation of energy crops.

We consider other environmental issues related to the revised strategy as of minor importance. As the Impact Assessment (European Commission, 2007) accompanying the Communication of the Commission shows the impact on transport demand in the EU25 and the impact on conventional air pollutant emissions is very limited.

General conclusion (environmental):

It will be clear that the major environmental benefit of the proposed legislation is a slowing down of both climate change and of the depletion of fossil fuel reservoirs. Both problems were the main reason for the European Commission to propose the revised strategy. However, there are some other environmental issues related to the strategy as well. The most important issue is related to the sustainability of the use of biofuels. There should be a clear definition of the sustainability criteria for biofuels before massive production takes place. Most important criteria are the following: Green House Gas balance, competition with food production, biodiversity & deforestation.

4.3.6 Practical

Although in our view implementation of the revised strategy to reach the 120 g/km target is possible both technically as financially, we should point out some practical problems related to reaching the target.

- When can the target be met: in 2012, in 2015 or later? Seen the very slow progress rate towards reaching the voluntary target of 140 g/km in 2008/2009, we consider it unlikely that the 120 g/km target will be met in 2012. 2015 however might be possible. This gives car manufacturers the time to change. Development times of cars have decreased significantly over the last decades. Given the state of the technology it should be feasible to produce a new car that meets the target in the time frame of a few years. We should not forget though that rebuilding production lines is time consuming and costly.
  In addition it deserves attention to provide clarity about the targets quickly and to implement these targets through European legislation without time delay. It also is recommended to provide clarity about emission reduction targets for the longer term, to enable car manufacturers to develop their investment strategies and also to focus research efforts.
- How will the necessary effort be divided among car manufacturers? Do all manufacturers individually need to meet the 120 g/km target for their new fleet or is there some kind of exchange with other manufacturers possible. In our view the latter would not be a bad idea: every car manufacturer has its own profile and they could benefit from each other if that means that the target for the whole European fleet can be met.
- What will happen when the average European new car fleet does not meet the 120 g/km target? Should there be sanctions for car manufacturers?
  The main driving force should be the behaviour of both consumers and manufacturers. Buying behaviour can only be influenced by financial impulses and awareness campaigns. This – in the end – will lead to a change at the fabrics of the manufacturers. Our society is consumer driven, and manufacturers will do what their clients ask them. Individual member states do have some instruments though to influence consumer behaviour. They can tax high emission cars and give bonuses to buyers of low emission cars. They can also give other preferences to clean car drivers. One could think of infrastructural preferences: the creation of lanes / areas only for clean cars. This was done in the US: hybrid car drivers can use rush hour lanes without an accompanying person, where the use of these lanes is normally only allowed for cars occupied by two persons. Not a bad idea for car crowded areas, traffic jam is an increasing problem everywhere.

General conclusion (practical):

Although in our view implementation of the revised strategy to reach the 120 g/km target is possible both technically as financially, there are practical problems in reaching the target.

- **When can the 120 g/km target be met: in 2012, in 2015 or later? 2015 might be possible, 2012 is unlikely given the slow progress of reaching the 140 g/km target in 2008/2009 and the time needed to develop new cars and change mass production lines.**
- **In addition it deserves attention to provide clarity about the targets quickly, to save time. It also is recommended to provide clarity about emission reduction targets for the longer term, to enable car manufacturers to develop their investment strategies and also to focus research efforts.**

- **How will the necessary effort be divided amongst car manufacturers? In our view the 120 g/km should be one for the entire European new car fleet. This gives individual car manufacturers the possibility not to give up their own identity while at the same time they can support other manufacturers to make the target possible.**
- **What will happen when the average European new car fleet does not meet the 120 g/km target? Should there be sanctions for car manufacturers? The main driving force should be the behaviour of both consumers and manufacturers. Consumer behaviour can be influenced by financial benefits and other benefits given to them to member states of the European Union. This will lead to a switch towards the buying of more clean cars and in the end to a switch of car manufacturers to focus on the production of cleaner cars.**

5. Conclusions

Given the state of the art of today's car technology, it is possible to meet the target of 120 g CO_2/km. For small cars this target is possible by optimisation of the engine, for larger cars hybridisation is necessary. An interesting development is in cars that use light materials to bring down the weight of the car. This can lead to an emission factor far below 120 g CO_2/km. The use of biofuels can be an interesting option for further reduction of the emission factor, but will unlikely be able to have a significant contribution in the short run (2010 - 2015). A significant use of biofuels (10 - 20 %) might be possible in 2020 - 2030.

The switch to cars that meet the 120 g CO_2/km target will work out more or less cost neutral for car buyers. The average increase in the retail price of cars will be compensated by the savings on fuel costs.

To reach the 120 g/km target for the entire European car fleet as a whole, more car drivers should switch to buying cleaner cars. Awareness campaigns can help to make the necessary change in mentality. There are some signals that indicate that a spirit of change is in the air. Recent years can be characterised as car drivers buying large high emission cars, but this might change rapidly because of the attention the CO_2/climate issue already has under the general public.

It will be clear that the major environmental benefit of the proposed legislation is a slowing down of both climate change and of the depletion of fossil fuel reservoirs. Both problems were the main reason for the European Commission to propose the revised strategy. However, there are some other environmental issues related to the strategy as well. The most important issue is related to the sustainability of the use of biofuels. There should be a clear definition of the sustainability criteria for biofuels before massive production takes place. Most important criteria are the following: Green House Gas balance, competition with food production, biodiversity & deforestation.

Although in our view implementation of the revised strategy to reach the 120 g/km target is possible both technically as financially, there are practical problems in reaching the target.

- When can the 120 g/km target be met: in 2012, in 2015 or later? 2015 might be possible, 2012 is unlikely given the slow progress of reaching the 140 g/km target in 2008/2009 and the time needed to develop new cars and change mass production lines.
- In addition it deserves attention to provide clarity about the targets quickly, to save time. It also is recommended to provide clarity about emission reduction targets for the longer term, to enable car manufacturers to develop their investment strategies and also to focus research efforts.
- How will the necessary effort be divided amongst car manufacturers? In our view the 120 g/km should be one for the entire European new car fleet. This gives individual car manufacturers the possibility not to give up their own identity while at the same time they can support other manufacturers to make the target possible.
- What will happen when the average European new car fleet does not meet the 120 g/km target? Should there be sanctions for car manufacturers? The main driving force should be the behaviour of both consumers and manufacturers. Consumer behaviour can be influenced by financial benefits and other benefits given to them to member states of the European Union. This will lead to a switch towards the buying of more clean cars and in the end to a switch of car manufacturers to focus on the production of cleaner cars.

6. References

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Table 3.9 CO_2-reduction potential and additional manufacturer costs of technical options to reduce CO_2-emissions of passenger cars on petrol

Technology options for petrol cars		Small					Medium					Large				
Description		CO2 reduction [%]	Costs [Euro]	Attribution to CO2 [%]	Attributable Costs [Euro]	Weight [kg]	CO2 reduction [%]	Costs [Euro]	Attribution to CO2 [%]	Attributable Costs [Euro]	Weight [kg]	CO2 reduction [%]	Costs [Euro]	Attribution to CO2 [%]	Attributable Costs [Euro]	Weight [kg]
Engine	Reduced engine friction losses	3.0	40	100%	40		4.0	50	100%	50		5.0	60	100%	60	
	DI / homogeneous charge (stoichiometric)	3.0	125	100%	125		3.0	150	100%	150		3.0	175	100%	175	
	DI / Stratified charge (stoichiometric)															
	DI / Stratified charge (lean burn / complex strategies)	10.0	320	100%	320		10.0	400	100%	400		10.0	480	100%	480	
	Mild downsizing with turbocharging															
	Medium downsizing with turbocharging	8.5	225	100%	225		10.0	300	100%	300		10.0	375	100%	375	
	Strong downsizing with turbocharging	12.0	390	100%	390		12.0	450	100%	450		12.0	510	100%	510	
	Variable Valve Timing	3.0	100	75%	75		3.0	150	75%	113		3.0	200	75%	150	
	Variable valve control	7.0	300	75%	225		7.0	350	75%	263		7.0	400	75%	300	
	Cylinder deactivation															
	Variable Compression Ratio															
	Optimised cooling circuit	1.5	35	100%	35		1.5	35	100%	35		1.5	35	100%	35	
	Advanced cooling circuit+ electric water pump	3.0	120	100%	120		3.0	120	100%	120		3.0	120	100%	120	
Trans-mission	Optimised gearbox ratios	1.0	50	100%	50		1.5	60	100%	60		1.5	70	100%	70	
	Piloted gearbox	4.0	300	100%	300		4.0	350	100%	350		4.0	400	100%	400	
	Continuous Variable Transmission															
	Dual-Clutch	4.0	600	75%	450		5.0	700	75%	525		5.0	900	75%	675	
Hybrid	Start-stop function	4.0	220	100%	220		4.0	250	100%	250		4.0	280	100%	280	
	Start-stop + regenerative braking	7.0	515	100%	515		7.0	600	100%	600		7.0	685	100%	685	
	Mild hybrid (motor assist)	11.0	1200	75%	900		11.0	1600	75%	1200		11.0	2000	75%	1500	
	Full hybrid (electric drive)	22.0	2800	75%	2100		22.0	3500	75%	2625		22.0	4200	75%	3150	
Body	Improved aerodynamic efficiency	1.5	75	100%	75		1.5	75	100%	75		1.5	75	100%	75	
	Mild weight reduction (5% BIW = 1.5% veh. weight)	0.9	22	100%	22	-14	1.0	28	100%	28	-19	0.9	34	100%	34	-22
	Medium weight reduction (12% BIW = 3.6% veh. weight)	2.2	57	100%	57	-34	2.3	90	100%	90	-45	2.2	115	100%	115	-54
	Strong weight reduction (30% BIW = 9.0% veh. weight)	5.5	212	100%	212	-86	5.8	294	100%	294	-113	5.4	418	100%	418	-135
Other	Low rolling resistance tyres	2.0	25	100%	25		2.0	30	100%	30		2.0	35	100%	35	
	Electrically assisted steering (EPS, EPHS)	3.0	100	100%	100		2.5	100	100%	100		2.0	100	100%	100	
	Advanced aftertreatment	-1.0	0	100%	0		-1.0	0	100%	0		-1.0	0	100%	0	

Ranking	Brand	2005 sales	CO_2 emissions in g/km				% of target achieved
			1997 average	2005 average	reduction 1997 - 2005	reduction target	
1	Fiat	681,613	169	139	-30	-21	**140%**
2	Citroen	875,389	172	144	-28	-24	**115%**
3	Renault	1,361,607	173	149	-25	-25	**100%**
4	Ford	1,167,602	180	151	-29	-30	**95%**
5	Peugeot	1,049,819	177	151	-26	-28	**94%**
6	Opel/Vauxhall	1,262,798	180	156	-24	-30	**81%**
7	Toyota	704,723	189	163	-26	-35	**76%**
8	Kia	231,434	202	170	-32	-44	**72%**
9	Skoda	265,486	165	152	-13	-19	**71%**
10	Seat	344,693	158	150	-8	-13	**63%**
11	Honda	224,258	184	166	-18	-31	**60%**
12	Mercedes-Benz	626,824	223	185	-38	-64	**59%**
13	Hyundai	294,468	189	170	-19	-34	**57%**
14	Volkswagen	1,387,628	170	159	-11	-22	**48%**
15	BMW	575,087	216	192	-23	-58	**40%**
16	Volvo	224,415	219	195	-24	-61	**39%**
17	Audi	582,220	190	177	-13	-38	**35%**
18	Mazda	214,105	186	177	-9	-32	**27%**
19	Suzuki	172,941	169	165	-4	-20	**22%**
20	Nissan	332,742	177	172	-5	-26	**20%**

Appendix 2