POSSIBLE REGULATORY APPROACHES TO REDUCING CO\textsubscript{2} EMISSIONS FROM CARS
070402/2006/452236/MAR/C3

Final Report – Technical Notes

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Technical Notes

This document includes all the Technical Notes which accompany the Final Report of the project “Possible regulatory approaches to reducing CO₂ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

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Possible regulatory approaches to reducing CO\textsubscript{2} emissions from cars

Technical note 1: Overview of Regulatory Approaches in Other Countries

1 Introduction

This note reports the results of the research into regulatory approaches in other countries performed in the context of the project “Possible regulatory approaches to reducing CO\textsubscript{2} emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

There are various vehicle standards among different regions and countries, and it was important to consider them in the context of this study. The aim of this Technical Note is therefore simply to outline the various regulatory approaches to fuel efficiency and CO\textsubscript{2} emissions which exist in other relevant parts of the world, namely the United States in general, California in particular, Japan, Korea and China. The purpose of describing the cases which follow was to provide some background context for the consideration of options for the future EU regulatory approach, rather than to use the approaches of other countries as a basis for the EU approach.
### Unit converter for CO2 emissions and fuel consumption

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<thead>
<tr>
<th>CO2 g/km</th>
<th>l/100km Petrol</th>
<th>l/100km Diesel</th>
<th>mpg Petrol</th>
<th>mpg Diesel</th>
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<td>423.4</td>
<td>681.4</td>
<td>17.64</td>
<td>15.68</td>
<td>13.3</td>
</tr>
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</table>

235.2 (mpg) = 235.2 / (l/100km) and vice versa
1.609344 km/mi
23.8 g/km of CO2 for 1l/100km of petrol
27.5 g/km of CO2 for 1l/100km of diesel
This note contains the following content:

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1.1 Methodology for this appendix

The methodology used to produce this appendix was primarily web-based research, along with some contact with professionals in the relevant countries.

1.2 Brief overview of general approaches around the world

Table 1, taken from a report for the Pew Center on Global Climate Change¹, illustrates the approaches to fuel economy and greenhouse gas standards for vehicles around the world.

Table 1 Fuel economy and GHG standards for vehicles around the world

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Type</th>
<th>Measure</th>
<th>Structure</th>
<th>Test method¹</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>Fuel</td>
<td>mpg</td>
<td>Cars and light trucks</td>
<td>U.S. CAFE</td>
<td>Mandatory</td>
</tr>
<tr>
<td>European Union</td>
<td>CO₂</td>
<td>g/km</td>
<td>Overall light-duty fleet</td>
<td>EU NEDC</td>
<td>Voluntary</td>
</tr>
<tr>
<td>Japan</td>
<td>Fuel</td>
<td>km/L</td>
<td>Weight-based</td>
<td>Japan 10-15</td>
<td>Mandatory</td>
</tr>
<tr>
<td>China</td>
<td>Fuel</td>
<td>L/100-km</td>
<td>Weight-based</td>
<td>EU NEDC</td>
<td>Mandatory</td>
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<tr>
<td>California</td>
<td>GHG</td>
<td>g/mile</td>
<td>Car/LDT1 and LDT2</td>
<td>U.S. CAFE</td>
<td>Mandatory</td>
</tr>
<tr>
<td>Canada</td>
<td>Fuel</td>
<td>L/100-km</td>
<td>Cars and light trucks</td>
<td>U.S. CAFE</td>
<td>Voluntary</td>
</tr>
<tr>
<td>Australia</td>
<td>Fuel</td>
<td>L/100-km</td>
<td>Overall light-duty fleet</td>
<td>EU NEDC</td>
<td>Voluntary</td>
</tr>
<tr>
<td>Taiwan, South Korea</td>
<td>Fuel</td>
<td>km/L</td>
<td>Engine size</td>
<td>U.S. CAFE</td>
<td>Mandatory</td>
</tr>
</tbody>
</table>

¹Test methods include U.S. Corporate Average Fuel Economy (CAFE), New European Drive Cycle (NEDC), and Japan 10-15 Cycle. See Appendix for more details.

²LDT1 and LDT2 are categories of light-duty trucks.

2 Country approaches

2.1 The United States

In the United States, the Corporate Average Fuel Economy (CAFE) regulations were adopted in the wake of the 1973 oil crisis. The standards, contained in the Motor Vehicle Information and Cost Savings Act into which they were introduced under Title V in 1975, cover the fuel consumption of cars and light trucks up to 3,855 kg gross vehicle weight rating. They apply to the overall fleet sold in a given year by a given manufacturer and are thus unfavourable to small volume/high end manufacturers, such as EU carmakers selling cars in the US. Enforcement is based on a fine system (e.g. in 2004 VW and Porsche both paid more than $3M in CAFE fines). However, the penalty is not severe enough to enforce full compliance: instead, for some manufacturers of high-value cars, the fines are in effect regarded as part of the cost of doing business in the US.

Two separate CAFE standards are in effect for passenger vehicles. The standard for passenger cars has remained unchanged since 1985 at 27.5 miles per gallon (mpg). In March 2006 the National Highway Traffic Safety Administration (NHTSA) issued a new ‘final rule’ for light truck vehicles. For the first time, the rule also concerns the largest sport utility vehicles (SUV) (those weighing between 3,855 and 4,536 kg), which will have to meet the standard from 2011. The fuel economy requirement for light trucks will increase from 21.6 mpg (for model year (MY) 2006) to 24 mpg (for MY 2011). A study has also recently been published on possibilities to increase the minimum fuel economy of passenger cars. While NHTSA also has competence to set higher or lower standards for passenger cars, it lacks competence to change rules governing the calculation of the standards. There are now some activities in Congress to increase the fuel economy standards, such as an initiative by Sherwood Boehlert (R-NY) and Edward Markey (D-MA), who want to see the fuel economy of both cars and light trucks increased to 33 mpg by 2016.

The final rule of March 2006 also restructures the fuel economy standards so that they are based on a continuous mathematical function rather than ‘bins’, and established a completely new utility parameter as the basis for targets, namely a vehicle’s ‘footprint’ (the vehicle’s wheelbase multiplied by its track width). A target level of fuel economy established for each increment in footprint, with vehicles with a smaller footprint having tighter mpg targets and those with a larger footprint having less demanding ones. Individual manufacturers are required to comply with a single fuel economy level based on the distribution of its production among the footprint categories in each particular model year. Vehicle weight and

2 http://www.nhtsa.dot.gov/portal/site/nhtsa/template.MAXIMIZE/menutem id.d0b5a45b55bfbe582f57529cd ba046a0;:sessionid=FOoPvLdqhLlZuGqJdplIkJqlwbl9fw4acJpgsGp19dDpCCQeTH1-12374852912/java v.portlet.tpsst=f2d14277f710b755fc08d51090008a0e_ws_MX&javax.portlet.prp_f2d14277f710b755fc08d51090008a0e_viewID=detail_view&javax.portlet.begCacheTok=token&javax.portlet.endCacheTok=token&itemID=199b8f4adcfcf4010VgnVCM100002c567798RCRD&viewType=standard [Last accessed 2006-09-18].


4 http://ucsaction.org/campaign/5_17_06_CAFE_Amendment_House 2006-09-19
‘shadow’ (ie pan area) had also been considered as possible functions on which to base the standards, but there were concerns that they could more easily be tailored (ie gamed) with the objective of subjecting a vehicle to a less stringent target and they were therefore discounted in favour of footprint. The latter is argued to be more integral to a vehicle’s design as it is dictated by the vehicle platform (which is typically used for a multi-year model lifecycle), and cannot therefore easily be altered between model years.

It is now well understood in the US regulatory community that a similar approach (ie a shift to a continuous utility function, and from weight to footprint as utility parameter) will also be applied to US cars in due time. In February 2007 the NHTSA opened a ‘request for comments’ from vehicle manufacturers regarding future reforms of the CAFE programme to set standards for MY 2007-2017 passenger cars and MY 2012-2017 light trucks.

The footprint approach also received support in a March 2004 meta-study by Dynamic Research Inc (DRI) which analysed a number of previous studies by DRI and C J Kahane into the effects of vehicle weight and size on accident fatality risk. All the studies reviewed used data on crashes for both light trucks and passenger cars. The study concluded that reducing wheelbase and track width (ie footprint) generally increased the number of fatalities, whereas reducing vehicle weight tends to decrease the number of fatalities. These findings regarding safety, to the extent that they are applicable in Europe, would be a significant further argument against a utility parameter that could encourage greater weight rather than footprint.

There is an extensive literature on the effectiveness or otherwise of the CAFÉ standards. In brief, it appears that they are generally regarded as having had a positive impact in improving car fuel economy, albeit at a rather unambitious rate and from a very low base by European standards. One well-known distortion caused by the system has been the more lenient standards applied to light trucks (including SUVs) in comparison to those applied to passenger cars. This in itself is believed to have been a significant contributor to the extremely high proportion of SUV sales in the US, and is considered to have contributed to a 7 per cent decrease in the overall light duty fleet fuel economy since 1988. In addition, vehicles that can run on biofuels enjoy a discount – without any guarantee that biofuels will actually be used by the vehicle owner. Differences in fleet and test cycle make a direct comparison difficult but the CAFÉ objectives are estimated to be in the range of 240 g CO₂/km.

In his 2007 State of the Union address, President Bush announced that he would seek a 20 per cent reduction in fuel consumption over 10 years. Further to a recent Supreme Court ruling calling on the US Environment Protection Agency to regulate greenhouse gas (GHG) emissions from vehicles, the President announced that he would put forward before the end of 2008 a revised fuel consumption regulation. However, because the new rule would take into account vehicle size (as opposed to the current overall fleet standard), the final outcome of the revision in terms of fuel efficiency progress is unclear (eg if cars sold become bigger

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6 Source: based on report by Feng An for the Pew Center on Climate Change

7 in the absence of federal legislation at present, some states have taken their own initiatives – see California
than the current average, there will be an overall net increase (worsening) in fuel consumption.

2.1.1 State vs Federal regulations

The US Supreme Court ruled in April 2007 that the Environmental Protection Agency (EPA) has the authority to regulate greenhouse gas emissions. In September 2007 a federal judge subsequently ruled that the US state of Vermont may adopt its own rules on CO₂ emissions from cars, inferring that the EPA and states, acting under the Clean Air Act, have the power to set more stringent emissions limits on cars and regulate greenhouse gases. Car companies had challenged new state regulations modelled on California’s pioneering pollution standards for cars (see 2.2 below), but the judge backed an earlier decision of Congress that California can draw up rules that are tougher than federal standards, and that other individual states may ‘monitor and regulate emissions’ by following the tighter Californian standards. Connecticut, New Jersey, New York and Pennsylvania have also adopted Californian standards. Car manufacturers still hope to have the latest Vermont ruling overturned in a higher court, but in the longer term the impact from the ruling may lead to a single US nationwide standard.

2.2 California

California is one of the US states that proposes to adopt tougher fuel economy standards than the federal government.8 Following the signing of Assembly Bill 1493 by Gov. Gray Davis in July 2002, California enacted the first state law requiring GHG emission limits from motor vehicles, to achieve the maximum feasible and cost-effective reduction of greenhouse gases from California's motor vehicles9. The California Air Resources Board (CARB) issued regulations in September 2004, limiting the ‘fleet average greenhouse gas exhaust mass emission values from passenger cars, light-duty trucks, and medium-duty passenger vehicles’. The regulations, adopted in 2005, include credit trading and provisions for small volume manufacturers, and cover not only tailpipe emissions but also GHG leaks from air conditioning (HFCs). The fleet average caps first apply to MY 2009 vehicles. The caps become more stringent annually, so that by 2016, the fleet average would be 30 per cent below the 2009 level (the final 2016 level would be in the range of 180 g CO₂/km10). Table 2 contains the new requirements for GHG emission limits on vehicles in California.11

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8 The administration's rules are considerably less daunting than new California global warming emissions regulations that would force steeper fuel economy increases on vehicles sold there. New York is planning to pass similar air-quality rules. [Link](http://www.nytimes.com/2006/05/02/washington/02suv.html?ex=1304222400&en=7c12841f56b1b96e&ei=5090&partner=rssuserland&emc=rss 2006-09-19)

9 [Link](http://www.arb.ca.gov/cc/cc.htm#what's%20new)

10 Source: based on report by Feng An for the Pew Center on Climate Change

11 [Link](http://www.arb.ca.gov/regact/grnhsgas/revfro.pdf)
Table 2 GHG emission limits on vehicles in California, 2009-2016+

<table>
<thead>
<tr>
<th>Model Year</th>
<th>Fleet Average Greenhouse Gas Emissions (grains per mile CO$_2$-equivalent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All PCs; LDTs 0-3750 lbs. LVW</td>
</tr>
<tr>
<td>2009</td>
<td>323</td>
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<tr>
<td>2010</td>
<td>301</td>
</tr>
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<td>2011</td>
<td>267</td>
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<td>2014</td>
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<td>2015</td>
<td>213</td>
</tr>
<tr>
<td>2016+</td>
<td>205</td>
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</table>

The emission requirements of California are important not just because of the size of that state, but also because other states can choose to adopt Californian regulations instead of national regulations owing to a legal precedent, but cannot adopt a third approach. Ten other US states have formally adopted California’s motor vehicle requirements for GHG emissions, including Oregon, Washington and eight states in the Northeast.

It is, however, worth noting that there is some dispute over whether California has the competence to introduce binding standards for CO$_2$ emissions of vehicles, and this point is subject to current litigation. The outcome of this case could delay or derail the implementation of the new standards in California and elsewhere.

### 2.3 Japan

In Japan, the so-called ‘Top Runner Programme’ was created under the Energy Conservation Law in 1999. It is applied to cars as well as to many other energy consuming goods (including air conditioners, refrigerators, computers, TVs, washing machines and fluorescent lights). Vehicles are grouped by weight classes, for which fuel efficiency targets are defined. These are based on using the best-performing vehicle in each class as the ‘target setter’ (ie the one with which others have to catch up over a defined time period) together with assumptions on expected technological developments. A report for the Swedish Environmental Protection

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12 “All new vehicles sold in the United States must be certified as meeting either the federal emissions standards set by the U.S. Environmental Protection Agency (EPA), or the California standards, set by the California Air Resources Board (CARB). The California standards apply to vehicles sold in California and in four Northeastern states -- New York, Massachusetts, Vermont, and Maine -- that have chosen to adopt California's vehicle regulations.” [http://www.environmentaldefense.org/TailpipeTally/methodology.cfm?synd=](http://www.environmentaldefense.org/TailpipeTally/methodology.cfm?synd=)

13 [http://www.eccj.or.jp/top_runner/index_contents_e.html](http://www.eccj.or.jp/top_runner/index_contents_e.html) 2006-09-19
Agency\textsuperscript{14} describes the process for setting the targets. Three levels of committees consisting of experts, academia, consumer groups, local government representatives and industry representatives are involved in determining the content of the standards, the target years, and so on. At the top level, the Advisory Committee for Natural Resources and Energy oversees overall policy making to promote proper use of energy. At the middle level, the product groups to be included in the Top Runner Program are determined by the Energy Efficiency Standards Subcommittee (taking into consideration the suggestions by the Natural Resources and Energy Agency under the Ministry of Economy, Trade and Industry (METI)). An evaluation standard subcommittee is then established for the respective product groups, which makes proposals (in close collaboration with METI, industry representatives, academia, experts and so on) on the scope of the product group, evaluation methods, parameters to be used, standards and target years. Typically it takes around two to two and a half years to produce standards for a product group. The standards, as well as the timescales for achieving them, are then reviewed when the target year arrives, or if a substantial proportion of the products meet the standards prior to the target year.

As regards enforcement aspects, the targets are compulsory and producers (manufacturers and importers) must ensure that the weighted average of energy efficiency of the products they place on the market during the target year meets the standard: this therefore allows the sale of products with energy efficiency lower than the standard provided enough products with higher energy efficiency are placed on the market to enable the average to equal or exceed the standard. However, although the targets are mandatory the enforcement provisions are fairly ‘low-key’ compared to European standards, ranging from public ‘name and shame’ activities to a minimal fine (equivalent to a few thousand euro).

All vehicle manufacturers have successfully met the targets: the majority of vehicles sold in Japan in 2002 were already in compliance with the 2010 standards, and in 2004 more than 80 per cent of the cars sold in Japan met the Top Runner standards.\textsuperscript{15} The standards have thus been reviewed in early 2007, and now aim at a fuel efficiency progress of more than 20 per cent by 2015 compared to the 2004 situation. Differences in the test cycle and the vehicle fleet between the EU and Japan makes direct comparisons with the 2015 target difficult. Estimates range from 120 g\textsuperscript{16} to 138 g\textsuperscript{17}, but probably the most authoritative is a recent report by ICCT that compares values across test cycles. This puts the Japanese standard as equivalent to 125g/km on the EU test cycle\textsuperscript{18}.

Table 3 illustrates the energy consumption efficiency standards relating to passenger vehicles with a riding capacity of 10 persons or fewer.

\begin{table}
\centering
\begin{tabular}{|c|c|c|}
\hline
Vehicle Type & Energy Consumption Efficiency Standards (g/km) \\
\hline
Passenger Vehicles & 125 \\
\hline
Commercial Vehicles & 130 \\
\hline
\end{tabular}
\end{table}

\textsuperscript{14} THE TOP RUNNER PROGRAM IN JAPAN: ITS EFFECTIVENESS AND IMPLICATIONS FOR THE EU, Swedish Environmental Protection Agency, November 2005
\textsuperscript{15} \url{http://www.naturvardsverket.se/bokhandeln/pdf/620-5515-1.pdf} 2006-09-19
\textsuperscript{16} Source: based on report by Feng An for the Pew Center on Climate Change
\textsuperscript{17} Source: Japanese Automobile Manufacturers Association
\textsuperscript{18} \url{http://www.theicct.org/documents/ICCT_GlobalStandards_20071.pdf}
Table 3 Energy consumption efficiency standards for passenger vehicles in Japan

<table>
<thead>
<tr>
<th>Category</th>
<th>Standard energy consumption efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gasoline</td>
</tr>
<tr>
<td>Vehicles weighing less than 703 kg</td>
<td>21.2</td>
</tr>
<tr>
<td>Vehicles weighing 703 or more and up to 828 kg</td>
<td>13.8</td>
</tr>
<tr>
<td>Vehicles weighing 828 or more and up to 1,016 kg</td>
<td>17.0</td>
</tr>
<tr>
<td>Vehicles weighing 1,016 or more and up to 1,266 kg</td>
<td>15.0</td>
</tr>
<tr>
<td>Vehicles weighing 1,256 or more and up to 1,516 kg</td>
<td>13.0</td>
</tr>
<tr>
<td>Vehicles weighing 1,516 or more and up to 1,766 kg</td>
<td>10.5</td>
</tr>
<tr>
<td>Vehicles weighing 1,756 or more and up to 2,016 kg</td>
<td>9.9</td>
</tr>
<tr>
<td>Vehicles weighing 2,016 or more and up to 2,266 kg</td>
<td>7.9</td>
</tr>
<tr>
<td>Vehicles weighing 2,256 kg or more</td>
<td>6.4</td>
</tr>
</tbody>
</table>

* A vehicle weight less than 1,110 kg is treated as the category.

Remarks
Vehicle weight is the weight of vehicles when not loaded as stipulated by the Road Trucking Vehicle Safety Standard (No. 67 Ministry Ordinance of the Ministry of Transport, 1951), article 1, 4.

Separate standards exist for buses that run on light oil and have a riding capacity of 11 persons or more.

The Swedish Environmental Protection Agency report attempts to evaluate the Japanese Top Runner Program. It suggests that the way in which the program’s standards are set is beneficial as it can contribute to industry-wide environmental improvement. This is because products having the highest energy efficiency on the market are used a starting point for standard setting, but the process also takes into account the potential for other manufacturers to realistically meet the standards, for example through technological developments. However, it also points out that setting standards at a ‘realistic’ level may facilitate steady improvement, but may not to contribute to radical change. Finally, the report highlights that the top runner approach can be integrated into other policy instruments; for example in the case of cars, the green automobile tax scheme incorporates the Top Runner standards as one criterion for the selection of environmentally superior cars, with the modest tax reduction for consumers perceived as being a particularly effective way to change the purchasing behaviour of consumers.

2.4 Korea

Mandatory average fuel economy standards for cars were due to be introduced in South Korea in March 2004, but enforcement was eventually delayed until January 2006. The new regulation is partly a response to declining average fuel economy, which can be seen as largely due to an increase in the sales of SUVs. The Average Fuel Economy (AFE) standard replaces the previous system under which the voluntary standards were suggested but not enforced.

The new standards (see table 4 below) were enacted in 2006 for domestic cars and will come into force in 2009 for imported cars with sales of less than 10,000 vehicles. Companies manufacturing or importing more than 10,000 vehicles per year will be subject to U.S. CAFÉ standards per South Korean law. The standards therefore seem to target mainly small-scale manufacturers and importers. The standards are based on vehicle engine size, with two size categories. If a manufacturer produces vehicles which exceed the fuel economy standard in the smaller engine size class, it earns credits that can be used to offset shortfalls in the other
class. This credit system is likely to only benefit Korean manufacturers, as importers do not sell vehicles in the small engine size category.

Table 4 South Korean Average Fuel Economy (AFE) standards for light-duty vehicles

<table>
<thead>
<tr>
<th>Vehicle engine size (by cylinder volume/displacement) (cm³)</th>
<th>km/L</th>
<th>mpg CAFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤1,500</td>
<td>14.4</td>
<td>39.9</td>
</tr>
<tr>
<td>&gt;1,501</td>
<td>9.6</td>
<td>26.6</td>
</tr>
</tbody>
</table>

With regards to enforcement, if a manufacturer fails to meet the standard, the South Korean government will issue them with an order to improve their fuel efficiency by a given date; however no such orders will be issued before the end of a grace period which runs until the end of 2009. If the requirement is still not met after the notice is issued, the penalty is along the lines of the ‘public shaming’ system in place in Japan (see above); no monetary or criminal penalty is envisaged, but the South Korean government will publish a list of non-complying, and therefore fuel-inefficient, vehicles. The AFE regulation will be re-examined in the second half of 2009 if manufacturers importing automobiles into Korea cannot meet the requirements of the regulation.\textsuperscript{19}

The Korean plans are as yet relatively poorly documented in terms of implementation and likely impact. The researchers of the current study will however endeavour to include more information on the situation in Korea in future drafts of this or other reports.\textsuperscript{20}

2.5 China

\textbf{China} has already adopted fuel economy standards for cars, and a second tier is scheduled for introduction in 2008. The fact that China’s domestic automotive industry is currently not as large as that of other countries, and that car ownership levels are still relatively low, may have made it easier for China to adopt tough fuel economy standards at an early stage.\textsuperscript{21} Given the rapid growth in the Chinese economy, however, the standards could have important implications for the norms to be followed by carmakers worldwide.

The new Chinese standards will be implemented in two phases, with Phase I running from 1 July 2005 for new vehicle models and from 1 July 2006 for continued vehicle models, and Phase II running from 1 January 2008 for new models and from 1 January 1 2009 for continued vehicle models. The standards are set on a weight-based system under which vehicles are classified into 16 weight classes. The standards cover passenger cars, SUVs and multi-purpose vans (MPVs), with separate standards for passenger cars with manual and automatic transmissions. SUVs and MPVs, regardless of their transmission types, share the

\textsuperscript{19} \texttt{http://www.eucck.org/trade2004_new/trade2004_e/auto_g.htm} 2006-09-19

\textsuperscript{20} Main source for the section on Korea: COMPARISON OF PASSENGER VEHICLE FUEL ECONOMY AND GREENHOUSE GAS EMISSION STANDARDS AROUND THE WORLD, Prepared for the Pew Center on Global Climate Change, \texttt{http://www.pewclimate.org/docUploads/Fuel%20Economy%20and%20GHG%20Standards_010605_110719.pdf} 2006-09-19

\textsuperscript{21} \texttt{http://newsroom.wri.org/wrifeatures_text.cfm?ContentID=2433} 2006-09-19
same standards as passenger cars with automatic transmissions. Commercial vehicles and
pickup trucks are not regulated under the standards.22

A November 2004 study by the World Resources Institute (WRI) has analysed the new
Chinese fuel economy standards.23 The WRI study concludes that the standards are slightly
more stringent than current fuel economy regulations in the US. If the US were to meet
Chinese standards, fleet average fuel economy would need to increase by 5 per cent for the
Phase I standards and by 10 per cent for the Phase II standards.

The standards require more fuel economy improvements for the light truck segments than for
cars. In 2003, 66 per cent of cars sold in China met the Phase I standards (with 35 per cent
likely to meet the Phase II standard); only 4 per cent of SUVs and minivans already meet the
Phase I standards, with no light trucks currently meeting the Phase II standard. As a result,
the standards are likely to disrupt future plans for car manufacturers who intend to introduce
larger and more powerful vehicles into the Chinese market.

The WRI study also indicates that manufacturers have varying degrees of readiness to
comply. Ford has 100 per cent of its 2003 sales already meeting the Phase I standards (with
72 per cent for Phase II), whilst the compliance rate for GM was only 42 per cent for Phase I
standards (and 32 per cent for Phase II). GM, and also DaimlerChrysler, may therefore
require higher capital expenditures in fuel economy improvements over the near term to meet
the Chinese standards. Toyota, Ford and PSA are best positioned, requiring little or no
investment over a longer period to meet the new standards.

The WRI study suggests that regulations could be tightened beyond 2008 in order for China
to demonstrate a commitment to reducing its domestic oil consumption; to do this, further
fuel economy improvements will be necessary to offset escalating vehicles sales. In addition,
enforcement of the standards will be key. It is not yet known to what degree the standards
will be monitored and enforced by Chinese authorities, particularly for the Phase II standards.
This leaves great uncertainty about the degree to which the standards may affect the financial
performance of automakers in China.

2.6 Other countries

The Worldwatch Institute reports that apart from the countries mentioned above, Australia,
Canada and Taiwan also have fuel economy standards.24 That said, they also claim that fuel
standards are in place in the EU, which is technically incorrect, so sources and definitions
would need to be checked carefully.

22 Source: based on report by Feng An for the Pew Center on Climate Change
23 TAKING THE HIGH (FUEL ECONOMY) ROAD - WHAT DO THE NEW CHINESE FUEL ECONOMY
STANDARDS MEAN FOR FOREIGN AUTOMAKERS? http://pdf.wri.org/china_the_high_road.pdf 2006-09-19
24 http://www.worldwatch.org/node/3877 2006-09-19
3 Conclusions

Some of the regulatory approaches outlined above are of interest to the current study, although many are less interesting as they tend to differ from the approach that this study is proposing for the EU to follow. In particular, the majority (with the exception of Korea) are based largely on vehicle weight which is not considered by the research team to be the most appropriate approach for the EU to take.

We therefore conclude that most of the components of systems overseas are of limited applicability in Europe and do not suggest important system design components which were not already under consideration for this and earlier research in the EU.
Possible regulatory approaches to reducing CO₂ emissions from cars

Technical note 2: Discussion of the options for a legal instrument

1 Introduction

This note reports the results of the discussion on the options for a legal instrument performed in the context of the project “Possible regulatory approaches to reducing CO₂ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

This note contains the following content:

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2 Overall Approach

In order to avoid analysis of endless different permutations of different components of a possible legal regime, we need, at least initially, to treat the separate components of a possible system independently. The broad components that we need to address in our analysis are primarily the following:

- Targets;
- Instruments;
- Obligated entities;
- Monitoring and reporting; and
- Enforcement regimes and penalties.
Clearly these components are not in reality separate, in that some combinations will work particularly well together, while others will be incompatible. Also, we do not treat all of these components in equal depth, as the primary focus is still on targets and instruments, as in earlier analysis. However, questions over the obligated entities and possible enforcement regimes and penalties in particular clearly become more important – and in some cases quite central – as we move towards designing a legal instrument and assessing its impacts. At the least, the relationship of various target/instrument combinations to the other components of the system are amongst the tests of practicality that we need to apply. In reality, it is the way in which the various components fit together that determines whether a particular combination will work or not, and also how well it will work against the range of agreed criteria. There is also the question of the legal or political acceptability to the main parties of each of the possible options, as this could well exclude important possibilities that might otherwise seem quite promising on technical grounds.

Considering every possible permutation of all the possible options under each of these five headings was quickly revealed to be impractical. As set out in the discussion that follows, however, it also becomes clear that some combinations of options are logically impossible, while others appear very unlikely to work in practice. Conversely, other relationships suggest strong alignments of the possibilities available under each of several different headings: for example, the nature of the enforcement regimes is clearly closely related to the question of who is the obligated entity; while some target/instrument combinations clearly lend themselves to certain sorts of sanctions, and not to others. In all cases, monitoring and reporting arrangements, although important and in some cases absolutely vital, appear to remain largely a ‘downstream issue’ in that it appears possible in principle to develop adequate arrangements for this almost irrespective of the design of the other components of the system.

The method in which this general approach was translated into a ‘long list’ of possible combinations of options that merit closer examination is described in Technical Note 5 after the more general discussion and conclusions below on the various components of a future system. The purpose of the latter is to set out the general considerations that apply to each component of the system in its own right, and to indicate how it might (or might not) relate to the other elements of the system. This discussion sets the stage for further analysis leading to the first ‘long list’ of options.

3 Legal and Institutional Issues

3.1 Type of Obligation to be Imposed

We are not asked to design a legal instrument in detail, but it is worth considering some aspects of the legal possibilities up front, in order to focus our work and to avoid wasting time on unpromising options.
By definition, we should assume that an effective legal instrument will place certain obligations on specific legal entities who will be required to ensure that the system is enforced. Equally, there must at least in principle be some sanctions available to be applied to these legal entities if they do not meet their obligations. In principle, different legal entities may be responsible for different aspects of the system, or may in turn impose obligations and possible sanctions upon third parties within their jurisdiction.

EU legislation available for the potential instrument includes directives and regulations, that each impose obligations upon the Member States. For Directives, the general aims and requirements are specified, and Member States pass complementary legislation to transpose the requirements into national law and fit it within the framework of their own legal, institutional, and cultural contexts. The requirements become binding through the national legislation and according to the timescale noted therein. Regulation is immediately binding (though timescales are noted therein) and MS often pass complementary legislation to help offer clarity and address complementary issues.

In most cases, environmental obligations are placed upon the Member States to be implemented by directives. The Member States in turn can designate competent authorities within their own country in order to implement various aspects of the legal requirements, and can place legal obligations upon commercial entities such as companies operating within their territory. They may also have some latitude in determining the nature of the sanctions to use for non-compliance; and a range of such sanctions are in use around the EU. This is equally the case with existing vehicle emissions regulations; it is not illegal for manufacturers to make vehicles that do not meet the current Euro emissions standards, but the Member States are obliged to ensure that such vehicles cannot be put on the market. Thus we have (in principle at least) a simple system of pass/fail criteria in relation to the various regulated pollutants, and equally a very simple sanction of exclusion from the market. Unfortunately, neither of these components is likely to work well in relation to CO₂ emissions, so we may need to consider a very different sort of system.

With Regulations, the specific requirements of the legislation have immediate effect within the Member States without needing to be transposed into national law. These are usually confined to relatively technical measures (eg standards) that can relatively easily be ‘dropped in’ to the existing national legal framework. It appears to be the expectation that a Regulation would be an appropriate route for legislating CO₂ from passenger cars, although it is not yet immediately clear how this would operate in practice.

A Regulation (unlike a Directive) can also place obligations on entities other than the Member States, so this is clearly a prima facie reason for preferring this approach if the primary obligation were to be on the carmakers, for example. However, any sanctions for non-compliance would almost certainly have to be imposed by the Member States in proportion to the level of performance of each carmaker within their own country. This is because the Commission does not have the legal powers to impose sanctions at Community level on economic
entities except in certain areas -- in particular competition law -- that are defined in the Treaty, and the range of sanctions available to it is also circumscribed. In contrast, there is a well-established system for the Commission to monitor the performance of the Member States in implementing Community law, and threatening or imposing sanctions where necessary. Clearly it would not be practicable to amend the Treaty to deal with requirements that fell outside of the existing norms, so a system of sanctions within each Member State appears more likely in practice, on the basis of our current level of understanding.

It is an important question whether the Commission is able and allowed to levy penalties on behalf of the Community\(^1\) in pursuing a policy such as this, and what sort of penalties it could or could not apply. There are some precedents for this (see Technical Note 3 on legal issues). If suitable sanctions are not available at Community level then this would need to be done by MS governments, which in turn would make it logical to make them responsible for or give them a greater role in the monitoring and other aspects, although in principle the monitoring could still be done at the EC level.

This question also relates to the type of targets to be applied. Thus if the target or limit value were applied at the level of the individual car, the Member States would be able to impose any relevant sanctions directly, for example levying charges at point-of-sale, or even excluding some vehicles. However, if targets or limits were based on some sort of corporate average, the choice would be between administering these limits at the national level, or for the Commission or some agent of the Commission to collate the performance data at Community level, and then to inform the Member States of any non-compliance (however that is defined), and to ask the Member States to impose the agreed sanctions at national level. The latter would seem to be the simplest solution, and it is difficult to see how differentiated targets could be imposed at national level on specific carmakers without causing excessive distortions in the single market. For example, if fines or prohibitions were to be imposed upon a certain model of car in one country because its manufacturer had failed to comply, but were not operated in a neighbouring country where the company was in compliance, then car buyers in the first country might well seek to buy their desired car in the second country instead.

Further practical difficulties could also arise in the question of imposing sanctions at the Member State level. For example, if a MS has only one importer for a given brand, the obligation or sanction could be imposed on this importer, but if there is more than one importer, which is in principle possible and is also encouraged by EU competition policy, it becomes impossible to punish individual companies for non-compliance of the national sales average. For these reasons, the option of implementation at the national level is a pivotal one, and it seems on the face of it that it will significantly limit the number of feasible options.

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\(^1\) Note that this is possible in the case of competition law.
3.2 The Obligated Entities

In this section, we set out the main options to be the principal obligated entities – that is, the legal entities that will be placed under the obligation to take action to reduce car CO₂ emissions, and to be responsible for ensuring that this takes place. However, in this we do not necessarily follow a strict legal definition, but focus on the entity principally required to take action to bring about an achievement of the target. For instance in the case of regulated pollutants the legal onus is on the Member States to police their car markets effectively, but in effect it is the manufacturers that are obliged to produce cars that comply with the standards.

In discussing possible obligated entities, we should also look at the powers and possibilities that these entities have to meet the standards. These options might work in a direct (own action) or indirect (stimulating or demanding action by others) way. For example, manufacturers can change the fuel efficiency of cars and can influence the sales averages by adjusting their wholesale prices and marketing instruments. Importers may have an indirect influence on the products offered by manufacturers, but will mostly have to rely on marketing instruments. The MS governments have no direct control over vehicle characteristics and marketing, but can certainly influence sales by means of fiscal instruments and information (eg labelling), and this is potentially an important component of the overall system. Thus several types of actors have or can have a major influence on the outcome in terms of average emissions, but arguably none of them is in complete control of the system.

This could become a critical issue. Previously, theoretical work on system design has implicitly worked under the assumption that the system would be imposed at the EU level. Imposing it at the MS level may ‘magnify’ or change the pros and cons of various options significantly, however. An assessment by TNO for VROM shows that per manufacturer sales distributions over vehicle segments differ dramatically from country to country, so that winners and losers and associated cost to various manufacturers may be very different in different countries. Hence ‘obligated entity’ is now a major axis for categorising options up front in this study, but one which has not been widely discussed hitherto. It is therefore also important to establish an understanding of stakeholder positions on this issue before selection of the short-list, as this can have an important knock-on effect on other aspects of system design.

3.2.1 Trade Associations

The current self-commitments were undertaken by the three main trade associations in Europe (ACEA, JAMA and KAMA) on behalf of their members.

Our working assumption, however, is that the trade associations are unlikely to be suitable as obligated entities for this legislation. Aside from the fact that they have lost some political credibility through failing to deliver fully on the voluntary agreements, it appears unlikely that they are suitable entities to undertake the necessary obligations, and they do not appear to have sufficient influence or legal powers over their members to impose effective sanctions upon them for any non-
compliance. It thus appears at first sight that they would not be able to deliver reliably on any obligations that they did undertake. This is also a critical assumption to be determined: if implementation were to take place at the Community level, then the appropriate obligated entities should probably be manufacturing companies or holding companies of various brands.

3.2.2 Manufacturers and Groups

Hence our working assumption to date has been that obligations would fall upon the car manufacturers, and this has been the assumption applied in earlier work on this issue. In this it is assumed that the manufacturer groups (as opposed to individual brands) would operate as single economic entities which would pay any fines or charges, be responsible for any trading of credits, etc. In this there would, if targets or limits were set at the manufacturer level rather than the car level, be scope for implicit pooling and burden sharing between the brands within each group.

A further point is that there appears no good reason why several manufacturers should not be allowed to work collectively to meet a shared group target or limit value, provided that legal and practical responsibilities under the scheme could be discharged in this way (for example, that there were still identifiable legal entities to be placed under the necessary obligations, that there were agreed internal mechanisms for burden sharing, payment of fines or charges, etc). This would be by analogy to the provisions of the Kyoto Protocol, for example, which allows countries to band together under a single collective ‘bubble’ for the purposes of meeting their CO\textsubscript{2} commitments. There would need to be suitable notification requirements put in place to facilitate this, and a suitable failsafe, eg manufacturers revert to and become responsible for their individual targets or limits if the collective target or limit is not met.

The purpose of manufacturers coming together in groups would be to pool their respective sales in order to modify their group average – ie for a manufacturer with below-target emissions to help balance out the excess emissions of one that was above-target. Note that this option only makes sense if a target (or limit) is to be imposed at a collective level – it appears to offer no benefits if a measure is to be imposed at the level of individual cars, unless the individual car targets or limits are to be totalled to corporate level. The impact of arrangements such as this would be to reduce the aggregate level of charges payable, or reduce the aggregate level of trading of credits, depending on what sort of system were to be adopted. This in turn would reduce the formal total cost of the scheme to the manufacturers, and also its running costs – although manufacturers working in a group might need to make their own arrangements to compensate their partners in the group in some way.

3.2.3 Importers, Distributors, Dealers

However, if monitoring sanctions were to be operated at Member State level, we might want to consider whether companies or company groups do offer the most appropriate option. That is, most manufacturers do not manufacture in most Member States, and even where they do, there is generally a rather weak
relationship between manufacturing output and sales. Since what we envisage will probably be operated as a market-oriented measure, it might make sense to consider in greater detail how we might involve sales and distribution organisations as well as or instead of manufacturers. There is an analogy for this in the ELV Directive, where obligations are imposed upon the so-called ‘economic operators’ who put cars on the market, as these are not necessarily the manufacturers themselves at Member State level. However, as argued above, imposing the obligation upon ‘economic operators’ seems to be rather problematic in connection with limits or targets based on sales averages, and would lend themselves much better to vehicle-based standards.

3.2.4 Member States as Obligated Entities

As noted, it is usually the MSs that are the main obligated entities for the purposes of EC environmental regulation. In this case there is a clear system of transposition, implementation and sanctions already in place that could be used to oversee the system. As discussed elsewhere, various flexibility mechanisms (e.g. trading) are also available that could deliver a fair burden sharing between Member States, along broadly the same lines as those that could be applied to manufacturers or groups in order to reflect their different starting positions. Also, as is possibly not the case with the car manufacturers, such a burden sharing would by definition be legal if agreed by the Member States and voted in by the Council and Parliament.

As against this, Member States might well be reluctant to commit themselves to binding limit values in an area where, rightly or wrongly, they might perceive that they have limited ability to affect the desired outcome. Also, it has been implicit in much of the analysis to date in this area that the manufacturers would be the obligated entities. In the case where the Member States bore the principal obligation they might in turn need to impose obligations on the manufacturers or dealers within their national territory; but it is as yet unclear how such an arrangement could work. Such an approach seems inherently complex and in great danger of leading to or exacerbating market distortions. It is therefore necessary to consider whether or how far the approaches taken by the Member States should be harmonised in these circumstances.

Member States do also have other mechanisms whereby they can indirectly affect the market for cars in their country – through taxation; labelling and other forms of consumer advice and information; subsidies for purchase of the most efficient vehicles; public procurement programmes; etc.

An option where obligated entities are MSs (rather than OEMs) is likely to be in combination with some flexibility mechanisms such as trading, as the differences at MS current average emission levels are probably as great as on OEM level. It would allow though to have money transfer from ‘big car driving countries’ to ‘small car driving countries’, which might be thought by some to be an equitable outcome, but which could well be resisted by others. The price for this would naturally be balanced with the price of CO\textsubscript{2} in sectors other than transport.
3.3 National Governments vs Community Action

As noted above, most EC law operates at the level of the Member States rather than the Community as a whole. This is also the method likely to be preferred by the Member States, insofar as it gives them greater control, and greater flexibility to design legislation that is in keeping with existing frameworks of national law and institutions. As noted above, it can be seen that in most cases the Member States, or competent authorities designated by them, carry out most of the detailed regulatory actions; that is they place obligations on other legal entities within their territories, eg by requiring them to meet certain standards, obtain operating licences, etc. In the case of the ETS, they can also require them to trade credits where needed. In the case of regulated pollutants, the Member States exclude from the market any vehicles which fail to meet the relevant type approval standards.

However, in the case of CO\textsubscript{2} we are likely to be considering a much more complex system than that for regulated pollutants. For example, it might involve sanctions or incentives based on corporate averages across the whole of the EU, or actions that need to be coordinated or consistent across several Member States. In these cases, we have to keep in mind the possibility that action will need to be coordinated or even enforced at Community level. Given the limited resources of the European Commission, this suggests the possibility that some kind of statutory agency at EU level might be needed with some of the options under consideration, for example to act as a clearing house for fines or feebates (levied at Community or MS level) or to run a community-wide trading system.

Conversely, particularly the larger and more Eurosceptic Member States (such as the UK) are instinctively wary of establishing new institutions or new competences at Community level. Also, the Community itself has few if any agencies that are entrusted to monitor and enforce Community environmental policy, and the Commission itself has only limited capacity to oversee a complex system. Thus even the EU ETS, which is a community wide trading system, is administered primarily by the Member States.

A closed trading system in the context of the EU passenger car CO\textsubscript{2} legislation could work similarly to the ETS, an important difference of course being that the credits are not expressed in tonne CO\textsubscript{2} but in g/km. If targets are set at the level the national sales averages of importers, Member States can be the authorities that monitor the CO\textsubscript{2} performance and the trading of legal entities based within their country. If targets are set at the EU sales averages of manufacturers, some monitoring mechanism at the EU level is probably necessary to establish the EU sales averaged CO\textsubscript{2}-emissions, but monitoring of the trading could still be in the hands of Member States supervising legal entities within their country. Further study, however, is needed to work out options for implementing trading in the context of the EU passenger car CO\textsubscript{2} legislation.
4 Target Types

Clearly we already have an agreed global target for the purposes of this exercise – a Community average of 130g/km by 2012. For various reasons discussed below, however, it is likely that this global target will need to be translated into different targets or types of targets to be used at particular points within a proposed system.

4.1 Targets vs Limit Values

There appears to be fairly good common ground as to a definitional distinction between targets and limit values, and what are the strengths and weaknesses of targets as against limit values. These are discussed below. In essence, limits define an upper threshold of emissions that should not be exceeded in any instance, whereas targets set a median value that on average should not be exceeded. These definitions and distinctions are vital to understanding the impacts of the different possibilities available.

4.1.1 Relationship of Target Types and Values to the Overall Objective

While it is possible that a single and uniform target may apply to all vehicles and all obligated entities, it is nonetheless important that, in the case of group average targets, a specific target should be applied to the obligated entity in a metric that is relevant to its own performance. For example, a Member State cannot meaningfully be bound by a Community-level target, so in this case this must be translated into a state-level target for each Member State. This in turn opens up the possibility of differentiated targets for each entity – a possibility discussed in greater detail below. However, it should be stressed that any deviation from a single and uniform target opens up the important question of the relationship between specific targets and the overall objective of the system – in this case 130g/km average emissions in 2012.

It should be borne in mind, in particular, that the two approaches outlined above can have very different relationships to the ultimate overall target (in this instance, 130g/km) and its attainment. That is, a target can be set at or around the value that is to be achieved, and provided that car sales remain more or less normally distributed above and below the target value (i.e., the sales meet the target on average), then the overall objective is achieved. This should certainly be the case with an effective credit trading system, for example. Note however that this is less so if a sloped utility curve is used as the certainty of meeting the target is reduced in this case (see separate discussion of utility curves).

With a limit value, however, the majority of sales are completely unaffected (because they are below the limit value), while those above are severely affected by heavy penalties or direct exclusion from the market. On the assumption of a static market it would still be relatively straightforward to calculate what proportion of the highest emitters would need to be excluded in order to meet the target on average, and to set the limit accordingly. However, there would clearly be important second round effects in this case that would change the structure of
the market, because those who would otherwise buy cars above the limit value would clearly need to modify their behaviour, normally by buying a different model of car that was compliant with the limit. It appears, however, difficult or impossible to predict or model exactly how this change (or rather, these many individual changes) of behaviour would occur, so the relationship between the limit and the eventual average result is far more uncertain. This means that the target might need to be subject to fairly regular adjustment, or that the overall average target might not be met.

4.1.2 Hard and Soft Versions of Limits and Targets

In most of those circumstances, a limit value is regarded as a completely hard limit that may not be exceeded. In the case of existing regulated pollutants, exceedance of the limit value is prevented by excluding from the market any models that exceed the limit. However, also an alternative variant has been proposed that could be viewed as a ‘soft’ limit value, ie with sanctions not based on exclusion from the market, but rather on fines that should be sufficiently large to deter widespread violations – ie in principle a percentage greater than the relevant cost of compliance, although this is not yet specified.

In addition, we might regard target values as having ‘hard’ and ‘soft’ variants, although the distinction is different in this case. Here we define ‘hard’ targets as those underpinned by a system of fines or feebates, and ‘soft’ targets as those that establish the baseline for the buying and selling of credits. Issues of penalties and enforcement are further discussed below, as these clearly bear heavily on the question of whether and to what extent targets are likely to be met. Note that other forms of sanction are also possible, depending on what entity is the subject of a target. For example, if each Member State had a target for a given level of sales-weighted average CO\textsubscript{2} emissions enshrined in Community law, then a country not in compliance with its target could be sanctioned through the normal mechanisms of compliance with Community law.

A first description and indication of the pros and cons of all these four main options would then be as follows.

4.1.3 Hard Limit Values

**Hard limit values** set an upper limit (single value or sloped curve) above which models are excluded. Thus there is a hard and fully effective sanction with no exceptions (or at least, very limited and designated ones, eg for limited and specialist markets). The sanction is highly punitive, but by definition prevents violation of the limit value. To set a sufficiently low limit value to have a significant impact on the fleet average would however be likely to exclude many models of car from the market; this is likely to distort the market and be politically unacceptable.

Pros:
- easy to understand and operate; and
- gives certainty to manufacturers in design of future models.
Cons:
- inflexible;
- can have drastic effects on manufacturers and market;
- highly sensitive to the exact nature of the utility function if one is used;
- weak link to attainment of the overall target, as market effects are unpredictable. There are two important components to this:
  - In the case of a utility function in particular, changes in the distribution of sales of compliant models over utility values influence the overall sales average are difficult to predict, as explained above.
  - In addition, the final sales average also depends on how closely vehicles that meet the standard are below the limit line. The dynamics of the response to such a hard limit are very important but difficult to predict. Clearly models above the line either need to be improved by applying CO$_2$-reducting measures or taken off the market. However models below the line have the option to remain as they are, and if the target becomes progressively more stringent over time there could be a ‘bunching’ of models just below the target. Worse still, compliant models could over time evolve towards the line through trends towards more power, comfort, etc. The latter possibility is counterproductive and this too needs to be taken into account in the assessment. And
- Given that the sales distribution under a limit value is uncertain, one needs to impose some level of overshoot in the setting of the limit (function) to be sure that the overall target is met, but it is extremely problematic to estimate how large this should be.

Note that, even if a hard limit were considered too crude as a principal measure to control the market, it might also be considered as a supplementary measure alongside another instrument in order to exclude the highest emitters from the market. This might in principle contribute as part of a ‘market transformation’ approach.

4.1.4 Soft Limit Values

Soft limit values set an upper limit (single value or sloped curve) above which models are heavily penalised. Note that this does not necessarily offer a clear distinction from a target (see below) in that the severity of the sanction is likely to be a matter of degree rather than a qualitative distinction (eg a more severe charge or fine). For this to operate any differently from a target and to retain the character of a limit value, therefore, it is critical that the sanctions should be severe enough to deter all but a few infractions, even for sellers of premium cars (this would be in distinction from fines levied under the US CAFE system, where the fines are reported to be regarded as ‘part of the cost of doing business’ to some luxury car importers, and are not effective in forcing some manufacturers to meet the desired average – see Technical Note 1 for a description of the CAFE system). Thus the fines would need to exceed by some margin the cost of the necessary abatement to reach the limit, such that it made poor economic sense to pay the fine except in
exceptional circumstances. The latter would include circumstances such as cases where, for technical reasons, it was exceptionally expensive to make the necessary measures on a particular car model; where the model or variant was sold only in small numbers; where it made sense to suffer fines only on an interim basis while a model update or new model range was under development; or in the case of unpredicted market trends. This is a critical point, as the limit value would be set at a level such that it would eliminate or virtually eliminate models above the limit, and that this should have been set such that it would have sufficient impact to deliver overall compliance with the target. Hence any significant degree of non-compliance would result in non-attainment of the target outcome; but as against this, manufacturers do get an element of choice in when and whether to meet the target.

**Pros:**
- easy to understand;
- gives strong incentive to manufacturers in design of future models (provided that penalties are adequate as discussed above); and
- less inflexible than hard limits.

**Cons:**
- still fairly inflexible;
- difficult to establish the ‘right’ level of fines to be effective but not unnecessarily punitive;
- levying of fines is generally problematic – see further discussion below;
- fairly sensitive to the nature of the utility function if one is used; and
- even weaker link to attainment of the overall target than a hard limit, as market responses of manufacturers are unpredictable.

### 4.1.5 Target Values

**Target values** set an average value (single value or sloped curve), probably for a manufacturer’s fleet, but potentially also in relation to individual car sales. We can distinguish a **hard target** as one accompanied by a credit trading system, in that provided that the system is effective, then the target is assured of being met overall.

**Pros:**
- more flexible and more likely to be ‘fair’ than a limit value system; and
- stronger link to attainment of overall target if trading is effective.

**Cons:**
- system harder to understand, especially for general public;
- inherently more complex to operate than limit values;
- needs averaging mechanism;
- needs regular monitoring and means of adjustment;
- uncertainties over effective operation of a trading system, and whether carmakers would be willing to participate; and
arguably more difficult for carmakers to plan ahead given uncertainties and possible fluctuation in carbon price; this is the other side of the coin for the freedom provided to manufacturers to implement their own cost or otherwise optimal distribution of reduction measures.

A soft target would be one enforced by fines, feebates or other similar sanctions. In this case the system of incentives and penalties might be more predictable and hence easier to respond to, but there is less assurance in this case that the target will be met, even if the system is operated effectively.

Pros:
- more flexible and more likely to be ‘fair’ than a limit value system; and
- the system of incentives and penalties should be more predictable and hence easier for carmakers to respond to effectively

Cons:
- weak link to attainment of overall target;
- system hard to understand, especially for general public;
- inherently more complex to operate than limit values;
- major uncertainties over correct level of incentives or fines and the effects of these on market behaviour;
- resistance in some quarters to application of fiscal measures in this way;
- resistance of carmakers to the concept of transfer of funds; and
- needs regular monitoring and means of adjustment.

4.2 Single Targets, Sloped Line Targets and Others

4.2.1 Sloped Line Targets

A sloped-line target is one whereby the target for models of car can be varied according to some measure of a vehicle’s ‘utility’. This is desirable in that it allows some flexibility to give a larger allowance of CO$_2$ emissions to vehicles that offer greater utility than others – most obviously through a capacity to carry more passengers or goods, for example. This could reflect the fact that, other things being equal, a ‘bigger’ vehicle will necessarily emit more CO$_2$ than a smaller one.

See below, however, on the technical difficulties in choosing a utility function that is fair and realistic, and for a summary of the possible options. (A more detailed discussion of utility functions can be found in Technical Note 4.)

4.2.2 Single Targets

A single target is (in most instances) one that discards the notion of a utility function and imposes a single limit or target value. At the level of the individual car, this greatly reduces the flexibility of the system, such that imposing a single CO$_2$ limit value for all cars, as is done for regulated pollutants, for example, would cause very severe disruption of the market, and is highly unlikely to prove
acceptable. However, it might prove more possible if other elements of flexibility were introduced – such as fines or feebates, or trading in credits, around a ‘soft’ limit or target value.

If a single value is applied at manufacturer or another kind of group level, then other elements of flexibility are also available. The first of these is that, provided that the value is a target rather than a limit, a collective target automatically allows pooling of performance across an economic entity’s total sales. That is, selling cars above target remains permissible without sanctions coming into question, as long as there are corresponding levels of sales of cars below the target. This applies even where fines, feebates, or trading in credits are also in operation, and so even if the pooled average result is still not fully in compliance with the target, pooling should greatly increase the extent to which there is recourse to sanctions relative to the case where the target is applied at the vehicle level.

4.2.3 Methods of Differentiating Targets

Single and sloped-line targets appear to be the only fair and viable options for regulating cars through limits or targets set at the level of the individual car mode and variant. In such cases, moreover, the same rule can (and arguably must) be applied to all cars on the market to ensure fair competition and a technology-neutral approach.

For group average targets, however, a second possibility is that the target might vary from company to company (or country to country, etc) to reflect their differing positions in the market and distinctive possibilities to reduce their emissions. The options available to do this in a way that was perceived to be ‘fair and equal’ are considered further below.

One special case is where the latter objective (ie differentiated company targets) is achieved by applying a utility function to the sales-weighted results of an economic operator in order to derive a single and differentiated target value for that operator, thereby allowing both normalisation against a sloped line and pooling simultaneously, potentially alongside further flexibility mechanisms such as fines, feebates or trading.

4.3 Development of Targets over Time

This assessment is strongly focussed on the collective target of 130g/km for 2012. This can be translated into one of a number of different configurations of targets at the level of cars, companies, groups, or Member States, as outlined above. However, it must also be borne in mind that a further target beyond 2012 (perhaps in 2015 or 2020) appears likely to be needed. Although no such target has yet been agreed, it is worthwhile to consider the possibility of a further such target, and to consider how far that would be compatible with the target proposed for 2012. For example, some target designs are much more suitable for the incorporation of new market entrants than others; and while this might not be judged to be a major issue between now and 2012, it almost certainly will be by 2020, for example.
Some consideration must also be given to defining the trajectory towards the designated target. That is, it may be judged useful to define a series of intermediate values to reflect the expected progress in the years between the entry into force of the expected legislation and the current target year of 2012. At the very least this would provide a useful benchmark for judging progress in the interim period; whereas if any incentives or sanctions are to be put in place in the intervening period (which seems desirable to encourage necessary progress) then annual targets of some sort arguably become essential. Particularly in the case of a credit trading system, for example, intermediate targets appear essential, as to impose the end-point target at a time significantly prior to 2012 would clearly result in a system in which far too few credits were available to allow effective trading.

However, the precise design of the trajectory of the target would depend on the type of target or limit value adopted. For example, for any ‘top down’ collective target based on a single target value for all entities, a simple percentage reduction target, reducing in a linear way towards the 2012 target, might be appropriate. However, if differentiated targets (eg for manufacturers or Member States) are to be considered, then a simple percentage reduction from the current values might be considered inequitable as it would give no credit for early progress before that date. One possibility is to select an earlier baseline to give credit for progress made since the industry self-commitments were first agreed; another would be to apply a ‘contraction and convergence’ approach as outlined below.

For ‘bottom up’ targets applied at the level of car models and variants, a linear percentage reduction appears likely to be the best option. In the case of limit values or targets using a sloped line and utility function, this has the effect of gradually flattening the slope of the line over time, such that ‘large’ or high-utility cars are required on average to make somewhat larger CO₂ reductions in absolute terms than ‘smaller’ ones. This seems to be the appropriate outcome.

A further consideration for the development of any target value is that the trajectory towards an ambitious longer term target may not be expected to be linear. Costs per g/km will increase supra-linearly and incremental reductions due to new technologies may be expected to diminish over time. However, it may be difficult to establish a sound scientific basis for any particular non-linear trajectory, and it may be possible to address non-linearity more robustly by addressing the flexibilities in the system to compensate for a linear target development than to generate an alternative trajectory.

### 4.4 Other Options on Targets

One idea recently suggested would be to set separate targets for new models as opposed to or within the target for fleet averages. The advantage of such an approach would be that it would reflect the greater technical possibilities available when designing and building a new model ‘from scratch’ and the more limited options during a model’s commercial lifetime, and would give a clearer signal on expectations for new models. This would also have some parallels to the Japanese
‘top runner’ system (see Technical note 1 for a discussion of this system), and also has some precedent in the legislation controlling regulated pollutants, whereby models newly type-approved are typically required to conform in advance of new cars of pre-existing models.

A disadvantage of this approach is that it would be more complex, eg the levels of achievement for new models would require separate negotiation and administration. The length of time a new model remained ‘new’ would also need to be established for the purposes of the legislation. In this it would also be essential to ensure that such a system were designed in such a way that it positively encouraged the bringing of new models to market, and did not build in perverse incentives to retain old models for longer.

This is a relatively new idea that has not been developed in detail, and is arguably a useful suboption that could be added to certain of the mainstream options rather than a proposal for a system in its own right. Certainly such an approach could not stand alone as some control over the rest of the new car sales would remain essential. This idea is not therefore reflected in the ‘long list’ of options.

4.5 Deriving Top-Down Targets for Group Averages

4.5.1 Undifferentiated – Equal Target for each Company

The simplest option for setting targets for each manufacturer or group would be an undifferentiated target per company – ie every trading entity has to meet 130g/km in 2012, subject to some flexibility mechanisms.

- *Pros* certainty of meeting target if full compliance is enforced (only a uniform target for all companies, or all cars, does this); and
- *Cons* probably does not meet the Commission’s criteria in terms of fairness, etc, or Germany's call for differentiated burdens, as this would clearly be much harder for some companies to achieve than others.

As companies would have limited technological flexibility in the short term, those substantially above the target would struggle to meet a ‘hard’ target for each manufacturer – ie that each one’s sales-weighted average should actually conform to the target. Such a measure would therefore have to be accompanied by significant flexibility mechanisms eg fines, feebates or trading. However, even if this allowed all companies to meet their ‘soft’ target, a very large tidal flow of money from one category of countries or manufacturers to another is still likely to be politically unacceptable, and needs to be carefully assessed.

4.5.2 Targets Differentiated by Company

Company-specific targets might be needed for burden-sharing purposes, as it is a requirement that any scheme should respect the different positions of manufacturers trading in different parts of the overall car market, while not discriminating between manufacturers in similar circumstances. Nonetheless company-specific targets run the risk of appearing discriminatory and could
therefore be open to endless argument and possibly a legal challenge. At the very least it seems that they could not be arrived at by the usual ‘smoke-filled room’ method, and an obviously fair or ‘objective’ method would probably be needed. It is currently unsure whether even ‘contraction and convergence’ (described below) could legally be used as a top-down method; and even a bottom-up target on the basis of utility function, for example, invites endless arguments about what is the right utility function to use. The latter also brings great uncertainty over meeting the target, without constant adjustment of the utility function parameters.

The only other obvious basis on which to proceed would be to apply a uniform percentage reduction to each company or group relative to an agreed baseline. If the agreed baseline were based on recent sales-weighted results this would clearly be inequitable in that it would penalise those who have already made progress and give an easier target to those who had done least. This could however be overcome to an extent by choosing an earlier base year (say, from the beginning of the self-commitment periods) or an average of performance over several years. In other respects this solution would be straightforward and would constitute a clear burden sharing, but it is less easy to be sure that it would constitute fair or equal treatment of the companies in legal terms.

4.5.3 Contraction and Convergence

The contraction and convergence principle is currently applied under global climate change commitments - ie the principle that everybody needs to reduce their absolute emissions (contraction) and that these reductions also need to be calibrated such that everybody’s emissions converge on a common per capita target. For car manufacturers, this might be translated as illustrated in the Figure below.
Other sorts of mathematical relationships might be possible, but in this case, all companies are simply required to converge towards a tougher target beyond 2012 - perhaps for 2020 (as shown for purely illustrative purposes in this example). This has the advantage of potentially linking the instrument to a longer term target such as that indicated in the Communication, and a clear benefit over the 'percent reduction' approach is that those who are doing well have to do less than those who are doing badly in terms of average emissions, irrespective of historical performance. Where a company emits more than average amounts of CO₂ that is the result of selling vehicles that are either less efficient or larger than average. In both cases the costs of abatement per g/km are likely to be lower for these companies than for companies with a lower average emission level.

It should be made clear that the contraction and convergence approach does not set a formal future target (eg for 2020), but that the future value is provisional and defined solely for the purpose of defining the mechanism.

In this case, the differentiated targets for 2012 are determined by the point which each trajectory reaches for that year. Obviously this gives major issues about achievement of the overall 2012 target, but the shape of the line and the long term target could be adjusted to deal with this, assuming that sales shares between manufacturers were unaffected, and this option is arguably no worse than some of the others that present a similar problem.

It does nonetheless need further thought whether this approach can be adjusted to meet the 2012 target – eg can the longer term target be manipulated to give a good expectation that we will meet the 2012 target as well? This would be difficult as
any 2020 target will be subject to huge political debate in its own right (as the 2012 target has been), and to set one in this way could reasonably be argued to be a serious case of ‘the tail wagging the dog’. In this case, the 2020 target value, for the purposes of meeting the 2012 threshold, would have to be regarded as being purely an indicative value without prejudice to the establishment of a further legal commitment at a later date.

The use of targets differentiated by company can clearly help to overcome the potential difficulties of a single target for all companies, by providing a ‘fair’ degree of differentiation or at least by providing a transition period and trajectory towards equal targets. On the other hand it does not really avoid the issue of whether a uniform target is ultimately fair in the first place. In 2020, as now, companies will have different market positions (in terms of sales of small or large and utilitarian or luxurious/sporty cars) and consequently different sales average CO₂ emissions. Key questions, though, are whether the proposed measure can literally seek to legislate for these differences, and if so, whether it is legitimate to seek to confer grandfather rights to a particular CO₂ profile on each company, or whether it is possible to predict how the market and the positions of the manufacturers will evolve in the future.

4.5.4 Targets Differentiated by Member State (see also above re obligated entities)

In principle this might be done (eg on a ‘contraction and convergence’ basis similar to what we might envisage for manufacturers).

- **Pros:** this leaves much in the hands of the MSs, by analogy with other legislation (including the ETS), so the MSs themselves might be more comfortable with this approach; and
- **Cons:** this probably also implies the MSs being the obligated entities (again as they are in the ETS). While there may be good arguments for this, eg that they have control over taxes and incentives, they might on the other hand be keen to place the responsibility for complying with targets with the manufacturers. Also, leaving wide scope for national implementation might easily lead to internal market problems. For example, if Sweden gets a higher national average target than Italy, in that case a Ford Mondeo will get different penalties/bonuses etc. in Sweden than in Italy, and this is likely to distort the price. This appears to be counter to the Commission's objectives in this area, eg its aversion to registration taxes. With an integrated market and a mobile product this could lead to serious distortions and potential distortions to the market, and hence great uncertainties in meeting the collective target. It is not currently clear if there is any way around this problem.

It is however difficult to predict how this would work out in practice, and how far fines or incentives would be passed through to consumers through the retail price. Already, for example, there are known to be substantial differences in the registration and circulation taxes on new vehicles from one country to another, and manufacturers adjust their pre-tax prices both to compensate for these
variations and to charge what they believe the market will bear in each country. As against this, there appears to have been some convergence of market prices between the Member States in recent years, and so any system which ran the risk of exacerbating disparities between countries could well be seen as a retrograde step.

Utility-based limit functions can be used to set differentiated targets per manufacturer at the MS level – and arguably this would be essential. An assessment by TNO for VROM shows that per manufacturer sales distributions over vehicle segments differ dramatically per country. A uniform target (= zero slope utility function) would therefore not work for setting targets at MS level.

5 Classes or Normalisation Parameters

Possible parameters on which to base limit values fall into two basic types – continuous (eg a measurable attribute such as mass) or discontinuous (eg vehicle class). The latter type can be used only to establish a set of vehicle classes for which separate CO₂ limit values or ‘bubbles’ can be set – ie they classify the car fleet. Continuous variables can be used in the same way – by banding – but can also be used to set a CO₂ ratio (ie they normalise CO₂ emissions), which may be better. In particular, banding would be in danger of causing serious boundary effects, which could distort the market.

In short a utility function is not essential for the planned legislation, particularly if other forms of flexibility (eg trading or differentiated group targets) are built into the system, but utility functions do represent one potentially-important means of reflecting the legitimate expectation that somewhat more CO₂ will be emitted by ‘large’ cars than ‘small’ ones if other things remain equal.

5.1 Classes and Market Segments

We have concluded that the car market segments commonly used by the industry to classify cars into groups such as ‘SUVs’, ‘small family cars’ etc are of no use for our purposes, as they are not based on hard and fast technical criteria. To take a legal perspective here, any definition of classes or utility function for the purposes of regulating CO₂ emissions would have to be based on attributes of the vehicle that can be quantified and independently verified (eg by the type approval authority), and market segments do not meet these criteria.

No other systems of qualitative classes have been proposed in this context, as far as the research team is aware.

Other bin-based or stepped-line approaches have been used elsewhere, but have obvious drawbacks:

- The best-understood options are based on parameters that are poor choices for normalisation (eg engine capacity, weight);
• Better normalisation parameters would lump together very different types of car into each bin, and most would see this as counterintuitive; and
• Steps or bins greatly increase the likelihood of perverse incentives near bin boundaries.

Thinking in the US, and reportedly in the auto industry, also seems to be moving towards favouring a continuous function.

5.2 Normalisation and Utility Functions

See separate technical Note 4 choice of utility parameters. Regarding normalisation parameters, car footprint appears to be emerging as an acceptable metric for cars at least both in the EU and in the US. The main drawback of this approach is that we do not have the data for footprint in Europe (ie neither Polk nor AAA databases have it, and it is not currently reported as part of the type approval process). In absence of footprint data in the Polk (or other) databases, we propose using pan area as a proxy to illustrate the general principle and the impacts of adopting this parameter. In terms of cost modelling we expect the difference to be negligible in any case. On the side we might then make a small assessment of how footprints works out differently from pan area for various types of cars and qualitatively assess the possible benefits and/or perverse effects. Additionally we might propose that the system use pan area for the time being, with footprint substituted for the next commitment period. If necessary the reporting sheet of the type approval could be amended to include wheel base and track width for a second phase, for example.

NGOs tend to favour the idea that the 'curve' should be flattened over time in order to gradually increase the incentive for downsizing and squeeze out the 'utility' element, as they tend not to be comfortable with this concept. This depends in part on what instrument the target is associated with, of course; but in principle it is important to consider whether or to what extent we would want to do this. That is, would we want to move to a point where there was no credit for a 'utility' car, or are we comfortable to assume that some people need a bigger car than others and that this should be factored in to the regulatory system? This is partly a moral question, of course, but there are also practical questions about how the market would be affected by a limit without a utility function.

In the end it is up to the legislative process to weigh the factual pros and cons (economy, practicality, etc) against moral issues and political support from various stakeholder groups. In this report we may point out the critical issues but would prefer not to use moral or political acceptability as criteria if we cannot base our judgements on rational or quantifiable arguments or documented input on the views of various stakeholders.
6 Monitoring and Enforcement

6.1 The Passenger Car CO₂ Monitoring Mechanism

The current Monitoring Mechanism (MM) (if seen as the full mechanism from data collection to publication of the Commission communication and including the step of ‘agreeing’ the joint reports with the automotive manufacturer associations) appears not to be working very effectively (ie probably not efficiently enough to serve the needs of a more dynamic system such as one that involved trading) – 2005 results have yet to be published even though Polk already has 2006 data. A significant source of the problem is the need for agreement (including agreeing where to disagree) on the joint reports by the Commission and the associations, and reconciling how to present differences in data – collected from MS under 1753/2000 and as supplied by the associations.

Although redesigning the MM is not part of this contract, it will be valuable to consider data availability and links to the data needs for different systems. Note that:

- Systems that operate at the level of car models and variants are inherently less dependent upon monitoring than those using some form of group average. However, in any system other than in which achievement of the target is virtually guaranteed (ie for most of the options available), monitoring is likely to continue to be important in order to verify progress towards the agreed goal.
- Whatever target/instrument is decided upon (aside perhaps from a single limit value), faster reporting will clearly be needed if anything is to be achieved over a 4-5 year commitment period. A key issue will be whether a joint agreement on data and joint reports will still be needed in a post CO₂ self-commitment world.
- Some possible configurations – eg those involving trading – would need much more timely reporting and a much shorter reporting cycle - perhaps monthly.

Additional points to note stem from the Ökopol report (2006) on why monitoring has proven difficult so far. This includes the following:

- confusion of sales data vs registration data;
- attribution of makes to manufacturers and/or associations;
- confusion about vocabulary of templates;
- confusion about monitoring approach in MS; and
- inclusion of incomplete or implausible data.

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2 In the early years of the CO₂ self commitments, the data was supplied by the automotive manufacturer associations on the basis of information purchased from two data suppliers. When the 1753/2000 data started to come both MS and association supplied data were used and presented side by side.

3 Service contract on the implementation and amendment of Decision 1753/200/EC, contract nr. 0704020/2004/395419/MAR/C1, S. Schilling et al., Ökopol, December 2006
Information from DG-ENV suggests that in principle MM data are of sufficient quality and available and publishable within 5 months after the end of the reporting year. The main delay is caused by the organisation of the monitoring in which agreement needs to be reached with the industry associations.

It appears that most problems identified so far stem from the fact that many countries have incomplete or poorly functioning registration systems. The monitoring mechanism of the voluntary agreement provides templates to the MS but does not require them to reorganise their registration system. This raises the question of whether monitoring of the new policy should be based on existing information tools or whether the importance of the CO\textsubscript{2} reduction objective can justify setting up a new system. This also relates to the issue of MS being the obligated entity or the party levying penalties on manufacturers or importers. If MS are the obligated entity the national registration at least needs to be monitored/verified by the Commission in order to provide sound proof for (non-)compliance. If manufacturers or importers are the obligated entity they will certainly question the completeness of national registration data before accepting fines.

Whether manufacturers meet the targets could still be monitored independently on a yearly basis. Manufacturers themselves would however need a much faster internal monitoring system to know when they will have to buy or sell credits, but this could be left to the manufacturers to solve. However they would arguably also need very good market intelligence to know how many credits were available in the market as a whole, to ensure that necessary credits would be available and not too expensive. The first step to achieve this is to have a proper sales or registration database. Manufacturers should know which vehicles are shipped to which country but probably do not oversee the actual sales or registration. The latter could be organised through the dealer network, but probably becomes increasingly difficult now the market is opening up (independent dealers, parallel imports etc).

For these reasons, there may be a need to reinforce monitoring and reporting capabilities in some at least of the Member States. For example it might be considered whether the MSs might be required to link CO\textsubscript{2} performance figures directly to their registrations data. This should presumably allow results to be produced virtually in real time. It does not appear difficult, at least in principle, to set up a good system in which either the identification number of a registered vehicle is coupled to a European type approval database (this would require centrally supplied manufacturer data linking vehicle identification number to type approved model variant or directly to CO\textsubscript{2}) or in which the required CO\textsubscript{2} data (plus utility function value) is included in the information on the identification plate of each vehicle and on the registration document. With present-day IT systems it should be possible to have the system be up-to-date on a yearly basis at minimum.
6.2 Compliance – Penalties, Incentives and Trading

In principle penalties or trading can be used to enforce or reinforce the action of the agreed system, and appear to be the main alternative options available.

6.2.1 Penalties

**Penalties**, if seen in a broad sense, could in principle take the form of *excluding non-compliant models from the market* (which is the current sanction for not meeting type approval requirements), but this would in most cases probably be considered too draconian. Also, it could probably only be attached to a limit value or limit curve – such that engineers would know in advance what was allowed and what not.

Any exclusions attached to a target value or trading system that might be subject to change over time (e.g. through repeated adjustments to keep the whole system on target) would probably be disallowed because it denied the principle of legal certainty (in simple terms, the principle that an economic operator should be able to know that, if something is legal this week it will not suddenly become illegal next week) – and also imposed excessive costs. Furthermore, exclusions attached to a collective hard target value or trading system seem to be only a very theoretical possibility. If the standard or target applies to a sales average there is no rational way of deciding whether the non-compliance is caused by some high emitting SUVs or sports cars in the product portfolio or by lack of progress in CO₂ reduction in the mid-size or small vehicle segments – and hence of determining which vehicles to exclude. This problem would be even worse if the system were administered on the basis of national targets.

The only alternative would be the ‘nuclear option’ version of excluding *all* a manufacturer’s models from the market in the event of non-compliance, but this could only be imagined as a last resort. There is also no parallel sanction that appears to be available if Member States were the obligated entities. A less drastic possibility for manufacturers in non-compliance might be to impose upon them a ‘standstill target’ whereby they were only allowed to sell cars up to an agreed bubble limit of total car.g/km of new sales. They would then have to choose whether to sell fewer cars with high CO₂, or more and cleaner ones.

6.2.2 Fines and Feebates

More likely is a system of **fines or feebates** associated with a softer target (but see also the discussion above over heavy fines in association with ‘soft limit values’).

- **Pros**: Known level of sanction; can be administered at MS level, for example. Seen to be ‘fair’; and
- **Cons**: Difficulty of setting the fine at the right level; too low and it becomes a ‘cost of doing business’, but really punitive fines might be nearly as bad as excluding from the market. Logically, fines should relate to the marginal cost on the cost curve, and be slightly above. Level of impact of fines is also unknown – hence difficulty in meeting the target.
The approach of ‘fines related to marginal costs’ seems sensible but may prove difficult to operationalise. In the case of a target set per manufacturer and a fully cost-optimised situation the marginal costs are equal for all segments for a given manufacturer. For such systems including trading the marginal costs are even equal for all manufacturers. In the case of a vehicle based limit, furthermore, the marginal costs depend on the slope of the utility function and on the value of the utility parameter.

A further difficulty for us is that fines and feebeates necessarily change market conditions - indeed, that is part of the idea. However this is a very sensitive issue insofar as it directly affects the competitive position of the different manufacturers.

It is also difficult or impossible for us to model these effects realistically, and hence to estimate the scale of impact. What could be modelled for some cases is:

a) the reduction per segment and average costs per vehicle under the assumption of overall cost optimisation per manufacturer for reaching the average target (or even a value above that); and

b) the average costs per vehicle of meeting the target per segment as set by the utility curve.

The cost difference between (a) and (b) then determines the amount of €/g/km fines that a manufacturer could recover by filling in the reductions differently or by overall non-compliance. At the least, this might provide information on the lower bound level of charges required.

In principle fines can also be coupled to the ETS system, i.e. manufactures having to buy CO₂-emission credits under ETS in case of non compliance with the g/km target. The amount of non-compliance can be translated into tonnes of CO₂ by multiplying the average g/km deficit with the overall sales number and a default lifetime vehicle mileage (e.g. 150,000 or 200,000 km). The major disadvantage of this approach is that the price of CO₂-credits under ETS will for a long time be lower than the cost of compliance with a 130 g/km CO₂-target through the application of CO₂-reduction measures. Buying ETS credits thus becomes a cheap buy-out option. The desired CO₂ reductions, however, will still be realised albeit in different sectors, but lessening the dependence on imported oil is not served by this approach.

6.2.3 Recycling the Revenues from Fines

Fines also generate revenues and something must be done with these. Who gets the revenue is also politically sensitive. Table 1 below presents some options for how to make use of revenues.
### Table 1 Options for making use of revenues from fines

<table>
<thead>
<tr>
<th>Target for Revenue</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>None specific – fines feed into general revenue</td>
<td>Gives MSs lots of flexibility</td>
<td>Looks suspiciously like a tax! Takes money out of the motor industry</td>
</tr>
<tr>
<td>Any climate-related projects</td>
<td>An internal logic of sorts</td>
<td>Takes money out of the motor industry</td>
</tr>
<tr>
<td>Climate-related transport projects</td>
<td>Greater public acceptability</td>
<td>Still takes money out of the motor industry, though not the transport sector as a whole</td>
</tr>
<tr>
<td>Buy ETS credits</td>
<td>Buying CO₂ emissions elsewhere</td>
<td>Still takes money out of the motor industry</td>
</tr>
<tr>
<td>Investment in reducing CO₂ from passenger cars</td>
<td>Seems a natural countermeasure for not meeting CO₂ emission requirements</td>
<td>Difficult to decide who should do the research (need independent body to decide on promising research). How can additionality be ensured in research funding? Would only European manufacturers benefit?</td>
</tr>
<tr>
<td>Returned to carmakers pro rata to sales</td>
<td>Keeps money in the industry – a limited feebate model</td>
<td>Weakens signal from fines, and manufacturers with a broad portfolio could factor this in to their cost structures</td>
</tr>
<tr>
<td>Returned to carmakers pro rata to car.g/km ‘below the line’</td>
<td>Strong dynamic driver for improvements beyond just ‘staying below the line’ A full feebate system</td>
<td>Unacceptably large redistributive effect? Scale of rebate hard to predict</td>
</tr>
</tbody>
</table>

The possibility of making a feebate system revenue-neutral has also been suggested in order to avoid some of the objections to fines-as-tax by working with fixed penalties per g/km per car, filling a pot with these, and handing out this pot in proportion to the number of cars or number of car.g/km sold under the curve. This would give a certain fee, an uncertain rebate, no revenues, and no direct trade, and could be acceptable to some. It might be operated by MSs, though a balancing mechanism at Community level would be needed to rebalance the funds somehow or market distortions would result. Not only does this keep the value within the industry, but it also provides incentives to make improvements wherever it is cost-effective to do so, rather than just ‘staying below the line’.

Fines can be treated from two different points of view:

- Fines can be supposed not to be used, ie that they are necessary for a few exceptional cases when manufacturers do not meet the target. In that case the fine should preferably be prohibitively high (as per soft limit values); and
- Fines can also be considered as a structural part of reality and of doing business. In that case they should be high enough to discourage
manufacturers to some extent but not so high that they become a source of market distortion.

The issue of what to do with the revenues is only really important to the second case.

Some stakeholders strongly oppose revenues being recycled as they do not want to pay competitors. It can be argued that this will lead to consolidation in the sector - eg Porsche taking over Fiat in order to avoid subsidising a competitor. It is not certain that this will actually happen - potential benefits or costs of CO₂ regulation will be priced into carmakers’ share prices so ‘losers’ will presumably find it more difficult to buy ‘winners’.

6.2.4 Trading

A system of trading has several major advantages in principle:

- Provided there is no buy-out price, it ensures that the target is met;
- No need to set the price of a car g/km; the market does this automatically;
- Gives carmakers extra flexibility; and
- Meets target at lowest cost in theory.

However, some difficulties that might exist in the real world should perhaps be considered:

- Difficult to plan future product ranges when the cost of carbon is unknown, variable and potentially volatile; hence market may be myopic and prefer short term ‘fixes’ to more expensive technological breakthroughs.
- Many in UK at least are convinced that companies will not trade if they can possibly avoid it. Like Germany they hate the idea of giving money to competitors. It has also been suggested that the ‘good’ companies might find market advantage in withholding credits from competitors who need them, thereby forcing them into costly short-term adjustments or restricted access to the market.
- Trading necessarily requires more transactions outside of the individual companies or groups, although this could be mediated through a third party agency. In either case, better and more timely performance data are generally needed in the case of trading-based systems than the other options under consideration. Also there need to be credible fallback sanctions to support a trading system.

The problem of reluctance to trade at least can be dealt with by measures that force liquidity into the market, eg a ‘use it or lose it’ rule. Some sort of independent authority that gathered in the credits and auctioned them off might reduce some of the resistance that would arise from direct trading between manufacturers.
7 Links to Other Measures

7.1 Utility Functions and Labelling

It is not within the scope of this study to go into detail on other related measures, except to reflect the context of the Passenger Car CO₂ Programme. However, it was suggested at the kick-off meeting that compatibility with other measures (e.g., labelling or taxation) could be included in the selection criteria.

Utility functions are a useful basis for relative labelling. Labels in turn can serve as a basis for tax differentiation. Relative labelling makes sense as it compares efficiency of comparable vehicles. But the use of relative labelling as a basis for tax differentiation may lead to possibly perverse effects in the sense that big cars may receive subsidy while some small vehicles are made more expensive. The problem with labelling and taxation thus is not so much the utility parameter or the target level but whether the system has an absolute or relative basis. The Dutch relative labelling system, based on CO₂ emissions that are for a large part normalised to $\frac{1}{l \times w}$, made perfect sense as a tool to inform consumers that there are more and less efficient vehicles within the class of car they were looking for, but is being questioned now that it is used as a basis for CO₂ differentiation of taxes. In contrast in the UK, where an absolute label class is in operation, there have been no major difficulties in linking the label to the annual circulation tax bands.

Elsewhere in Europe FIA is in favour of an absolute system. On the other hand SNM (a leading environmental NGO in the Netherlands) is still in favour of relative labelling and tax differentiation. This is just to make clear that the use of a utility function does not automatically provide an acceptable basis for an (improved) labelling system, particularly not if it is also to link to taxes or charges.

8 Regulatory approaches in other parts of the world

In preparing the current report, the project team undertook some research into the various regulatory approaches to fuel efficiency and CO₂ emissions which exist in other parts of the world. The detail of this research is included in Technical Note 1, which covers the United States in general, California in particular, Japan, Korea, and China. The purpose of describing the cases in these countries was to provide some background context for the consideration of options for the future EU regulatory approach, rather than to suggest that the approaches of other countries be used as a basis for the EU approach.

Whilst some of the regulatory approaches outlined in Technical Note 1 are of interest to the current study, many are less interesting as they tend to differ from the approach that this study is proposing for the EU to follow. In particular, the majority (with the exception of Korea) are based largely on vehicle weight which is not considered by the research team to be the most appropriate approach for the EU to take.
The research team therefore conclude that most of the components of systems overseas are of limited applicability in Europe and do not suggest important system design components which were not already under consideration for this and earlier research in the EU.
Possible regulatory approaches to reducing CO₂ emissions from cars

Technical note 3: Consultants’ legal questions and answers

1 Introduction

This note includes a range of legal questions that the consultants team felt it was important to clarify in designing and assessing a possible legal instrument in the context of the project “Possible regulatory approaches to reducing CO₂ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

Having clarified the key questions, they then posed these questions to a number of legal experts, including Jane-Michelle Barton of DG Environment and Marc Pallemaerts of IEEP. The authors are grateful for these valuable contributions.

However, it is important to note that the answers to questions below are in some cases a composite of several views, and have been subject in some respects to interpretation by the project team for their own purposes. As such what follows should be regarded merely as a guide to some of the key legal issues, and should in no circumstances be regarded as constituting a formal legal position, either of those named above or of the project team.

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2 Questions and Answers

2.1 Can a company or similar entity be obligated under a Regulation, e.g., to meet a specified average emissions value for its car sales?

- Are there any limitations on this?
- What sanctions for non-compliance are available if so?

A: Regulations are binding on Member States. Regulations have effect within the territory of a Member State without requiring any legal act of the national legal systems (in this sense a regulation can be contrasted with a Directive which merely sets out the objective and leaves the detailed provisions to the Member States). Once a Regulation enters into force it is thus part of the national law. Regulations may confer rights or impose obligations on individuals and legal entities. Sanctions are usually provided by Member States in accordance with their legal system (see further comments below).

2.2 Can a Member State impose a target and accompanying fines (in case of non-compliance) on a legal entity (manufacturer or manufacturer group) based in another country?

- If so by what means?
- Is it possible or practicable to hold them in compliance anyway by threatening a ‘nuclear option’ (e.g., exclusion from the EU market) if not?
- Or if the CO₂ policy is implemented at MS-level, do the obligated entities have to be legal entities based in the MS?

A: The key question is not the identity of the regulated entity but rather the activity that is being regulated. The mere fact that an entity is based outside a Member State does not mean that the Member State cannot regulate the activities of that entity in its territory. For example, the Emissions Trading Directive regulates emissions from installations in Member States. These rules apply equally to all installations regardless of the nationality of the operator – therefore the UK applies the scheme to installations in the UK operated by French and US operators.

Thus a fine at point of sale seems viable, but almost certainly must be vehicle-based not average-based. There could otherwise be serious problems with invoking criminal law (which is specific to each Member State) on the basis of a Community level average. That is, if the group average is violated, where exactly was the crime committed? And which cars within the overall fleet were non-compliant? Further, if this action is to be imposed in a vehicle-based way but on the basis of a Community average, then it would be essential to have a full feebate system whereby the fines and rebates would balance out, as a fine only system could result in a manufacturer paying fines in certain countries even if it was in compliance overall. This would be difficult to achieve.

Although we refer to ‘fines’ in a generic sense, we need to be clear that what we have in mind here are administrative penalties rather than criminal sanctions. One option would be to assess compliance with the overall average and only look to individual MS to apply fines if the manufacturer is not in compliance at the European level (possibly with the possibility to offset overachievements in some MS).

A possible constraint could be WTO rules, but preliminary advice was that this is unlikely to be an issue as long as the system is fair and transparent, and not obviously discriminatory.
2.3 Can the EU (Commission?) impose a target and accompanying fines (in case of non-compliance) on a company based outside EU?

- How is this done in other sectors? The EU has the power to punish companies like Microsoft for monopolistic activities… Is this imposed on Microsoft US or on a Microsoft-owned trade company based in the EU?

A: As above, there is no reason why Community legislation could not impose obligations on companies based outside the EU.

As regards penalties, competition is an exceptional area where provisions for fines and periodic penalties at Community level are provided for in the Treaty. In other areas such as environmental provisions, it is normal practice for the Member States to adopt suitable penalties to enforce Community law. Regulations will typically contain provision requiring Member States to determine the necessary penalties applicable to breaches of the Regulation and requiring such penalties to be effective, proportionate and dissuasive. If they do not then the Commission can take action against the Member State under the Treaty. [Comment:] This in practice would take far too long, so some sort of Community-level penalties would probably be needed.

In rare cases Community legislation has provided for harmonised administrative penalties. For example the emissions trading Directive provides for harmonised penalty payments of 100 euros per tonne CO$_2$e to be applied to operators who fail to surrender sufficient allowances to cover their emissions. Further research has identified some areas where Community legislation provides for the Commission to fine manufacturers directly (e.g. in the field of marketing authorisations for medicinal products Regulation 726/2004). We are considering further whether this approach could also be used in this context.

The Commission has also recently proposed a Directive on the protection of the environment through criminal law which establishes a list of environmental offences which should be treated as criminal and seeks to set minimum levels of sanction for particularly serious offences. This in part reflects a judgment of the ECJ on 13 September 2005, which makes it clear that the Commission can stipulate fines and require the Member States to establish an effective system for levying the penalties. There are however limits to this power, and it may be a bit of a stretch to justify this, but theoretically possible. It is not intended to seek to prescribe criminal penalties in this legislation, however, so this is probably not fully relevant.

2.4 Can manufacturers (= brands) be considered as legal entities or do we need to apply obligations to the holding companies in order to have a legally valid basis?

A: What is important is that we are able to identify the legal person responsible for complying with the obligations under the scheme. We need to carry out some more research into how the car market operates to know how best to define the responsible entity. However previous legislation on end of life vehicles (Directive 200/53/EC) has imposed obligations on the producers which were defined as "the vehicle manufacturer or the professional importer of the vehicle". The Monitoring Decision (1753/2000/EC) for CO$_2$ from cars defines manufacturer as "the person or body responsible for the approval authority for all aspects of the type-approval process and for ensuring conformity of production..."

The latter may well prove to be the best precedent for an obligated entity -- although the logical sanction to associate with type approval would of course be exclusion from the market. Though not necessarily so – this definition could also be combined with administrative penalties.
2.5 Could an EU-level agency be set up, for example to act as a clearing house for fines or charges, or to administer a credit trading system (separate from ETS)?

A: It is possible to set up EU-level agencies to carry out particular functions such as monitoring although as mentioned above penalties is a matter normally left to Member States.

2.6 What if any is the Treaty or other basis for requiring that similar companies be treated equally in the EU?

- Is there anything like a legal definition of what constitutes ‘fair’ or ‘equal’ treatment?
- Similarly, are there any precedents to what might be interpreted as ‘some products or businesses [are] treated differently from others in a comparable situation?’ (this from IA Guidelines)?

A: The principle of non-discrimination is a general principle of Community law developed by the European Court of Justice. This principle requires that in exercising the discretion afforded by EC law, Member States and the Community institutions must neither treat like cases differently, nor treat dissimilar cases alike, unless that treatment is objectively justified. What this means in practice, of course, depends on the circumstances of the particular case.

The method chosen to determine the targets must also be proportionate to the end envisaged, which should not be problematic in this case, as ability to meet the agreed target is a clear criterion for our assessment.

One respondent was of the view that a mathematically-based target could probably be demonstrated to be non-discriminatory; but that any one of single target, percentage reduction or contraction and convergence might be considered to be ‘objective’, provided the necessary arguments were given in justification. He was of the opinion that a legal challenge was quite possible no matter which approach was chosen, but that this does not in itself prevent the system from operating, unless and until the challenge is upheld and the system declared invalid.

2.7 Are there any precedents or useful models for a scheme such as is being designed in this exercise?

Nobody we approached was aware of any particularly close precedents for the sort of system that is under development here within the EU. Most likely were suggested to be fish or milk quotas. Of these only the latter is obviously related to a market, and then perhaps not closely. Subsequent investigation confirmed that the value of this analogy was limited (see box).

### The example of milk quotas

Milk quotas have been established across the EU since the mid-1980s. Quotas are allocated at member state level, initially on the basis of the output of the Member States at that time. There have been periodic readjustments, based on semi-objective numerical criteria, but apparently with an element of political judgement as to ‘who gets what’.

Member States have a certain amount of discretion as to how they allocate quotas to individual farmers within their territory, although there are also guidelines as to how this should be done. In brief the Member States apply a range of systems; for example, in the UK, although the origin of the quotas is in grandfather rights, quotas are currently quite widely tradeable; in certain other Member States, ability to shift quota is much more restricted.
Thus there are important differences between milk and cars, as the milk quota system has a much stronger territorial element for very good reasons. That is, the international market for fresh milk, at least, is limited, and cows too are less widely traded internationally than vehicles.
Possible regulatory approaches to reducing CO\(_2\) emissions from cars

Technical note 4: Choice of parameter for sloped (utility based) limit functions

1 Introduction

This note reports the results of the consideration of utility parameters performed in the context of the project “Possible regulatory approaches to reducing CO\(_2\) emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

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2 Shortlist of utility parameters

In this and earlier analysis we have studied the possibility of utilising a wide variety of possible parameters as a basis for a utility function to be applied in a sloped line target with a future legal instrument. We applied a range of criteria to select a shortlist of options, including in particular the following:

- Good measure of ‘utility’ (ie encourage acceptable aspects of utility rather than controversial or less acceptable ones)
- Preference for a continuously-variable function
- Availability (actually available or easily obtainable) of required data
- Understandable – hence preference against a complex function or variable
- Perverse effects (ie incentive to ‘gaming’) should be minimised
- Adverse effects (eg reduced vehicle safety) should be avoided
- Should not exclude specific technical options
- Distributional impacts should not unfairly disadvantage any particular manufacturer group on account of characteristics of their model portfolio

Although complex functions and composite parameters cannot be excluded in principle on technical grounds, our preference was to avoid these for two main reasons:

- They tend to be difficult to understand
- They offer literally an infinite range of possibilities and there is no rational basis on which to make a final choice.

Reflecting this, the Steering Group agreed a provisional shortlist of options, proposed on the basis of our initial analysis, as follows:
- $U = m$, vehicle weight (empty) in kg
- $U = l \times w$, pan area = vehicle length x vehicle width in m$^2$
- *Alternative future option:* $U = wb \times tw$, footprint = wheel base x track width in m$^2$

In the figures below, scatter diagrams show the distribution of CO$_2$ emissions in relation to the two principal utility parameters currently available as listed above. A regression line also illustrates that either of these parameters is at first sight a suitable choice. That is, they show a reasonably close correlation to CO$_2$ emissions, but also have a significant $R^2$ value, i.e. there is a significant ‘bandwidth’ which suggests that there is room for improvement in relation to either parameter. Both also exhibit a significant number of ‘outlier’ models towards the top or right-hand side of the cloud.

Figure 1: Vehicle pan area $[l \times w]$
Criteria for selecting a suitable utility parameter

3.1 Important aspects to be considered

For assessing the appropriateness of a utility parameter U for the purpose of setting CO\textsubscript{2} limit functions the following aspects are of importance:

- Arguments relating to a static situation (ie ‘snapshot’)
  - There should be some level of correlation between U and CO\textsubscript{2}, because otherwise there would be no reason for differentiation of the limit according to the value of U.
  - The choice of the utility parameter (together with the slope a of the limit function (U + b) determines to a large extent the distributional effects, ie the distribution of compliance costs among manufacturers with different model ranges and market positions, so the distributional impact must be considered.
  - The utility parameter U, however, should not correlate too well with CO\textsubscript{2}.
    - A too-perfect fit indicates that there are few leaders and laggards within the same characteristic band, and hence that there might be rather little scope for applying an instrument, which would force the ‘laggards’ to improve their performance. Conversely a wider spread of CO\textsubscript{2} emissions at a given point against any particular measure of utility indicates that there is a spread of CO\textsubscript{2} intensity for the characteristic, and therefore significant potential for improvement simply by bringing the majority up to the standards of ‘best in class’.
• **Arguments relating to dynamics of reaching the target**
  - The utility parameter $U$ should also not correlate too well with CO$_2$ from the perspective of system dynamics.
    - If it does it is very likely a determinant of CO$_2$ and thus a means to reduce CO$_2$ emissions. Using a parameter that correlates too well thus discourages the application of effective CO$_2$ reduction measures. This is especially the case for vehicle mass (weight reduction reduces CO$_2$), engine capacity (engine downsizing reduces CO$_2$) and also for power (or more accurately power-to-weight ratio: lower power-to-weight improves efficiency).

• **The utility parameter should not lead to perverse incentives.**
  - If the value of $U$ for a given vehicle can be increased by simple means that do not affect CO$_2$ emissions significantly, then the utility parameter can be misused to increase the CO$_2$ limit for that vehicle (perverse effect). An example would be to fit larger bumpers on a car to increase pan area.
  - The utility parameter should not promote undesired trends over time that increase average CO$_2$ emissions of the fleet. This is an important consideration as choice is made now are likely to remain in effect for some time. The separate light trucks standard under the US CAFE system is a very powerful example of how perverse incentives can be built into the system and result in trends that are highly adverse from the fuel economy perspective.

Below the various general aspects listed above are summarised from earlier analysis for each of the chosen utility parameters.
Table 1 Summary of criteria analysis of short listed options

<table>
<thead>
<tr>
<th>Criterion</th>
<th>U=Weight-based</th>
<th>U=area-based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Pan area</strong></td>
<td><strong>Footprint</strong></td>
</tr>
<tr>
<td>Good measure of utility</td>
<td>Proxy for other measures of utility, eg vehicle size, special features</td>
<td>Reasonable proxy for vehicle size</td>
</tr>
<tr>
<td>Continuously variable</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Available</td>
<td>Yes – reported in MM</td>
<td>Yes – available but not reported</td>
</tr>
<tr>
<td>Understandable</td>
<td>Yes - very</td>
<td>Yes - fairly</td>
</tr>
<tr>
<td>Perverse effects/ gaming</td>
<td>Yes(^1)</td>
<td>Yes to an extent – eg deeper bumpers</td>
</tr>
<tr>
<td>Adverse effects</td>
<td>Yes – safety(^1)</td>
<td>No</td>
</tr>
<tr>
<td>Not excluding options</td>
<td>Could exclude weight-reduction measures to reduce CO(_2); tends to favour heavier options eg diesels, hybrids</td>
<td>No</td>
</tr>
<tr>
<td>Distributional impacts</td>
<td>Appears ‘fair’ and quite similar to pan area(^3)</td>
<td>Appears ‘fair’ and quite similar to weight(^4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not known – probably similar to pan area</td>
</tr>
</tbody>
</table>

Thus there is a balance of pros and cons between the two options. Weight is readily available and very easily understandable, and has been declared to be the favoured option of the car manufacturers.

As against this, there is some evidence to suggest that pan area (or at least footprint) are technically superior in other respects – ie possibly a better measure of utility, promoting better safety, and with lesser concerns about future perverse trends.

These points are discussed further below under the following headings:

- Possible implications of weight as parameter for choice of future technology packages
- Relevant developments in the US

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\(^1\) See discussion below of US analysis

\(^2\) But see analysis below of package options

\(^3\) The separate note on “Quantitative analysis of various options with updated model” (currently v2 August 30) shows that the distributional effects of mass and pan area as utility parameters is very similar, although for some manufacturers the sensitivity to the slope of the limit function strongly depends on the parameter chosen. For more details the reader is referred to the note

\(^4\) The separate note on “Quantitative analysis of various options with updated model” (currently v2 August 30) shows that the distributional effects of mass and pan area as utility parameters is very similar, although for some manufacturers the sensitivity to the slope of the limit function strongly depends on the parameter chosen. For more details the reader is referred to the note
3.2 Possible implications of weight as parameter for choice of future technology packages

3.2.1 Weight as a means of reducing CO₂ emissions

Vehicle weight is a strong determinant of a vehicle’s CO₂ emissions and as such weight reduction is an important technical option for reducing CO₂ emissions from passenger cars. Choosing weight as utility parameter thus reduces or even cancels the potential of weight reduction as an option for contributing towards meeting any utility-based limit or target. With weight as utility parameter, reducing the weight of a vehicle also leads to a lower CO₂ limit value for that vehicle, thus reducing the incentive to cut weight. The extent to which weight reduction brings a vehicle “closer to the sloped limit function” depends on the slope of the utility-based limit function, as illustrated in the two figures below. These are based on the relation between weight and CO₂ as used in [TNO 2006]:

\[ \Delta \text{CO}_2 / \text{CO}_2 = 0.65 \Delta M / M \]

Changing vehicle weight for a given engine and power train configuration will lead to a change in vehicle performance. The above formula is valid for the case in which the vehicle performance (acceleration, top speed, towing capability, etc.) is maintained through adjustment of the power-to-weight ratio when a vehicle “gains weight” or “looses weight”.

Using this formula a 10% weight reduction will yield a 6.5% reduction in CO₂ emissions. Starting point of the example is a vehicle with average weight and a CO₂ emission that is 5 g/km above the limit (which is 130 g/km for vehicles with average weight). In the case of the limit function #1 it is clear that weight reduction hardly brings the vehicle closer to the line. Only if the slope is significantly less steep, eg in the cases of limit function #2 and #3, does weight reduction help to comply with the utility-based target.

In contrast, pan area is generally not affected by weight reduction. Thus if l x w is used as utility parameter, the full CO₂ reduction caused by weight reduction contributes to comply with the utility-based target (as in right-hand figure).

Figure 3: Impact of mass increase/decrease (accompanied by measures to maintain vehicle performance) on a vehicle’s CO₂ emissions in relation to the CO₂ reduction target set by a utility-based limit function.
Reducing the effectiveness of weight reduction for complying with a utility-based limit function reduces the number of options available to the industry for meeting the target, and this could lead to higher compliance costs depending on whether or not other options with similar cost effectiveness are available alongside weight reduction. The impact of (fully) excluding weight reduction as a reduction option on the cost curve is shown in figure 4 below. The light grey dots are the 24,000 original packages with all possible combinations of individual CO\textsubscript{2} reduction options as discerned in [TNO 2006], while the black dots are all packages that do not contain weight reduction as one of the measures. Excluding weight reduction reduces the number of packages to 6,000 – a significant reduction in the number of options available for reaching a given CO\textsubscript{2} reduction within a given cost range. Nevertheless the overall spread of the cloud of possible combinations of options remains similar and would certainly not lead to a significant shift in the cost curve. Only for reductions above 70 g/km (which for most manufacturers is beyond what is necessary to achieve the 130 g/km target, see [TNO 2006]) one can observe that a small band with the cheapest options is excluded. As such it can be concluded that exclusion of weight reduction is not likely to significantly influence the costs of reaching the desired levels of CO\textsubscript{2} reduction in most cases, but does reduce the number of approaches available to manufacturers for reaching a certain level of CO\textsubscript{2} emission reduction in a way that not only serves CO\textsubscript{2} reduction and cost optimisation but also meets other targets set in vehicle design.

Figure 4: Impact of (fully) excluding weight reduction as a reduction option on the cost curve for a medium-size petrol vehicle

3.2.2 Reducing the potential for gaming by adjusting the utility curve slope

Conversely, any parameter that offers the possibility of artificially raising the utility parameter value of a given vehicle without genuinely increasing its utility offers the possibility of ‘gaming’ – ie gaining a higher CO\textsubscript{2} limit (and possibly reducing the required CO\textsubscript{2} reduction through technical means) by raising the parameter value. This is certainly possible for either of the parameters currently available on our shortlist – eg increasing the weight or overall vehicle length through redundant design changes – although possibly less so for footprint, according to the US analysis presented further on.

To assess the extent to which a utility-based limit function creates perverse incentives one needs to look at the effects of a utility value increase or decrease on a vehicle’s CO\textsubscript{2} emission and compare these effects with the effect of the same utility value variation on the limit value.
set by the utility-based limit function. If increasing a vehicle’s utility (eg adding weight to a vehicle in the case of a mass-based limit) moves the vehicle closer to the target line, the utility-based limit function can be said to create a perverse incentive for manufacturers to game the legislation by increasing the utility value of their vehicles.

In Annex A to Technical Note 8 of this report a detailed analysis is given of the impact of mass increase on a vehicle’s CO₂ emissions and of the consequences of that for the required CO₂ reduction efforts for meeting the target as function of the slope of the mass-based limit function. Some main conclusions are summarised below.

In the case of mass as utility parameter 3 types of gaming can be identified⁵:

1. Manufacturers may simply add weight to vehicle without modifying the powertrain. Weight can be added to the body-in white or the manufacturer may add removable items to the vehicle (eg additional seats) that add weight on the type approval test but are removed from the car by most users. This gaming option is often referred to as the proverbial ‘brick in the boot’. For this option the relation between CO₂ and mass is given by \( \Delta CO₂ / CO₂ = 0.35 \Delta M / M \) (see also Annex A to Note 8 of this report).

2. When a new vehicle becomes heavier due to eg increased size or added components and auxiliaries, manufacturers can choose to compensate the increased mass by an increase in engine power to maintain vehicle performance. This mechanism also applies to vehicle models getting heavier over time due to eg additional passive safety measures and increased comfort, and is what is meant by the term autonomous mass increase (AMI), implemented in the modelling as an annual weight increase of all models within a given vehicle class. For this option the relation between CO₂ and mass is on average given by \( \Delta CO₂ / CO₂ = 0.65 \Delta M / M \) (see Annex A to Note 8 of this report and Annex C of [TNO 2006]).

3. The last gaming option is a mechanism that corresponds to upward or downward market shifts, eg consumers buying on average larger and better performing cars or smaller and less performing cars. In case of an upward market shift this trend will also lead to an increase of the average mass of newly sold vehicles over time. In general CO₂ rises faster with mass for this option than for option 2 as larger and heavier cars in the market generally have better performance than smaller / lighter vehicles (see also Annex A to Note 8 of this report).

In Annex A to the technical note 8 it is demonstrated that a slope of 80% or less should be sufficient to substantially reduce the risk of gaming by means of options 2 and 3 in the case of weight as parameter. The likelihood and impacts of gaming option 1 were not considered in detail in this project.

A similar approach could be applied for other parameter choices. Possible drawbacks of the approach to set a maximum to the slope to minimize chances of gaming are that it limits the possibilities of tuning the slope to optimise total cost or distribution of costs. It also fails to give full ‘credit’ for greater utility in the case of vehicles with genuinely greater utility as well as those which have been manipulated.

An alternative approach (available for a group average but not at vehicle level) is to ‘freeze’ the average utility value for each manufacturing group at a value at a specific point in time,

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⁵ For a more detailed discussion see Annex A to the technical note 8 on “Definition of utility-based limit functions”
and calculate future CO₂ targets according to this value rather than the actual utility value in the period in question. This approach eliminates effects caused by any attempt to increase or reduce the average utility value in future years. However this approach could arguably not be maintained over a longer period of years, and implies a degree of grandfathering that might be considered undesirable.

### 3.3 Developments in the US

In March 2006 the National Highway Traffic Safety Administration (NHTSA) issued a ‘final rule’ reforming the structure of the US CAFE programme for light trucks and establishing higher fuel economy standards for model year (MY) 2008-2011 light trucks and minivans[^6[^6]](http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/2006FinalRule.pdf). The reform will increase the industry-wide fleet fuel economy average to an estimated 24.0 miles per gallon (mpg) in MY 2011 (from 21.6 mpg in MY 2006), and up to 28.4 mpg for some light trucks. The new standards set individual mpg targets for all models of passenger truck sold in the US, and from 2011, for the first time, the standards will also apply to the largest sport utility vehicles (SUVs), those weighing between 3,855 and 4,536 kg.

The reformed CAFE programme also restructures the fuel economy standards so that they are based on a continuous mathematical function rather than ‘bins’, and established a completely new utility parameter as the basis for targets, namely a vehicle’s ‘footprint’ (the vehicle’s wheelbase multiplied by its track width). A target level of fuel economy established for each increment in footprint, with vehicles with a smaller footprint having tighter mpg targets and those with a larger footprint having less demanding ones. Individual manufacturers are required to comply with a single fuel economy level based on the distribution of its production among the footprint categories in each particular model year. Vehicle weight and ‘shadow’ (ie pan area) had also been considered as possible functions on which to base the standards, but there were concerns that they could more easily be tailored (ie gamed) with the objective of subjecting a vehicle to a less stringent target and they were therefore discounted in favour of footprint. The latter is argued to be more integral to a vehicle’s design as it is dictated by the vehicle platform (which is typically used for a multi-year model lifecycle), and cannot therefore easily be altered between model years.

It is now well understood in the US regulatory community that a similar approach (ie a shift to a continuous utility function, and from weight to footprint as utility parameter) will also be applied to US cars in due time. In February 2007 the NHTSA opened a ‘request for comments’ from vehicle manufacturers regarding future reforms of the CAFE programme to set standards for MY 2007-2017 passenger cars and MY 2012-2017 light trucks.

The footprint approach also received support in a March 2004 meta-study by Dynamic Research Inc (DRI)[^7][^7] which analysed a number of previous studies by DRI and C J Kahane into the effects of vehicle weight and size on accident fatality risk. All the studies reviewed used data on crashes for both light trucks and passenger cars. The study concluded that reducing wheelbase and track width (ie footprint) generally increased the number of fatalities, whereas reducing vehicle weight tends to decrease the number of fatalities. These findings


regarding safety, to the extent that they are applicable in Europe, would be a significant further argument against a utility parameter that could encourage greater weight rather than footprint.
Possible regulatory approaches to reducing CO₂ emissions from cars

Technical note 5: Developing the list of options

1 Introduction

This note reports the process and results of the development of the list of options performed in the context of the project “Possible regulatory approaches to reducing CO₂ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

The January 2007 Commission Communication¹ indicated that the voluntary agreements already in place were not on track to be met and that a legislative proposal was therefore necessary. This analysis therefore focuses on the options for such a regulation. The Commission also indicated that it favoured options to be operated at the Community level rather than the Member State level.

The purpose of this note is to present the method which lay behind the development of the list of options for a regulatory system. A separate note (Technical Note 2) discusses the various elements of the regulatory system at greater length. This initially took the form of a long list of all the permutations of options that were considered to be logically possible. This long list was then reduced to a medium list of the most promising options through the application of a set of criteria designed to characterise their strengths and weaknesses, in order to cut down the options to the presented short list.

It should also be noted that, although sufficient data are not available to allow a detailed analysis, the project team utilised the results of a previous analysis on N1 vehicles (light vans) in order to ensure that the analysis is also relevant to the potential inclusion of light vans within a future system (see Technical Note 12).

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2 Developing the long list of options

Considerations taken into account during development of the long list of options included: revisiting and extrapolating the results of past research by the project team, the institutional aspects of a regulatory system, intensive discussions within the project team, further reference to the expertise of third parties across Europe, and investigation into other relevant systems of regulating passenger car fuel economy or CO\textsubscript{2} emissions around the world.

Given that there were potentially an almost infinite number of different permutations for combining the different components of a possible legal regime, the project team initially considered the separate components of a possible system independently. The broad components addressed in our analysis, and the options for each, were:

- **Obligated or responsible entity** (trade associations; manufacturers or groups; importers, distributors and dealers; and Member States)
- **Target focus** (level and nature of obligation, including car model/variant or group target)
- **Target type** (sloped line targets; single targets; and others)
- **Instrument/sanction** (exclusion of non-compliant models from the market; fines associated with a target; feebates – a system of fines with rebates, to punish the worst performing cars and reward the best; and trading)
- **Choice of a utility function** (vehicle weight in kg or pan area (vehicle l x w) in m\textsuperscript{2}, or a possible future option of footprint (wheelbase x track width))

A brief description of each of the main components is presented in the following paragraphs.

2.1 Obligated or Responsible Entity

This refers to the legal entities to be placed under the obligation to take action to reduce car CO\textsubscript{2} emissions, and to be responsible for ensuring that this happens. Four different entities were considered:

- **Trade associations**: namely the three main trade associations in Europe (European Automobile Manufacturers’ Association (ACEA), Japan Automobile Manufacturers’ Association (JAMA) and Korea Automobile Manufacturers’ Association (KAMA))
- **Manufacturers and groups**: whether manufacturer groups (as opposed to individual brands) or several manufacturers working collectively to meet a shared group target or limit value
- **Importers, distributors and dealers**: as in the End-of-Life Vehicles Directive, where obligations are placed upon the so-called ‘economic operators’ who put cars on the market, which are not necessarily the manufacturers themselves
- **Member States**: which are usually the main obligated entities for the purposes of EU environmental regulation

It was assumed that trade associations were unlikely to be suitable obligated entities given that they have lost some political credibility through failing to deliver fully on the voluntary agreements, that it appears unlikely they are suitable entities to undertake the necessary obligations, and they do not appear to have sufficient influence or legal powers over their members to impose effective sanctions upon them for any non-compliance. Furthermore, it has been noted that the structure of the market is changing to reflect new structural realities – Toyota is in the process of joining ACEA, for example. Manufacturers or groups, importers,
distributors and dealers and Member States were therefore considered to be more appropriate obligated entities.

2.2 Target Focus

Under this heading, two distinct elements were combined in order to simplify the analysis:

- **Level of obligation or group obligation**: individual vehicle or model/variant, which would enable, for example, a fine to be levied at the point of sale
- **Nature of group obligation**: group targets offer a degree of flexibility relative to vehicle targets, would allow implicit internal averaging within the group, and can be imposed at the level of the obligated entity, at the Member State level or even the EU level

In most cases the focus of a group obligation will be the same as the obligated entity – that is, for example, Member States might be obligated on the basis of a national sales average. There is however an important class of obligations where this would not be the case, eg where Member States impose individual targets on manufacturers or dealers within their own country. The focus of the target also includes options above the state level – eg a possible EU-wide target for each manufacturer or group.

2.3 Target Type

The global target was already laid down – a Community average of 130g/km by 2012 – but it was considered likely that this global target will need to be translated into different targets or types of targets to be used at particular points within a proposed system. The types of target considered were:

- **Sloped line targets**: where a target varies according to some measure of a vehicle’s ‘utility’
- **Single targets**: such targets would generally discard the notion of a utility function and impose a single limit or target value for all vehicles
- **Others**: for example setting separate targets for new models, or a percentage reduction target

The first two were deemed the only fair and viable options for regulating cars through targets set at the model/variant level. Sloped line targets were deemed desirable as they allow some flexibility to give a larger allowance of CO\(_2\) emissions to vehicles that offer greater utility than others. The choice of a utility function is, however, another issue. Single targets would reduce greatly the flexibility of the system and increase the chances of market disruption or distortion, unless other elements of flexibility were introduced such as fines or feebates, trading in credits, or applying the single target at manufacturer/group level rather than individual vehicle level. Group average targets, on the other hand, may be designed to vary from company to company (or country to country, etc) to reflect their differing positions in the market and distinctive possibilities to reduce their emissions, for example through a percentage reduction or some sort of ‘contraction and convergence’ option.

Separate targets for new models would enable the greater technical possibilities available when designing a new model from scratch to be reflected, as well as giving a clearer signal on expectations for new models. There is also some precedent in the legislation controlling regulated pollutants, whereby models newly type-approved are typically required to conform in advance of new cars of pre-existing models. However, this idea was seen to have some
drawbacks, notably complexity in terms of negotiating and administering the levels of achievement for new models, defining the length of time that a new model remained ‘new’, and ensuring that such a system positively encouraged the bringing of new models to market without building in perverse incentives to retain old models. Given that this was still a relatively new idea and had not yet been developed in detail, it was decided not to reflect it in the long list of options.

2.4 Instruments and sanctions

A number of potential sanctions were considered as a means of ensuring compliance, namely:

- **Exclusion of non-compliant models from the market:** probably this could only be attached to a limit value or limit curve, to allow engineers to know in advance what was allowed and what not
- **Fines and feebates:** fines would likely be associated with a target; feebates can be explained as a system of fines with rebates, to punish the worst performing cars and reward the best
- **Trading:** companies could trade CO₂ allowances or permits

It was considered that market exclusion for non-compliant models would be seen to be too draconian and inflexible (not easy to change over time as this would deny the principle of legal certainty). Fines and feebates were considered to be possibly a more appropriate option, providing a known level of sanction and being seen to be ‘fair’, although they could affect the competitive position of manufacturers, and it could be difficult to set the fine at the right level to ensure that fines are not set so high that they would effectively result in market exclusion, but likewise are not so low that they are simply seen as a ‘cost of doing business’. There would also likely be issues related to using the revenues obtained from fines. Trading was considered, in principle, to have several major advantages, including ensuring that the target is met (provided there is no buy-out price), removing the need to set the price of a car g/km, providing manufacturers with extra flexibility, and meeting the target at the lowest cost. However, potential difficulties include creating a short-sighted market which prefers short-term ‘fixes’ to more expensive technological breakthroughs, a perceived general reluctance of companies to trade credits, the need for reliable and timely performance data, and the need for a credible fallback sanction to support the trading system.

2.5 Choice of a Utility Function

See Technical Note 4 for details of the short listing of options for a utility parameter. In principle, however, criteria applied to the other components of the system would operate largely independently of the choice of utility parameter or the precise utility function adopted.

2.6 Combinations of the four components

Considering every possible permutation of all the possible options for each of these four components was quickly revealed to be impractical. However, it also became clear that some combinations of options are logically impossible, while others appeared very unlikely to work in practice. Conversely, other relationships suggested strong alignments of the possibilities available under each of several different headings: for example, the nature of the enforcement regimes is clearly closely related to the question of who is the obligated entity; while some target/instrument combinations clearly lend themselves to certain sorts of sanctions, and not to others. In all cases, monitoring and reporting arrangements, although
important and in some cases absolutely vital, appear to remain largely a ‘downstream issue’ in that it appears possible in principle to develop adequate arrangements for this almost irrespective of the design of the other components of the system.

Reflecting this, the separate design components of a legal system were therefore assembled to produce a ‘long list’ of 78 logically possible options (ie avoiding conflicting design components) as described in the next section. Each option was given a simple qualitative score (+++, +, 0, -, --, ---) for each criterion agreed for the medium listing exercise (see below), to create an overview enabling a first intermediate selection of options to be identified for more detailed assessment.

Figure 1 and Figure 2 at the end of this technical note provide an illustration of the ‘family’ groupings of options, whilst Figure 3 shows the scoring matrix used to assess the long list of options.

3 Developing the medium list of options

To create the final short list of options (in effect these became ‘families’ of options from the medium list), assessment criteria for evaluation of the different options for implementing the 130 g/km policy followed the Impact Assessment (IA) Guidelines\(^2\). However, for the purpose of the assessment of the 78 policy options identified, a shorter list of filtering criteria was applied to allow a more simple and transparent assessment. These are discussed in the next section.

3.1 Filtering criteria applied to develop the medium list of options

- **Market distortion (exclusion of models):** a strict interpretation of market distortion was applied (ie formal or de facto exclusion of models from the market). The rationale for scoring was as follows:
  - exclusion combined with uniform target will exclude large part of existing model range
  - exclusion combined with sloped target will still lead to significant exclusion, especially relatively small and light sports cars
  - uniform limit per car + fines or fines & rebates formally does not exclude cars but will make various models prohibitively expensive for some buyers
  - uniform limit per car + trading resolves this problem as high compliance costs can be avoided by buying credits from manufacturers who can reduce emissions in a cheaper way
  - all options based on sales averaging are considered not to lead to exclusion, and the application of formal exclusion as a sanction at the group level is impractical

- **Distortion of EU open market (price difference between countries):** focus on the possibility of creating differences in vehicle base price for specific models between countries (or over time which may be the case with vehicle based systems with trading if buying credits is to be done in real time). The rationale for scoring was as follows:
  - it is assumed that exclusion does not affect prices of cars in different countries

- fines at the vehicle level may affect price differences between countries if fines are set at Member State level and are not uniform
- rebates at the vehicle level do not affect price differences between countries if they are uniform and set beforehand, but will lead to differences if set at Member State level and especially if level of rebates is based on redistributing collected fines
- it is assumed that manufacturer as responsible entity will be able to do internal banking and averaging, even over sales in different countries, so that fines, fines & rebates and trading do not lead to different impacts on prices of vehicles in different countries
- if member state is responsible entity then one expects large differences in national policies so that impacts on vehicle prices may be different for different countries
  - effect will be more pronounced with uniform target than with sloped line or %-reduction
- a uniform target for the national sales average of dealers/importers is expected to lead to large price differences due to very different markets per country
- if the fines/rebates or trading costs for a given model are different in different countries, due to the way the system is implemented, then this is likely to lead to differences in vehicle base prices between countries
- dealers have less room for banking/averaging than importers, and importers less than manufacturers

**Even distribution of burden over manufacturers:** compares distribution of compliance costs as well as distributional effects of fines and rebates between manufacturers/groups. The rationale for scoring was as follows:

  - 'fairness' is defined in this case as even distribution of costs over manufacturers
    - this implicitly assumes that differences in CO₂ emissions between manufacturers are largely based on market position rather than them being early movers or laggards
  - formal exclusion is considered 'unfair' distribution
  - fines + rebates leads to less even distribution than just fines – effects magnified
  - under systems with trading manufacturers can comply by buying credits at lower costs than the fines under systems with fines/rebates, so this leads to more even distribution
  - sloped line generally improves distribution of burden
    - sloped line + fines & rebates is less fair than sloped line + fines (see above)
    - sloped line + trading reduces costs of compliance and leads to smaller chance of manufacturers having to pay fines
  - trading combined with sloped line or %-reduction is most equal solution
    - trading combined with uniform target leads to high cash flows between manufacturers
  - for systems based on overall national sales average it is difficult to judge on this criterion - depends heavily on how MS implement legislation
  - for %-reduction based systems compliance costs are almost the same with and without trading

**Fairness to early movers:** ability to reward early movers (who have already improved their fuel efficiency) relative to those (laggards) who have not. The rationale for scoring was as follows:
uniform target and sloped limit function both give credits to early movers
%-reduction is a form of grandfathering giving credits to market positioning (selling more large cars) or technological position (selling more vehicles with low fuel efficiency)
  - equal relative reduction targets means lower absolute reduction targets for the early movers but the difference between the targets for early movers and laggards under this scheme is smaller than for uniform target of sloped line
  - early movers are further up the cost curve so that a given absolute reduction is more expensive than same reduction for laggards
under the category ‘other’ alternative options may be devised that better give credits to early movers
systems with rebates or trading give financial benefits to early movers

Polluter pays principle: from a societal/moral point of view the system is ‘fair’ when owners or makers of large or high CO₂ emitting cars pay more towards meeting the 130 g/km target. The rationale for scoring was as follows:

vehicle based systems most directly influence retail price
  - a uniform limits leads to the highest costs for high emitters and the lowest for low emitters
  - a system with fines and rebates amplifies this distribution of costs the most while fines only increase costs of high emitters
  - a system with trading reduces this distribution of costs as it leads to lower compliance costs for large vehicles but still gives cost benefits to smaller or more efficient vehicles
the use of a sloped limit function implicitly violates the ‘polluter pays’ principle as it allows cars with high ‘utility’ to emit more
sales average based systems give opportunity for distributing costs
%-reduction is a form of grandfathering giving credits to market positioning (selling more large cars) or technological position (selling more vehicles with low fuel efficiency)
  - this also violates the ‘polluter pays’ principle but to a lesser extent than in the case of the sloped limit function as market trends towards larger cars after the implementation of the legislation are not translated into higher CO₂ credits

Certainty of meeting 130 g/km average: whatever system is applied, there will be questions about the sanctions and the degree of compliance that results. These must be dealt with later in detailed evaluation of the shortlist. However, even in the case of full compliance, some systems give much greater certainty that the overall target will be met than others. The rationale for scoring was as follows:

provided that target is set at 130 g/km (or something close to that) uniform target per car + exclusion is only combination that gives 100% certainty of (over)achieving 130 g/km average overall sales target
uniform target + trading is expected to come very close as it reduces the compliance costs for manufacturers of large and/or sporty cars
with sufficiently high fines uniform target + fines (per car or per manufacturer) will still come close to overall target
combining fines with rebates generally improves chances of reaching overall target as overachieving is rewarded
• trading reduces compliance costs so generally reduces risks of non-compliance

• for all options with a sloped line market a possible trend towards larger cars will result in the overall sales average moving away from the overall 130 g/km target
  ▪ certainty of reaching target is therefore low for these options

• in case of % reduction the overall average is not influenced by market trends concerning car size or weight, but is influenced by changes in the market shares of different manufacturers
  ▪ certainty of reaching target is lower than for uniform target but higher than for sloped line

• **Average compliance cost per car**: assessment based on data from TNO 2006.

• **Average compliance costs for small cars**: assessment based on data from TNO 2006.

• **Practicability**: difficulty or complexity for implementation and operation of the system or of components of it. The rationale for scoring was as follows:
  o if rebates are to be paid to vehicle buyer this can only be arranged in a practical way if rebates are determined beforehand
  o trading is difficult to implement with dealers/importers as responsible entity
    ▪ large number of actors is difficult for trading system
    ▪ also difficult to set caps for parallel trading
  o vehicle based systems with trading make it difficult to establish vehicle price as costs of credits will change over time
    ▪ can be overcome by banking, but this essentially leads to a system that is based on sales averages rather than vehicles
  o combination of Member State as responsible entity and vehicles as target focus with fines, fines and rebates or trading seem less practical as these require national policy to influence the sales of non compliant cars (other than exclusion)
    ▪ MS paying fines to the EU is possible, but MS receiving rebates is probably not yet common practice
  o setting targets at national sales average for dealers is very difficult due to large number of actors
    ▪ combining this with rebates or trading increases complexity, the latter especially in case of parallel trading by different importers of same brand
      ▪ this is less difficult if member state is responsible entity that has to buy/sell credits on behalf of dealers/importers
    ▪ setting targets at national sales average for importers involves fewer actors, but will be increasingly difficult due to trend that cars of the same brand are imported by more than one importer in the same country (diversity of market is increasing)
  o uniform target at level of dealer/importer is not practical as these entities have too limited control over their sales average
    ▪ using a sloped limit may work as it acknowledged differences in market position of dealers/importers
  o a %-reduction target is difficult in a market of small companies which come and go, i.e. it might be difficult to apply to dealers, etc., but much easier at level of Member State or manufacturer/manufacturer group
  o setting target at national level for sales average per manufacturer is possible and has little practical problems, provided that Member States can impose fines upon legal entities outside their country
setting target at EU level for sales average per manufacturer is possible and has few practical problems, provided that EU can impose fines upon manufacturers
  - as monitoring of sales is probably done by compiling national data this system is not more practical than setting targets at national level
complexity of setting target for overall national sales average with MS as responsible entity is as yet difficult to judge
  - complexity is in the diverse ways in which member states can work out legislation in their own country
  - currently score set at ++, as system is easy to implement at EU level and the implementation of national policy by MS is not necessary a complicating matter for the EU

- **Enforceability:** difficulty of enforcing compliance (including receipt of fines or payment of rebates and the obligation to trade), once the system has been implemented. As such complementary to ‘practicability. The rationale for scoring was as follows:
  o enforcement of legislation on a large number of dealers/importers is more difficult than enforcement of similar legislation placed upon a limited number of manufacturers
    - trading further increases difficulties of enforcement: fines are needed as a backup for non-compliance and also if insufficient credits are available
  o in general enforcement is easier if the responsible entity has a high level of control over/influence on the target focus
    - a dealer does not have direct influence on the CO₂ emissions of vehicles offered by the manufacturer
    - a manufacturer can be held responsible for meeting vehicle based limits or targets set at the level of sales averages
      - manufacturers do not have full control over market developments but do have significant influence on the market and can reduce CO₂ emissions of cars by technical means
    - a member state does not have direct influence on the CO₂ emissions of vehicles offered by the manufacturer and only limited influence on dealer/importer or manufacturer sales averages
    - on the other hand a member state can be held responsible for meeting an overall national sales average as this can be done by means of a large number of policy instruments at the disposal of the Member State to influence the market

- **Accommodation of new player/mergers:** The rationale for scoring was as follows:
  o only a problem for %-reduction based systems
    - difficult to find general solution but may be possible to solve in individual cases so not a ‘killer’ argument

- **Assessment of comprehensibility of the option:** ease of understanding of the option. The rationale for scoring was as follows:
  o based on deducting one point per complicating factor
  o uniform limit and exclusion or fines are easy to explain
  o EU sales average target per manufacturer is also easy to understand
  o complicating items:
    - rebates (formula for determining rebates)
    - trading
- sloped limit function or percentage reduction
- dealer/importer national sales average instead of manufacturer national or EU sales average

- **Other (specific issues or problems):** used to deduce points for difficulty of making Member States responsible for implementation. The rationale for scoring was as follows:
  - now used to deduce points for difficulty of making MS responsible for dealer/importer national average relative to scores for dealer/importer as Responsible Entity and to deduce points for difficulty of making MS responsible for manufacturer national average relative to scores for Mfr/Mfr Group as Responsible Entity

### 3.2 Applying the filtering criteria

For each option the criteria outlined above have been applied and assessed according to an agreed scoring rationale and translated into a matrix with the help of simple qualitative scores (+++, +, 0, -, --, ---), as illustrated in Figure 3.

| --- | impossible option – ‘killer’ arguments identified |
| -- | unfeasible option - very strong con arguments |
| - | unlikely option - fairly strong con arguments |
| 0 | neutral with regards to this criterion |
| + | possibly feasible options - problems identified, pros and cons balanced |
| ++ | feasible option - pros strongly outweigh cons, no serious or insurmountable con arguments |

The scores have been then grouped and weighted, and an average weighted result has been derived as a composite of all the criteria. This result was then manipulated to ‘amplify’ the scoring differences between best and worst options (this was done as all options tend to regress towards the mean when evaluated across a range of options, reflecting the fact that rarely are any options good or bad on all counts). A filter has been then applied to select the options above a specific threshold of score that retained a suitable list of options. These were grouped into three ‘families’ corresponding to ‘responsible entity’, ‘target focus’ and ‘target type’ respectively. The matrix clearly showed that there is no single option that does not have negatives and only a few that have no double-negatives. All show a combination of very different scores on different criteria. That is, there is no clear ‘winner’.

a. **Family = Responsible Entity**
   - In the case of responsible entities, Manufacturer / groups was the strongest branch with most options getting + or ++; and
   - The branches Dealer/Importer and Member States only had a couple of options each that bear fruit.

b. **Family = Target Focus**
   - In this option Dealer/Importer national sales average had only two options that in some scoring methods get a +. For the rest this branch was not bearing fruit at all.
   - Manufacturer / groups EU sales average got the highest scores, and Mfr / Mfr national sales average combined with Mfr / Mfr groups as Responsible Entity ends in second place overall.
• Depending on the exact amplification method, the family ‘Car model/variant’ had up to 50% options with a + or ++, but the rest were 0 or below.

c. Family = Target Type
This family categorisation showed a very mixed picture:
• Under the current weighting the Sloped line target option did not get any ++ scores at all. This reflects the fact that it scores poorly on meeting the 130g target, violates the polluter pays principle, is complex and can be impractical in some contexts.
• For overall weighted score sloped line is getting positive scores for less than half of the options while %-reduction scores positive on more than half of the options, including a number of ++ values.
• Uniform limit with trading generally gets high score.

From these certain generalisations have been made using a range of ‘family’ criteria:
• Options with trading often score highly even in configurations where other instruments and target focuses are judged too inflexible - eg a uniform target operating at the level of individual vehicles. Here trading gives much added flexibility and other components of the system can be kept relatively simple.
• The other large block is with Manufacturer / group as the responsible entity. Here even some options with national sales averages appear possible, although systems based on a pan-EU target seem possible. Within this group, most if not all possible combinations of target and instrument appear possible, and the focus of choice needs to be further refined once final weightings are agreed.
• Only a few options operated at the Member State level are retained. These mainly involve trading, although one fine and rebate option appears possible.

Following the above ‘intermediate assessment’, the Commission proceeded to the selection of a short list of options. Three families of short listed options have been applied in the quantitative model as described in Technical Note 9.

a. Uniform limit
  • applied per vehicle
  • applied to the sales weighted average in 2012 per manufacturer
  • applied to the sales weighted average in 2012 per manufacturer with trading

b. Utility based limit function
  • applied per vehicle
  • applied to the sales weighted average in 2012 per manufacturer
  • For each model sold by the manufacturer the CO\textsubscript{2} emission limit is calculated based on the vehicle’s utility value (see explanation further on). The target per manufacturer is then calculated as a sales-weighted average of the limit values per model.
  • This is identical to defining a sales-weighted average utility for the manufacturer and inserting that average utility value in the utility based limit function.
  • applied to define targets for 2012 based on the sales weighted average in 2006 per manufacturer
  • applied to the sales weighted average in 2012 per manufacturer with trading
c. **Percentage reduction**
   - applied to the sales weighted average in 2012 per manufacturer
   - applied to the sales weighted average in 2012 per manufacturer with trading
Figure 1 'Family Tree' of Options based on Responsible Entity & Target Focus & Target Type
Figure 2: ‘Family Tree’ of Options based on Target Type & Instrument & Responsible Entity
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Dealer / importer
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Dealer / importer
Dealer / importer
Manufacturer / Mfr group
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Manufacturer / Mfr group
Member States
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Dealer / importer
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Responsible
Entity

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Target Focus

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Dealer/importer national sales average
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Mfr / Mfr group national sales average
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Mfr / Mfr group EU sales average
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Mfr / Mfr group EU sales average
Overall national sales average
Overall national sales average
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Overall national sales average
Dealer/importer national sales average
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Mfr / Mfr group national sales average
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TN 5: Developing the list of options

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Target Type

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Instrument /
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Figure 3 Scoring Matrix for the Long List of Options

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Average
compliance
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Other (specific
issues or
problems)
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stretched to
span 0 to ++)
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Filter (++ if
weighted score
> threshold)

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Technical note 6: Methodological aspects regarding update of the cost assessment model

1 Introduction

This note reports on the model adaptations carried out in the context of the project “Possible regulatory approaches to reducing CO₂ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

This note contains the following content:

1 Introduction...........................................................................................................................................77
2 Update of the TNO cost assessment model and regarding baseline scenarios......................................77
   2.1 Model adaptations ...........................................................................................................................77
   2.2 Baseline scenarios ...........................................................................................................................78
   2.3 Autonomous mass increase .............................................................................................................79
   2.4 Cost curves ......................................................................................................................................79
3 Alternative model and costs curves for assessing the “per car” options...............................................81

Annex A Methodology for cost assessment (general description of the model)
Annex B Input data
Annex C Method for assessing the amount of CO₂ reduction applied in 2002-2006 period

2 Update of the TNO cost assessment model and regarding baseline scenarios

2.1 Model adaptations

- The model used in [IEEP 2005] and [TNO 2006] has been adapted and updated.
- Base year of the cost curves is still 2002. Starting point for the calculation of applied CO₂ reduction measures is still the Polk data for 2002. The following modifications have been made to the 2002 data:
  - Daewoo has been taken over by GM (Chevrolet). The 2002 data for GM in the present model version have been constructed as a sales weighted average of the previous 2002 data for GM and Daewoo.
    - For the monitoring of the voluntary agreement Daewoo is still part of KAMA. For the assessment of the 2012 situation, however, it is more realistic to treat Daewoo as integral part of GM, especially for the options with internal averaging per manufacturer (target set at level of sales averaged CO₂ emission per manufacturer).
  - The “Other manufacturers” included in the previous model version have been excluded. Rover has ceased to exist and the other small European manufacturers and imports are too small to have an influence on the calculation results (and will probably be exempted from the CO₂ emission limit anyway).
- The intermediate year 2008/9 has been replaced with 2006. Instead of predicting the situation in the intermediate year the model now contains data for 2006 that have been aggregated from AAA data supplied to the consultants by the Commission. By comparing...
the 2006 AAA data with the 2002 Polk data an estimate is made of the amount of emission reduction that has been applied through technical measures between 2002 and 2006. This estimate takes account of developments in the average CO₂ and mass per segment per manufacturer between 2002 and 2006. The 2002-2006 CO₂ reduction associated costs are used as starting point on the cost curve for the assessment of costs from going from the 2006 situation to the 2012 target.

- An overall description of the modelling methodology is presented in Annex A.
- The input data for 2002 and 2006 are presented in Annex B.
- An explanation of the method for assessing the amount of CO₂-reduction applied in the 2002-2006 period is explained in Annex C.

- Calculations of the costs for reaching the 2012 targets are made with the same methodology as applied in [TNO 2006] and [IEEP 2005] for determining the costs of going from the intermediate 2008/9 year to 2012.

- Besides absolute cost / price increase the model now also presents relative cost / price increases based on dividing the additional retail price for a manufacturer or segment by the average 2006 retail price for that manufacturer or segment.

2.2 Baseline scenarios

- Cost for reaching various possible targets in 2012 are now calculated relative to 2012 baseline without the new CO₂ policy for passenger cars, and are expressed as the costs of technical reduction measures applied between 2006 and 2012 to comply with the assessed option in which the 130 g/km target for 2012 is applied.

- As a baseline scenario for the 2006-2012 period two options are modelled:
  - **b0**: manufacturers do not apply additional CO₂ reduction measures between 2006 and 2012 so that for each manufacturer in each segment the average CO₂ emission rises proportional to the autonomous mass increase that is assumed to occur between 2006 and 2012;
  - **b1**: manufacturers apply CO₂ reduction measures between 2006 and 2012 to compensate the impact of autonomous mass increase (or other trends) on CO₂ and so maintain the average CO₂ emission in each segment at the 2006 level. The costs of these measures are subtracted from the costs for reaching the 2012 target.

- The difference between the two baselines in terms of assessed costs for reaching the 2012 target is illustrated in Figure 1 below:

![Figure 1](image-url)
2.3 Autonomous mass increase

- Four scenarios have been assessed for the autonomous mass increase (AMI) that is assumed to occur between 2006 and 2012.
  - Scenario a assumes an average autonomous mass increase of 0.82% p.a.. This value is derived from scenario a in Table 3.27 of [TNO 2006] and has also been used as central estimate in the IA.
  - Scenario b uses an autonomous mass increase of 1.5% p.a., which was the baseline in the calculations for [TNO 2006].
  - Scenario c assesses the costs for meeting the target under the assumption that there is no autonomous mass increase between 2006 and 2012 (AMI = 0.0% p.a.).
  - Finally scenario d explores the impacts of a more extreme assumption for the autonomous mass increase of 2.5% p.a..
  - Data for the four scenarios are presented in Table 1 below.

<table>
<thead>
<tr>
<th>new reference year</th>
<th>scenario a</th>
<th>scenario b</th>
<th>scenario c</th>
<th>scenario d</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>1.13%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2008</td>
<td>1.00%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2009</td>
<td>0.88%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2010</td>
<td>0.75%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2011</td>
<td>0.63%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2012</td>
<td>0.50%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>average 2007-2012</td>
<td>0.82%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
</tbody>
</table>

- In the case of using baseline b1 the costs for compensating autonomous mass increase are not attributed to the 130 g/km CO₂ policy. This reduces the impact of the assumption on autonomous mass increase. Costs for reaching 130 g/km will, however, still increase with increasing annual mass increase percentage as the measures taken to maintain CO₂ emissions in the baseline at the 2006 level push the additional measures for reaching 130 g/km further up the non-linear cost curve.
  - For scenario c the baselines b0 and b1 are identical.

2.4 Cost curves

2.4.1 Consistency with the Impact Assessment guidelines

- In [TNO 2006] cost curves for CO₂ reduction in passenger cars have been derived, using the methodology developed in [IEEP 2004] but based on new input data and updated expert judgment. Cost curves are expressed as third order polynomials \( y = a x^3 + b x^2 + c x + d \), with \( x \) the CO₂ reduction in g/km and \( y \) the retail price increase. In this update additional literature input was used as well as new information supplied by the automotive industry (ACEA, CLEPA and individual suppliers) in response to a detailed questionnaire that was sent out by TNO. The cost data supplied by the industry were all expressed as manufacturer costs. Retail price information from literature was translated into manufacturer costs using a factor 1.44. This mark-up factor between additional manufacturer costs and retail price increase was derived in Annex A of [TNO 2006] based on an analysis of available information on the cost structure of passenger cars and assumptions regarding the extent to which various cost mark-ups are applicable to the additional costs of vehicle modifications induced by legislation. The factor 1.44 includes
manufacturer profit, dealer costs, dealer profit and taxes. Cost curves were constructed on the basis of an analysis of the manufacturer cost data from all input sources. Cost curves based on manufacturer costs were subsequently translated into additional retail price curves using the mark-up factor of 1.44.

- For the purpose of this project the additional retail price curves derived in [TNO 2006] have been adapted to provide consistency with the methodology used in the Impact Assessment SEC(2007) 60 as well as in other Impact Assessments eg related to Euro standards for regulated emission components. In Impact Assessments carried out by the Commission Services price increases resulting from application of new (environmental) technologies to vehicles are always based on manufacturer cost estimates plus tax. For the present study therefore manufacturer margins and dealer costs and margins have been excluded from the [TNO 2006] cost curves expressed in retail price, so that the resulting mark-up from additional manufacturer costs to retail price increase only includes taxes. On average these taxes in the EU equal 19% of vehicle retail price resulting in a mark-up factor that equals $1 + 0.19/(1 – 0.19) = 1.235$. The resulting cost curves based on retail price increase are given in Table 2 and Figure 2. Costs curves defined in terms of additional manufacturer costs remain identical to the ones used in [TNO 2006].

Table 2 Cost curves for small, medium and large passenger cars on petrol and diesel

<table>
<thead>
<tr>
<th></th>
<th>additional manufacturer costs [€/vehicle]</th>
<th>additional retail price [€/vehicle]</th>
<th>maximum reduction [g/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$x^2$ b</td>
<td>-0.100</td>
<td>-0.110</td>
</tr>
<tr>
<td></td>
<td>x c</td>
<td>22.0</td>
<td>18.0</td>
</tr>
<tr>
<td></td>
<td>d</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

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Table 2 Cost curves for small, medium and large passenger cars on petrol and diesel

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<td>22.0</td>
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</tr>
<tr>
<td></td>
<td>d</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
• The maximum reductions in Table 2 above are derived from the data clouds in Figs. 3.4 to 3.9 in [TNO 2006].
  o These maximum values are not affected by the adaptation made to the cost curves relative to [TNO 2006], i.e. exclusion of margins from the additional retail price. This adaptation only shifts the curves vertically.
  o The model does not contain precautions to avoid that manufacturers apply higher reductions than these maximum values. The results, however, are checked for this. Excursions beyond the established reduction potential only occur in a limited number of cases (most in the “per car” option) and for a limited number of manufacturers (mainly Subaru and Porsche), and the amount of “overshoot” is generally limited.

3 Alternative model and costs curves for assessing the “per car” options

• In the TNO cost assessment model used here the calculations for the option in which a utility-based limit function is applied at the level of individual vehicles (“per car – utility”, see section) are performed at the level of the average utility and CO₂ emission values per segment per manufacturer. This calculation therefore contains some level of averaging within each segment.
  o For a more detailed analysis of the “per vehicle” options a new calculation method has been developed based on the complete vehicle database rather than the averages per manufacturer for the 6 segments. Some first calculations based on individual vehicles are presented in this document but will be further elaborated at a later stage.
  o Some characteristics of the model are:
    ▪ Targets are set per vehicle based on the sloped limit function and the vehicle’s utility value (mass or l x w).
    ▪ Cost curves need to be applied to individual vehicles. This is achieved by expressing the cost curves for each fuel as a function of relative CO₂ reduction rather than absolute CO₂ reduction. In that case the curves for the three segments are somewhat closer together so that a generalised, size independent, cost function
can be obtained by averaging the cost curves for the three segments. This indicated in the Figure 3 below.

- Other approaches would be:
  - To still use the discrete cost curves per segment and apply the cost curve for the segment in which a vehicle belongs. This, however, gives unwanted boundary effects.
  - An attempt was made to determine a linear least squares fit through the a, b, and c values of the three segments per fuel as function of the average utility of the segments. Due to negative slopes in some of the fits this, however, gives negative costs for vehicles with high utility values, and therefore does not work.

Figure 3 Cost curves for small, medium and large passenger cars on petrol and diesel based on relative CO₂ reduction

\[ y = 45343x^3 + 12779x^2 + 1960.8x \]
\[ y = 37404x^3 - 3067.9x^2 + 4078.8x \]

- As the cost curves from [TNO 2006] are defined relative to average 2002 reference vehicles a default relative reduction for the 2002 – 2006 period has to be assumed. This reduction adds to the reduction required in the 2006 – 2012 period for meeting the target.
- The average cost curve as a function of relative CO₂ reduction is then applied to all individual vehicle models in the database to estimate the costs involved in reaching the target set for that vehicle.
- If the required reduction is larger than the maximum reduction potential identified in [TNO 2006] (a fit of the values in the table above to the average utility value per segments yields a continuous function describing the maximum reduction as a function of utility) a vehicle model either needs to be excluded or the manufacturer needs to pay a fine for the remaining distance to the target, after applying all cost effective measures. Only the first option has been modelled so far.
Annex A  Methodology for cost assessment (general description of the model)

In [IEEP 2004] a spreadsheet model has been developed to assess the costs of meeting a 2012 CO₂ target for passenger cars in Europe (EU-15) by means of different combinations of target definitions and implementation measures. An updated version of this model has also been used for [TNO 2006]. This Annex is based on an excerpt from [IEEP 2004] (see also Annex D of [TNO 2006]) and describes the principles and structure of the model and the way in which the different target-instrument combinations have been worked out. For the purpose of the current project further updates have been made which are described in the main text of this note. In general terms these updates have been included in the overall model description given here.

The calculation model for overall cost assessment for reaching a 2012 target

Overall structure of the model

The model is based on the following main inputs:

- 2002 sales numbers per manufacturer per market segment – based on Polk Marketing Systems data;
- 2002 average values for CO₂ emissions, vehicle mass and pan area per manufacturer per segment – based on Polk Marketing Systems data;
- 2006 sales numbers per manufacturer per market segment – based on AAA data;
- 2006 average values for CO₂ emissions, vehicle mass and pan area per manufacturer per segment – based on AAA data;
- Estimated sales numbers per manufacturer per segment for 2012. These are calculated on the basis of the 2006 data, accounting for overall sales volume changes and a continued shift from petrol to diesel occurring in the periods 2002 – 2006 and 2006 – 2012;
- Cost curves (describing costs as a function of CO₂ emission reduction (g/km)) per segment, with 2002 as base year – as described in Chapter 3 of [TNO 2006].

Market segments

The following market segments are discerned:

- petrol, small (p,S)
- petrol, medium (p,M)
- petrol, large (p,L)
- diesel, small (d,S)
- diesel, medium (d,M)
- diesel, large (d,L)

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2 Review and analysis of the reduction potential and costs of technological and other measures to reduce CO₂ emissions from passenger cars, contract nr. SI2.408212, carried out by TNO, IEEP, and LAT on behalf of DG-ENTR, 2006.
This division has been based on the segments given in the Polk Marketing Systems data, see the table below:

**Market Segments: Small, medium and petrol vehicles**

<table>
<thead>
<tr>
<th>Segment as used/defined by Polk Marketing Systems</th>
<th>Segments for the purpose of our analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment: Name</td>
<td>Small</td>
</tr>
<tr>
<td>1 1 Mini</td>
<td>X</td>
</tr>
<tr>
<td>2 2 Small</td>
<td>X</td>
</tr>
<tr>
<td>3 3 Lower Medium</td>
<td></td>
</tr>
<tr>
<td>4 4 Medium</td>
<td></td>
</tr>
<tr>
<td>5 5 Upper Medium</td>
<td></td>
</tr>
<tr>
<td>6 6 Luxury</td>
<td></td>
</tr>
<tr>
<td>7 7 Sport</td>
<td></td>
</tr>
<tr>
<td>M M MPV</td>
<td></td>
</tr>
<tr>
<td>F F Off-Road</td>
<td></td>
</tr>
<tr>
<td>G G Pick-Up</td>
<td></td>
</tr>
<tr>
<td>J J Unspec.</td>
<td></td>
</tr>
</tbody>
</table>

**Base year**

The base year for the model is 2002. Before assessing the 2012-situation, the previous version of the model first made an estimate of the CO₂ emissions per manufacturer per segment in 2008. Subsequently for each combination of target definition and implementation measure an assessment was made of the additional costs for going from the 2008-situation to the 2012-situation in which an overall goal (e.g. 130 or 120g/km) is to be met. In the present version of the model this intermediate step has been replaced by a description of the situation in 2006 based on 2006 sales data and an estimate of the amount of CO₂ reduction measures applied per segment by each manufacturer based on a comparison of 2002 and 2006 data, as described in Annex C of this note.

**Cost curves**

The model uses costs curves defined per segment using 3rd order polynomials \( y = a x^3 + b x^2 + c x + d \). Values for the coefficients \( a, b, c, \) and \( d \), as used in this study, are given in Table 2 in the main text of this note. The curves are illustrated in Figure 2 in the main text of this note.

**Definition of costs**

Costs, in this calculation, concern the additional vehicle costs to the manufacturer, related to implementing improved engine and power train technology and reducing mass and resistance factors. Combining the results on technology costs with the established CO₂ reductions, also allows calculation of the net costs to the consumer, accounting for fuel costs savings during the life of the vehicle. As explained in more detail further on, all costs in the model are expressed in Euros retail price, assuming full cost pass through and a constant factor between additional manufacturer costs and additional retail price.
Target-instrument combinations

In the model calculations can be made for the following options of target-instrument combinations:

- car-based targets:
  - fixed target per car;
  - percentage reduction target per car;
  - different versions of utility-based targets per car.

- manufacturer-based targets:
  - fixed target per manufacturer;
  - percentage reduction target per manufacturer;
  - different versions of utility-based targets per manufacturer.

- manufacturer-based targets with allowing trading of CO$_2$ credits:
  - fixed target per manufacturer including the possibility of emission trading;
  - percentage reduction target per manufacturer including the possibility of emission trading;
  - different versions of utility-based targets per manufacturer including the possibility of emission trading.

The calculation method for assessing overall costs is dependent on the combination of target definition and policy instrument (implementation of a measure to achieve the target).

For the options with utility-based targets two different utility definitions are explored (mass and pan area). The choice for these parameters is partly based on availability of data. For each utility parameter different variants can be assessed, in terms of the slope and offset of the utility based limit function that is applied. One with a fixed function describing the CO$_2$ emission limit as a function of vehicle utility and one with a CO$_2$ emission limit function which is optimised either to reach overall minimum costs or, in the case of emission trading, to minimise the trading volume. Further explanation of the meaning of utility-based CO$_2$ limit functions is given in Note 8 of this report.

Modelling of individual manufacturers

In the calculations four groups of manufacturers can be distinguished – with analysis carried out at the level of individual group members (independent manufacturers or holding companies):

- ACEA members, incl. US-imports of cars from the same company
- JAMA members
- KAMA members
- Other, including independent European manufacturers (not member of ACEA) and all other imports, appropriately grouped to reflect company type but not corporate groups

The updated model version used for this report contains 9 ACEA members, 7 JAMA members and 1 KAMA member. Other small manufacturers have been excluded from the latest analyses.

It should be noted that the results of the cost assessment model should not be interpreted as predictions of the strategies that individual manufacturers will follow to achieve the 2012-
target. Consequently the estimated costs per manufacturer are not predictions of the actual burden that different target-instrument combinations will pose on different manufacturers. Rather, the above definitions of manufacturers / manufacturer groups and the corresponding 2002 and 2006 input data on sales numbers average CO\(_2\) emission per vehicle per segment for the different manufacturers are used as an example and starting point to assess how some aspects of the different ways in which manufacturers are represented in the market influence the costs under various target-instrument combinations. Obviously the real strategies of manufacturers are determined by a multitude of factors. While the model always assesses least cost solutions, manufacturers may decide to apply different CO\(_2\) reduction measures to vehicles in different segments, eg based on the possibility of creating added value or the possibilities in different segments to absorb additional costs.

**Assessment of developments in the 2002 – 2006 period**

In general the average CO\(_2\) emissions per manufacturer per segment differ between 2002 and 2006. In order to assess the remaining CO\(_2\) reduction potential and associated costs for CO\(_2\) reductions in the 2006 – 2012 period it is necessary to determine the amount of CO\(_2\) reduction through technical measures that manufacturers have applied to their vehicles in the different segments in the 2002 – 2006 period. The methodology for that is explained in Annex C to this note.

**Assessment of developments in the 2006 – 2012 period**

In the updated model 2006 is the starting point for the assessment of the costs of reaching a 2012 target. For each manufacturer CO\(_2\) reduction targets are defined based on the assumed target-measure combination. The way in which the costs of reaching those targets is assessed for the different target-measure combinations is explained below.

**2012: Fixed target / per car**

Under this option each car has to meet a fixed CO\(_2\) emission limit (in the case of this report 130 g/km). Reduction values per car per segment and manufacturer are calculated from the difference between the 2006-value and the 2012 target, in this case the fixed 130g/km value. Using the cost curves and the sales numbers per segment, this directly yields the costs per segment, per manufacturer, for the manufacturer groups, and the total costs.

In the present case, as well as for some other target-instrument combinations, reduction values per segment per manufacturer can be negative, when the 2006 value was already below the 2012 target, in this case 130g/km for each vehicle. For the calculations it is assumed that the manufacturer for which this is true will reverse some of the reductions reached between 2002 and 2006 in order to save costs. The model could be adapted to prevent this kind of “reverse engineering”, but for the purpose of this project it was considered more illustrative to make situations visible in which the targets allow a CO\(_2\) increase per car.

Average marginal costs for this option are calculated by performing the calculation for a goal of 130g/km exactly and for a goal of 130 – \(\Delta CO_2\), with \(\Delta CO_2\) a small extra reduction, and dividing the difference in overall cost by the difference in total CO\(_2\) emissions.
2012: Percentage reduction target / per car

Under this option the average emission per car of each segment of each manufacturer has to be reduced by the same reduction percentage, which is the percentage with which the overall average emissions per car have to be reduced to reach the 2012 goal based on the 2006 EU sales average. Reduction values per car per segment and manufacturer are calculated by multiplying the 2006-values with this reduction percentage. Using the cost curves and the sales numbers per segment, this directly yields the costs per segment, per manufacturer, for the manufacturer groups, and the total costs.

Average marginal costs for this option are calculated by performing the calculation for a goal of 130g/km exactly and for a goal of 130 – Δ\text{CO}_2, with Δ\text{CO}_2 a small extra reduction, and dividing the difference in overall cost by the difference in total CO\text{2} emissions.

It should be noted that this target-instrument combination can of course not be implemented in practice. There is no way to objectively determine with which 2006 model a car in 2012 is to be compared to assess whether or not CO\text{2} emissions have been reduced by a given percentage.

2012: Utility-based targets / per car

The concept of utility-based CO\text{2} limit functions

The concept behind utility-based CO\text{2} limit functions is that it may make sense to allow cars to emit more CO\text{2} per kilometre driven if they have a higher functional transport performance or “utility”. For practical implementation this utility parameter (here named \text{U}) can obviously not be a function of the actual transport performance of the car (eg how many persons or goods are being transported at a given time), but should rather be a function of static characteristics of the car which can be objectively measured or defined. These characteristics can be purely functional aspects related to the carrying capacity of the car (eg volume, number of chairs, maximum payload), but could also include less practical aspects related to the level of comfort or maybe even “fun of driving” with which a certain transport performance can be carried out (eg expressed by means of engine power or acceleration characteristics).

In this study the following two utility parameters have been explored:

- \text{U} = m, with m the car’s empty vehicle mass (kerb weight);
- \text{U} = l^*w (pan area), which is used in many national fuel consumption labelling schemes as the parameter defining categories of comparable vehicles.

For the purpose of this modelling exercise a CO\text{2} emission limit function can be defined as:

\[ E(U) = a*U + b \]

with \text{U} the utility of the car. Given that in 2012 an overall average of 130 g/km is to be reached the parameter \text{a} can be written as a function of \text{b}, the average utility values for the different segments, and the total sales numbers per segment, or vice versa. As all limit functions have to reach 130 g/km as a fleet average all utility functions pivot around the point defined by (\text{<U>}_{2012}, 130), with \text{<U>}_{2012} the average utility value in 2012.
In the model, emission limits are calculated per vehicle class based on the 2012 average utility value for that class, which is based on 2006 AAA data corrected for assumed trends eg related to autonomous mass increase and the continued petrol-to-diesel shift. More details on the implementation of the different utility parameters and the utility-based CO₂ limit functions used in the different variants are presented Note 8 of this report.

Costs of reaching the targets set by a CO₂ limit function applied per car

Under the “Fixed utility-based CO₂-limit function / per car” option each car has to reach the emission limit valid for its class. Reduction values per car per segment and manufacturer are calculated from the difference between the 2006 value and the 2012 target, in this case the different utility-based limits for the different segments. Using the cost curves and the sales numbers per segment, this directly yields the costs per segment, per manufacturer, for the manufacturer groups, and the total costs. Also in this case reduction values per segment per manufacturer can be negative, when the 2006 value was already below the utility-based limit value. It is assumed that the manufacturer, for which this is true, will reverse some of the reductions reached between 2002 and 2006 in order to save costs.

Average marginal costs for this option are calculated by performing the calculation for a goal of 130g/km exactly and for a goal of 130 – ΔCO₂, with ΔCO₂ a small extra reduction, and dividing the difference in overall cost by the difference in total CO₂-emissions.

2012: Fixed target / per manufacturer

Under this option each manufacturer has to meet a fixed 130g/km limit for the average CO₂-emission per car of its fleet of newly sold cars in 2012. It is assumed that each manufacturer tries to reach this goal at minimum costs. For each manufacturer separately, the reductions per car for each segment are found using a solver-function which minimises the total costs for the manufacturer by varying the reductions per car for the six segments under the condition that the resulting average emission per car in 2012 is 120g/km. When this minimum is reached, the reductions per car per segment are such that the marginal costs are equal for all segments.

Marginal costs are different for different manufacturers, depending on their 2006 situation and their distribution of sales over different segments. Overall marginal costs for this option are calculated by performing the complete calculation for all manufacturers for a goal of 130g/km exactly and for a goal of 130 – ΔCO₂, with ΔCO₂ a small extra reduction, and dividing the difference in overall cost by the difference in total CO₂-emissions.

2012: Percentage reduction target / per manufacturer

Under this option each manufacturer has to reduce the average CO₂-emission per car of its fleet of newly sold cars by a reduction percentage, which is the percentage with which the overall average emissions per car (all manufacturers) have to be reduced to reach the 2012 goal based on the 2006 average. It is assumed that each manufacturer tries to reach this goal at minimum costs. For each manufacturer separately, the reductions per car for each segment are found using a solver-function which minimises the total costs for the manufacturer by varying the reductions per car for the six segments under the condition that the resulting average emission reduction per car in 2012 equals the above mentioned percentage. When
this minimum is reached, the reductions per car per segment are such that the marginal costs are equal for all segments.

Marginal costs are different for different manufacturers, depending on their 2006 situation and their distribution of sales over different segments. Average marginal costs for this option are calculated by performing the calculation for a goal of 130 g/km exactly and for a goal of $130 - \Delta_{CO2}$, with $\Delta_{CO2}$ a small extra reduction, and dividing the difference in overall cost by the difference in total CO$_2$-emissions.

2012: Utility-based target / per manufacturer

*Costs of reaching the targets set by a CO$_2$ limit function applied per manufacturer*

Under this option for each manufacturer a target for the average CO$_2$-emission per car of its fleet of newly sold cars in 2012 is determined by multiplying the sales in the different segments with the utility based emission limit of the segments, summing these emissions per segment to a total emission of the manufacturer and dividing this by the total sales of the manufacturer. In this case the same utility-based emission limits are used as in the case when a “fixed utility based CO$_2$-limit function” is applied to each car.

Also in this case the following two utility parameters are explored:

- $U = m$, with $m$ the car’s empty vehicle mass (kerb weight);
- $U = l*w$ (pan area), which is used in many national fuel consumption labelling schemes as the parameter defining categories of comparable vehicles.

More details on the implementation of the different utility parameters and the utility-based CO$_2$ limit functions used in the different variants are presented Note 8 of this report.

It is assumed that each manufacturer tries to reach this goal at minimum costs. For each manufacturer separately, the reductions per car for each segment are found using a solver-function which minimises the total costs for the manufacturer by varying the reductions per car for the six segments under the condition that the resulting average emission per car in 2012 is equal to the goal calculated as described above. When this minimum is reached, the reductions per car per segment are such that the marginal costs are equal for all segments.

Marginal costs are different for different manufacturers, depending on their 2006 situation and their distribution of sales over different segments. Average marginal costs for this option are calculated by performing the calculation for a goal of 130 g/km exactly and for a goal of $130 - \Delta_{CO2}$, with $\Delta_{CO2}$ a small extra reduction, and dividing the difference in overall cost by the difference in total CO$_2$ emissions.

2012: Fixed target / per manufacturer including emission trading

Under this option each manufacturer has to meet a fixed 130 g/km limit for the average CO$_2$ emission per car of its fleet of newly sold cars in 2012, but is allowed to trade emission credits. This means that a manufacturer which does not meet the target can buy emission credits from manufacturers for which the sales averaged CO$_2$ emission is below the target. It is assumed that each manufacturer tries to reach this goal at minimum costs, where the total costs are the costs for reducing the emissions of the vehicles produced by the manufacturer...
plus the costs of buying emission credits or the revenues from selling credits. The option of banking is not taken into account.

It can be proven that for each manufacturer minimum costs are reached when the marginal costs of reductions in the different segments are all equal to the value/price of the traded emission credits. As the latter are assumed to be established in a transparent market, the price of emission credits is the same for all manufacturers. In the calculation therefore the marginal costs for all segments are set equal to the price of emission credits for each manufacturer. The CO\textsubscript{2} reduction values per segment can then be calculated using the inverse of the marginal cost curve (CO\textsubscript{2} reduction as a function of marginal costs). Subsequently, using the costs curves, the costs per segment are calculated for each manufacturer and these costs are summed to calculate total costs for the complete market. Using a solver these total costs are then minimised by varying the price of emission credits (= marginal emission reduction costs).

Besides total costs also the trading volumes per manufacturer are calculated.

**2012: Percentage reduction target / per manufacturer including emission trading**

Under this option each manufacturer has to reduce the average CO\textsubscript{2} emission per car of its fleet of newly sold cars by a fixed reduction percentage, but is allowed to trade emission credits if he does not meet this goal or achieves a higher reduction percentage. The reduction goal is the percentage with which the overall average emissions per car (all manufacturers) have to be reduced to reach the 2012 goal based on the 2006 average. Again it is assumed that each manufacturer tries to reach this goal at minimum costs, where the total costs are the costs for reducing the emissions of the vehicles produced by the manufacturer plus the costs of buying emission credits or the revenues from selling credits.

Calculations for this case follow largely the same procedure as for the case of a fixed target per manufacturer including the possibility of emission trading. The only difference is that the target per manufacturer is determined at the level of the sales averaged CO\textsubscript{2} emissions instead of by sales-weighted averaging of the targets per segment.

**2012: Utility-based target / per manufacturer including emission trading**

Under this option for each manufacturer a target for the total CO\textsubscript{2} emission of its fleet of newly sold cars in 2012 is determined by multiplying the sales in the different segments with the utility based emission limit of the segments, and summing these emissions per segment to a total emission of the manufacturer.

It is again assumed that each manufacturer will adopt a rational strategy by which he will reduce emissions for the different segments until the marginal costs for the different segments are equal to the price of traded emission credits. Calculations for this case then follow the same procedure as for the case of a fixed target per manufacturer including the possibility of emission trading.
Annex B  Input data

Input data for the assessment model contain the following main categories:
- data on sales numbers, average CO\textsubscript{2} emission, average mass and average pan area per segment per manufacturer for 2002 and 2006;
- assumptions on market trends related to sales shifts, the petrol-to-diesel shift and autonomous mass increase
- cost curves (described in the main text of this note).

Assumptions on market trends

Sales growth 2006 - 2012

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Shift petrol -> diesel

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Notes:
- Assumed sales growth is uniform and does not affect costs and distributional effects.
- The end point for the petrol to diesel shift is kept the same as in previous calculations: 45% petrol and 55% diesel as shares of new vehicle sales in 2012.
- For autonomous mass increase four scenarios have been assessed: AMI = 0.0%, 0.82%, 1.5% and 2.5% p.a. (see main text of this note).

Data on sales numbers, average CO\textsubscript{2} emission, average mass and average pan area per segment per manufacturer

The tables on the next pages present the data on sales numbers, average CO\textsubscript{2} emission, average mass and average pan area per segment per manufacturer for 2002 and 2006. 2002 data are derived from information supplied by Polk Marketing Systems. 2006 data are aggregated from AAA data supplied to the consultants by the European Commission.
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Annex C  Method for assessing the amount of CO₂ reduction applied in 2002-2006 period

Defining plausible upper and lower limits for the CO₂ reduction through technical means

The cost curves from [TNO 2006] are defined relative to average 2002 reference vehicles for the six segments. In order to be able to calculate the cost for going from the 2006 value for a given segment to the 2012 target, also the applied level of CO₂ reduction measures in the 2002 – 2006 period has to be known. Due to the non-linearity of the cost curves higher reductions applied between 2002 and 2006 lead to higher the costs for a given absolute reduction in the 2006 – 2012 period.

Obviously we do not have information about which technologies and which associated CO₂ reductions have been applied in the 2002 – 2006 period to the vehicle models in our database or to the average vehicle in every segment for the different manufacturers. We therefore have to make an approximate estimate based on the known information. This information is:

- average CO₂ emissions per segment per manufacturer in 2002 and 2006, referred to as CO₂²⁰⁰² and CO₂²⁰⁰⁶;
- average mass per segment per manufacturer in 2002 and 2006, referred to as m²⁰⁰² and m²⁰⁰⁶.

In a first approximation we can now write the amount of CO₂ reduction through technical measures applied in the 2002 – 2006 period as:

\[ \Delta \text{CO}_2^{\text{techn.red.meas}} = \text{CO}_2^{2002} - \text{CO}_2^{2006} + 0.65 \times \text{CO}_2^{2002} \times (m^{2006} - m^{2002}) / m^{2002} \]  

(1)

in which we assume as first order approximation that all change in average mass is the result of autonomous mass increase (AMI). Mass changes between 2002 and 2006, however, can result from two main causes:

- autonomous mass increase, i.e. every new version of a model gaining mass compared to the previous version;
- sales shifts within a segment, e.g. increases of the sales of a given model within a segment that is more or less heavy than the 2002 average mass for that segment.

In a generalised form the amount of change in CO₂ emissions between 2002 and 2006 can therefore be written as follows:

\[
\Delta \text{CO}_2^{2002 - 2006} = \Delta \text{CO}_2^{\text{techn.red.meas}} - \Delta \text{CO}_2^{\text{AMI}} - \Delta \text{CO}_2^{\text{sales shift}}
\]

\[
= \Delta \text{CO}_2^{\text{techn.red.meas}} - 0.65 \times \text{CO}_2^{2002} \times \Delta m^{\text{AMI}} / m^{2002} - g \times \Delta m^{\text{sales shift}}
\]  

(2)

with g the slope of the relation between average mass and average CO₂ emission of vehicles. The slope g can be derived from an unweighted least squares fit through the CO₂ and mass values of all vehicles in the database and equals about 0.117. Using the relation:

\[
\Delta m^{2006-2002} = m^{2006} - m^{2002} = \Delta m^{\text{AMI}} + \Delta m^{\text{sales shift}}
\]  

(3)
we can rewrite the formula (2) to read:

\[
\Delta CO_2^{\text{techn.red.meas}} = CO_2^{2002} - CO_2^{2006} + \Delta m^{\text{AMI}} \times (0.65 \times CO_2^{2002} / m^{2002} - g) + g \times \Delta m^{2006-2002}
\]  

(4)

In this equation the only unknown variable is \(\Delta m^{\text{AMI}}\). Varying \(\Delta m^{\text{AMI}}\) in formula (4) over a bandwidth of reasonably possible values gives information about the bandwidth in which \(\Delta CO_2^{\text{techn.red.meas}}\) for a given manufacturer and segment can fall.

As a lower limit we can assume:

\[
\Delta m^{\text{AMI}} \geq 0
\]  

(5)

as vehicle models certainly have not become lighter over the past 4 years. As:

\[
(0.65 \times CO_2^{2002} / m^{2002} - g) < 0 \text{ for } g = 0.117,
\]

filling in \(\Delta m^{\text{AMI}} = 0\) in formula (4) gives an upper limit for \(\Delta CO_2^{\text{techn.red.meas}}\). There is no fixed upper limit to \(\Delta m^{\text{AMI}}\). Assuming the maximum mass increase is n\% p.a. the upper limit for \(\Delta m^{\text{AMI}}\) would equal \((n\%)^4 \times m^{2002}\). Using the fixed lower limit and estimated upper limit for \(\Delta m^{\text{AMI}}\) formula (4) can be used as a plausibility check on the value of \(\Delta CO_2^{\text{techn.red.meas}}\) as estimated by formula (1):

\[
\Delta CO_2^{\text{techn.red.meas}} \leq CO_2^{2002} - CO_2^{2006} + g \times \Delta m^{2006-2002}
\]  

(6)

\[
\Delta CO_2^{\text{techn.red.meas}} \geq CO_2^{2002} - CO_2^{2006} + (n\%)^4 \times m^{2002} \times (0.65 \times CO_2^{2002} / m^{2002} - g) + g \times \Delta m^{2006-2002}
\]  

(7)

- If for a given manufacturer and segment the value of \(\Delta CO_2^{\text{techn.red.meas}}\) from formula (1) exceeds the value from formula (6) the value is set equal to that of formula (6) for that manufacturer and segment;
- If for a given manufacturer and segment the value of \(\Delta CO_2^{\text{techn.red.meas}}\) from formula (1) is below the value from formula (7) the value is set equal to that of formula (7) for that manufacturer and segment;

As we may assume that vehicles do not become less efficient (although they may consume more energy due to increased mass or increased use of accessories) another known limit is that:

\[
\Delta CO_2^{\text{techn.red.meas}} \geq 0
\]
Corrections to $\text{CO}_2^{2002}$ to account for a possible petrol to diesel shift occurring in the 2002 – 2006 period

For the diesel vehicles in the cost assessment model the value of $\text{CO}_2^{2002}$, as used in the formula's above, is not the $\text{CO}_2$ value from the 2002 Polk database but a baseline value corrected for effects of occurring petrol-to-diesel shifts. If in the period 2002 – 2006 a sales shift occurs from a given petrol segment to the equivalent diesel segment (eg because a given model is now also offered with a diesel engine) then the 2002 reference $\text{CO}_2$ value for these new diesels is not the original 2002 average $\text{CO}_2$ emission of that diesel segment but a value that relates to the $\text{CO}_2$ emission of the equivalent petrol model. In the model the 2002 baseline $\text{CO}_2$ emission for these diesel vehicles is calculated as the 2002 baseline value for the petrol vehicles times a correction factor accounting for the average $\text{CO}_2$ benefit of diesels over petrol vehicles. This baseline $\text{CO}_2$ emission is then mixed in with that of the already existing diesel share in 2002 (if any, which is not the case for Porsche) on the basis of sales weighted averaging to arrive at a corrected 2002 reference value of the average $\text{CO}_2$ emissions of the diesel segment under consideration.

Obviously the amount of petrol-to-diesel shift occurring in the 2002 – 2006 period can not be known exactly from the know data. The method used to estimate the amount of petrol-to-diesel shift and the necessary amount of correction of the 2002 reference $\text{CO}_2$ value is:

- If the sales growth in a given diesel segment is larger than the growth of the sales of that manufacturer averaged over all segments then the surplus is interpreted as sales shifted from petrol to diesel.

**Results**

Using the above described approach the following $\text{CO}_2$ reductions through application of technical measures are estimated for the various manufacturers.
Introduction

This note analyses the 2006 sales of all manufacturers offering cars on the European market, as part of quantitative assessments performed in the context of the project “Possible regulatory approaches to reducing CO\textsubscript{2} emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

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   2.1 Bubble graphs for overall sales .....................................................................................................101
   2.2 Bubble graphs for sales of petrol vehicles .....................................................................................102
   2.3 Bubble graphs for sales of diesel vehicles .....................................................................................103

Analysis of 2006 sales in terms of average CO\textsubscript{2} emissions and utility parameter values

- All data shown and analysed in this note are based on 2006 AAA data supplied to the consultants by the Commission.
- In the table below manufacturers are listed from top to bottom based on increasing sales averaged 2006 CO\textsubscript{2} emissions.

<table>
<thead>
<tr>
<th>manufacturer</th>
<th>CO\textsubscript{2} mass</th>
<th>CO\textsubscript{2} pan area</th>
<th>CO\textsubscript{2} sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSA</td>
<td>141,7</td>
<td>1201</td>
<td>7,12</td>
</tr>
<tr>
<td>Fiat</td>
<td>143,8</td>
<td>1112</td>
<td>6,75</td>
</tr>
<tr>
<td>Renault</td>
<td>147,5</td>
<td>1234</td>
<td>7,30</td>
</tr>
<tr>
<td>Toyota</td>
<td>151,9</td>
<td>1214</td>
<td>7,07</td>
</tr>
<tr>
<td>Honda</td>
<td>153,5</td>
<td>1261</td>
<td>7,41</td>
</tr>
<tr>
<td>GM</td>
<td>156,9</td>
<td>1257</td>
<td>7,34</td>
</tr>
<tr>
<td>Ford</td>
<td>161,6</td>
<td>1319</td>
<td>7,78</td>
</tr>
<tr>
<td>Nissan</td>
<td>164,2</td>
<td>1202</td>
<td>6,99</td>
</tr>
<tr>
<td>Suzuki</td>
<td>164,4</td>
<td>1152</td>
<td>6,59</td>
</tr>
<tr>
<td>Hyundai</td>
<td>164,8</td>
<td>1349</td>
<td>7,26</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>165,0</td>
<td>1366</td>
<td>7,71</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>168,8</td>
<td>1245</td>
<td>7,19</td>
</tr>
<tr>
<td>Mazda</td>
<td>173,2</td>
<td>1296</td>
<td>7,75</td>
</tr>
<tr>
<td>BMW</td>
<td>182,2</td>
<td>1453</td>
<td>7,95</td>
</tr>
<tr>
<td>DaimlerChrysler</td>
<td>183,9</td>
<td>1472</td>
<td>8,01</td>
</tr>
<tr>
<td>Subaru</td>
<td>215,9</td>
<td>1384</td>
<td>7,77</td>
</tr>
<tr>
<td>Porsche</td>
<td>282,1</td>
<td>1596</td>
<td>8,24</td>
</tr>
<tr>
<td>Average</td>
<td>159,2</td>
<td>1289</td>
<td>7,43</td>
</tr>
</tbody>
</table>
• The bubble graphs on the next pages are derived from the table above and separate data for petrol and diesel sales and compare manufacturers with respect to average weight, average pan area, average CO\textsubscript{2} emissions and sales.
  o These bubble graphs are helpful in explaining how different options (especially different slopes for the utility based limit functions) work out for different manufacturers.

• Some observations from the bubble graphs:
  o In the graphs for $U = l \times w$ in combination with overall sales as well as diesel sales Suzuki has an extreme position with low average $l \times w$ and an above-average CO\textsubscript{2} emission.
  o Subaru only sells relatively large petrol vehicle with above average weight and $l \times w$ and a CO\textsubscript{2} emission that is slightly above average. The absence of diesel vehicles in the Subaru sales leads to an extreme position in terms of average CO\textsubscript{2} emissions in the graphs for overall sales.
  o Based on overall sales for Hyundai the average mass is above average while average $l \times w$ is below average. The high average mass is caused by sales of heavy SUVs (with relatively low $l \times w$) in the diesel segment.
  o The diesel sales for Mitsubishi are mainly heavy SUVs with relatively low $l \times w$.

• Fiat on average sells the smallest and lightest cars but the average CO\textsubscript{2} emissions are above average (i.e. above the least squares fit through the sales of all manufacturers). In the diesel segment the average CO\textsubscript{2} emission for Fiat is higher than for PSA, which sells vehicles with higher average weight and $l \times w$. 

2.1 Bubble graphs for overall sales

- Average CO₂ emissions per manufacturer as function of average utility (total sales): size of bubbles indicates total sales.
2.2 Bubble graphs for sales of petrol vehicles

- Average CO$_2$ emissions per manufacturer as function of average utility (sales of petrol vehicles only): size of bubbles indicates total sales of petrol vehicles.
2.3 Bubble graphs for sales of diesel vehicles

- Average CO$_2$ emissions per manufacturer as function of average utility (sales of diesel vehicles only): size of bubbles indicates total sales of diesel vehicles.
Possible regulatory approaches to reducing CO₂ emissions from cars

Technical note 8: Definition of utility-based limit functions

1 Introduction

This note reports on methodological aspects of the definition of utility-based limit functions in the context of the project “Possible regulatory approaches to reducing CO₂ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

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  2.1 Definition of utility-based limit functions with different slopes ......................................105
  2.2 Definition of slopes optimised for costs or equal distribution ...........................................109
  2.3 Slope of mass-based limit function i.r.t. CO₂ impacts of mass increase or mass reduction.....112

Annex A Note on slope of mass-based limit function i.r.t. perverse effects

2 Utility-based limit functions

2.1 Definition of utility-based limit functions with different slopes

• In the discussion below only mass (m) and pan area (l x w) are considered as utility parameters.
• Utility-based limit functions are defined and named as follows¹:
  o First a sales-weighted least squares fit \((a U + b)\) of the 2006 data is calculated (see graphs below).
    ▪ The vehicles with zero CO₂ emission in the graph below are electric vehicles. Due to the low sales numbers these do not affect the fit.

¹ For ease of communication this method is chosen equivalent to the one used by ACEA.
Unweighted and sales-weighted least squares fits \((aU + b)\) through the 2006 new vehicle sales plotted by \(\text{CO}_2\) as function of mass for all vehicle models.

\[
\begin{align*}
\text{2006 } \text{CO}_2 \text{ vs mass} \\
\text{sales weighted least squares fit: } \text{CO}_2 &= 0.0034 \times \text{mass} + 38.705 \\
\text{unweighted least squares fit: } \text{CO}_2 &= 0.111 \times \text{mass} + 21.8056
\end{align*}
\]

Unweighted and sales-weighted least squares fit \((aU + b)\) through the 2006 new vehicle sales plotted by \(\text{CO}_2\) as function of pan area \((l \times w)\) for all vehicle models.

\[
\begin{align*}
\text{2006 } \text{CO}_2 \text{ vs } l \times w \\
\text{sales weighted least squares fit: } \text{CO}_2 &= 22.703 \times (l \times w) - 9.1539 \\
\text{unweighted least squares fit: } \text{CO}_2 &= 22.156 \times (l \times w) + 18.1956
\end{align*}
\]
Starting point for the definition of 2012 limit functions is the so-called “100%” line which is determined assuming that all vehicles have to undergo the same relative CO₂ reduction between 2006 and 2012. To this end a factor \( \alpha \) is applied to both the a and b of the fit on the 2006 data to determine the reference utility function for 2012.

- If the average utility stays the same between 2006 and 2012 this relative reduction \( \alpha = 130 / <\text{CO}_2>_{2006} \) with \( <\text{CO}_2>_{2006} \) the sales weighted average CO₂ emission in 2006. The latter is 159.2 g/km yielding \( \alpha = 0.817 = (1 – 18.3\%) \).
- However, if the average utility changes between 2006 and 2012 (in the case of mass as utility parameter this would e.g. be the result of autonomous mass increase), then \( \alpha \) is determined from the relation \( \alpha (a <\text{CO}_2>_{2012} + b) = 130 \).
- In the case of the scenario studied in this note with an assumed autonomous mass increase of 0.82% p.a. the value of \( \alpha = 0.786 = (1 – 21.4\%) \).

The above means that in setting the utility based limit function for 2012 requires an assumption about the autonomous evolution of the average value of the utility parameter. If this value is assumed to remain constant but increases in practice the 130 g/km target will not be reached in 2012!

Alternative limit functions for 2012 can now be defined by rotating the sloped line around the \( (<U>_{2012}, 130 \text{ g/km}) \) pivot point (see above graph). The alternative limit functions can then be labelled according to the ratio between the slope of the line and the “100%” reference function.

Slopes higher than 100% give a tighter limit for smaller vehicles and a less tight limit for large vehicles. For slopes below 100% the required reduction on small cars becomes less, while the limit for large vehicles becomes tighter.
Sloped limit functions for 2012 always fulfill the condition that:
- \( a <U>_{2012} + b = 130 \), with \(<U>_{2012}\) the sales weighted average utility value in 2012, so that for any value of \( a \) the y-axis intercept \( b \) can be calculated.
- In the calculations presented in Note 9 on “Quantitative analysis of various options with the updated model” slope values between 0% (uniform target of 130 g/km) and 120% have been used. As an example for the case of zero autonomous mass increase (AMI = 0.0% p.a.) the slope values are:

Utility based limit functions for scenario c (AMI = 0.0% p.a.).

<table>
<thead>
<tr>
<th>utility-based limit function ((a \times U + b))</th>
<th>mass</th>
<th>l x w</th>
</tr>
</thead>
<tbody>
<tr>
<td>least squares fit 2006</td>
<td>0.0934</td>
<td>38.7</td>
</tr>
<tr>
<td>slope 120%</td>
<td>120%</td>
<td>0.0914</td>
</tr>
<tr>
<td>slope 100%</td>
<td>100%</td>
<td>0.0762</td>
</tr>
<tr>
<td>slope 80%</td>
<td>80%</td>
<td>0.0610</td>
</tr>
<tr>
<td>slope 60%</td>
<td>60%</td>
<td>0.0457</td>
</tr>
<tr>
<td>slope 40%</td>
<td>40%</td>
<td>0.0305</td>
</tr>
<tr>
<td>slope 20%</td>
<td>20%</td>
<td>0.0152</td>
</tr>
<tr>
<td>slope 0%</td>
<td>0%</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Slope values for other AMI scenarios (0.82%, 1.5% and 2.5% p.a.) are reported in Note 9 on “Quantitative analysis of various options with the updated model”.
2.2 Definition of slopes optimised for costs or equal distribution

- Besides these straightforward slope variations also the following options have been investigated for the case of utility-based limit functions applied per manufacturer without trading:
  - a “cost optimised slope” for which the average costs per vehicle are minimal (in the per manufacturer - utility variant without trading);
  - a “weighted equalised distribution” and an “unweighted equalised distribution variant in which the slope is optimised for an even distribution of the burden over all manufacturers;
  - The optimised slope values given in the table below are for the exemplary case of zero autonomous mass increase (AMI = 0.0% p.a.). Optimised slope values for other AMI scenarios (0.82%, 1.5% and 2.5% p.a.) are reported in Note 9 on “Quantitative analysis of various options with the updated model”. Explanation on how these values have been derived is given below.

Utility based limit functions for scenario c (AMI = 0.0% p.a.): specific cases

<table>
<thead>
<tr>
<th>utility-based limit function (a U + b)</th>
<th>mass</th>
<th>l x w</th>
<th>a</th>
<th>b</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>cost optimised slope</td>
<td>123%</td>
<td>0.0936</td>
<td>9.1</td>
<td>123%</td>
<td>22.63</td>
<td>-38.4</td>
</tr>
<tr>
<td>weighted equalised distribution</td>
<td>80%</td>
<td>0.0606</td>
<td>51.7</td>
<td>67%</td>
<td>12.37</td>
<td>38.0</td>
</tr>
<tr>
<td>unweighted equalised distribution</td>
<td>39%</td>
<td>0.0295</td>
<td>91.8</td>
<td>18%</td>
<td>3.26</td>
<td>105.8</td>
</tr>
</tbody>
</table>

- For the “cost optimised slope” variant the slope is determined by running the model for a large number of increasing slope values. See the graphs below.
  - As can be seen from the graphs below the cost optimised slope is above 100% for both mass and pan area as utility parameters.
  - However, for the options with a target applied to the sales weighted average per manufacturer it is clear that the average costs per car vary only slightly with the value of a for slopes between 60% and 140%.
  - Both for mass and for pan area minimum costs are achieved with a 123% slope.
  - The mass-based limit function yields a somewhat lower value of the minimum costs than the limit function based on pan area.
- When utility-based limit functions are applied per car the cost optimal slope may be different.
- For utility-based limit functions applied to manufacturers with the possibility of trading all slopes (and all other options) yield the same average costs per vehicle.
The “weighted equalised distribution” and “unweighted equalised distribution” variants are based on the slope for which the relative retail price increase per manufacturer is most evenly distributed. This slope is determined by minimizing the sum of the squared distances between the average relative retail price increase per manufacturer and the overall average relative retail price increase.

For each manufacturer we calculate the difference (“distance”) between the average relative retail price increase for that manufacturer and the overall average relative cost increase. The square of these distances for each manufacturer can be summed (either with equal weights or weighted by the overall sales number per manufacturer). The assessment of costs is then performed for a range of values for the slope of the limit function. In the results (see the two graphs below) we then look for the slope that yields the lowest result for the sum of squared distances. This approach is basically the least squares approach.
In case of the “weighted equalised distribution” the squared distances are weighted by the sales per manufacturer. This comes down to minimising the difference between the relative retail price increase per vehicle and the average over all vehicles sold.

In case of the “unweighted equalised distribution” the distances per manufacturer have equal weights. This comes down to minimising the difference between the relative retail price increase per vehicle and the average over all manufacturers. This option will yield the most optically even distribution in the graphs presented later on.

Both variants are only assessed for the option of a utility-based limit function applied per manufacturer without trading.

For both calculations the values for Porsche and Subaru have been excluded. Both manufacturers have high average CO₂ emissions, only have sales in a limited number of segments and sell vehicles which are not representative for these segments. Including these manufacturers creates a strong leverage on the equalisation that goes at the expense of the costs for other manufacturers.
The fact that the minimum in the 4 curves shown in the graphs above is always significantly above zero means that there is no value of the slope for which the relative cost increase is the same for all manufacturers. There will always be manufacturers above and below the average!

2.3 Slope of mass-based limit function in relation to CO₂ impacts of mass increase or mass reduction

- For mass-based utility functions it is important to choose the slope in such a way that perverse effects and stimulation of unwanted market trends are avoided.
  - **Perverse effects**: When adding mass to the vehicle leads to an increase in CO₂ emission limit that is higher than the additional CO₂ emission due to the added mass, manufacturer can manipulate their vehicles to make it easier to meet the target set per vehicle or on the sales weighted average CO₂ emissions per manufacturer.
  - **Unwanted market trends**: For high slopes of the mass-based limit function the required relative CO₂ reduction is smaller for larger, heavier vehicles than for small, light vehicles. As a consequence the relative (and maybe even absolute) retail price increase associated with the required CO₂ reduction will be smaller for larger vehicles. In that case manufacturers might be tempted to promote these large, heavy vehicles as means to alleviate the efforts required to meet their CO₂ reduction target. Even without marketing efforts to this extent, the change in the relative price ratio of large and small cars will lead to a shift in sales towards larger, heavier cars.

- Besides these above unwanted effects a mass-based limit function with a high slope also reduces the contribution of weight reduction measures to meeting the target per vehicle or per manufacturer.
- In Annex A a comparison is made between the slope of mass-based limit functions and the effect of mass increase or decrease on CO₂ emissions.
- From Annex A it is clear that mass-based limit functions with a slope less than about 80% would eliminate the incentive to use mass increase as a perverse means to reduce the required amount of CO₂ reduction through technical measures for a given vehicle model.
- For slopes lower than 80% the required reduction effort increases if vehicle mass increase, with smaller slopes leading to an increasingly stronger disincentive for mass increase.
Annex A  Note on slope of mass-based limit function i.r.t. perverse effects

Introduction

To assess the extent to which a mass-based limit function creates perverse incentives one needs to look at the effects of mass increase or decrease on a vehicle’s CO₂ emission and compare these effects with the effect of the same mass variation on the limit value set by the mass-based limit function. If adding weight to a vehicle moves the vehicle closer to the target line, the mass based limit function can be said to create a perverse incentive for manufacturers to game the legislation by making vehicles heavier or by selling heavier vehicles.

Three types of gaming

Option 1 is a gaming option which is often referred to as the proverbial “brick in the boot”. Manufacturers may simply add weight to the body-in white or other parts of the vehicle or may even add removable items to the vehicle (e.g. additional seats) that add weight on the type approval test but are removed from the car by most users. This added weight will lead to a loss of performance (due to lower power-to-weight ratio), but this could be acceptable if the added weight is limited. In the short term this may be a means of achieving a sales weighted CO₂ emission target at low costs, but in the longer run it would seem that heavier cars with reduced performance will be hard to sell. In the initial analysis performed in the course of this study this gaming option was not considered likely. As a consequence is it was not studied in detail and was not taken into account in determining the maximum slope for avoiding perverse incentives, However, this possible cheating route might deserve further study in the future.

Option 2 is to add mass to the car while at the same time applying compensating measures to engine and powertrain to maintain vehicle performance. This is the mechanism that also corresponds to the term autonomous mass increase where vehicle models get heavier over time due to e.g. additional passive safety measures and increased comfort. This autonomous mass increase (AMI) is taken into account in the modelling as an annual weight increase of all models within a given vehicle class.

Option 3 is the mechanism that corresponds to upward or downward market shifts, e.g. consumers buying on average larger and better performing cars or smaller and less performing cars. In case of an upward market shift this trend will also lead to an increase of the average mass of newly sold vehicles over time. Manufacturers can to some extent influence this trend by marketing and pricing strategies.

---

2 An issue to be assessed is the option of after sales chip tuning of the engine to compensate for possible performance loss due to mass increase. This option might also be a gaming opportunity irrespective of the choice of utility parameter.
The relation between mass and CO$_2$

CO$_2$ emissions generally increase with increasing vehicle mass. The amount by which CO$_2$ emissions increase depends on whether measures are taken to compensate for loss of performance$^3$, and will thus be different for the three gaming options identified above.

In the TNO/IEEP/LAT 2006 study$^4$ the following generalised formula is used to describe the impact of a (relatively small) mass increase/decrease on CO$_2$ emissions (and fuel consumption):

$$\Delta CO_2 / CO_2 = \gamma \times \Delta m / m$$ (1)

One reason to use this somewhat complex power law relation between CO$_2$ and mass is that it in good approximation allows the same formula to be applied with the same average value for $\gamma$ for all size segments discerned in the cost assessment model. Formula (1) has been derived on the basis of information on existing vehicles, but the power law relation (expressed in formula (1) as a linear relation between relative changes of CO$_2$ and mass) also enables application of the formula to future vehicles which may be more efficient (lower CO$_2$) or lighter/heavier (lower/higher $m$).

All of this, however, means that it is a generalised formula that is valid for current and future average cars but not necessarily to all individual cars, and that not all mathematical details of the formula necessarily have a physical significance. For the moment we will, however, use formula (1) as a starting point for our analysis.

The value of $\gamma$ in formula (1) depends on other measures applied to the vehicle in relation to the mass increase/decrease, as has been explored in Annex C of [TNO/IEEP/LAT 2006], and will thus be different for the three gaming options identified above:

Option 1 is equivalent to the situation of adding a payload to an existing vehicle. Based on measurements carried out on light commercial vehicles on petrol as well as diesel$^5$, [TNO/IEEP/LAT 2006] reports a average value for $\gamma$ of around 0.35 for this option.

When a new vehicle becomes heavier due to e.g. increased size or added components and auxiliaries, manufacturers can compensate the increased mass by an increase in engine power to maintain vehicle performance. Under these circumstances, which are represented by gaming option 2, the value of $\gamma$ is around 0.65 according to Annex C of [TNO/IEEP/LAT 2006]. This value is derived on the basis of relations between fuel consumption and mass supplied by ACEA for 2002 petrol and diesel vehicles. According to information from ACEA adding 100 kg to a petrol vehicle results in a fuel consumption increase of 0.4 l/100km. For diesel vehicles adding 100 kg results in a fuel consumption increase of 0.3 l/100km. The

$^3$ Or vice versa to reduce engine power to maintain performance in the case of mass reduction.
$^4$ [TNO/IEEP/LAT 2006] - Review and analysis of the reduction potential and costs of technological and other measures to reduce CO$_2$ emissions from passenger cars, R. Smokers et al., study carried out on behalf of the European Commission DG ENTR (contract. nr. SI2.408212), October 2006. Report can be downloaded from: http://ec.europa.eu/enterprise/automotive/pagesbackground/pollutant_emission/index.htm#co2
appropriateness of using a constant factor of the order of 0.65 is further confirmed by the fact that calculations on the effect of weight change on the energy $E$ required at the wheels, calculated for small/medium/large vehicles with typical values for mass and resistance factors on the NEDC. This relation can be written as $\Delta E/E = \eta \Delta m/m$ with $\eta = 0.62 - 0.69$. Assuming that the (scaled) engine map remains roughly the same when the engine is scaled to adapt to the changed power requirement at the wheels, the powertrain efficiency can be assumed constant so that $\Delta CO_2/CO_2 \approx \Delta E/E$.

Assuming that the relations provided by ACEA are valid independent of vehicle weight or size, the table below translates these relations into the coefficient $\gamma$ in formula (1) and the slope of the line that determines the ratio between CO$_2$ increase and mass increase for petrol and diesel vehicles in the three size segments:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Segment</th>
<th>CO$_2$ [g/km]</th>
<th>m [kg]</th>
<th>fc [l/100km]</th>
<th>$\Delta m$ [kg]</th>
<th>$\Delta fc$ [l/100km]</th>
<th>$\Delta CO_2$ [g/km]</th>
<th>$\gamma = (\Delta CO_2/CO_2)/(\Delta m/m)$</th>
<th>$\Delta CO_2/\Delta m$</th>
<th>Slope</th>
<th>Relative slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol</td>
<td>Small</td>
<td>149</td>
<td>957</td>
<td>6.3</td>
<td>100</td>
<td>0.400</td>
<td>9.5</td>
<td>0.61</td>
<td>0.095</td>
<td>124%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>184</td>
<td>1261</td>
<td>7.8</td>
<td>100</td>
<td>0.400</td>
<td>9.5</td>
<td>0.65</td>
<td>0.095</td>
<td>124%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>238</td>
<td>1500</td>
<td>10.0</td>
<td>100</td>
<td>0.400</td>
<td>9.5</td>
<td>0.60</td>
<td>0.095</td>
<td>124%</td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>Small</td>
<td>123</td>
<td>1029</td>
<td>4.7</td>
<td>100</td>
<td>0.300</td>
<td>7.8</td>
<td>0.65</td>
<td>0.078</td>
<td>103%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>153</td>
<td>1365</td>
<td>5.9</td>
<td>100</td>
<td>0.300</td>
<td>7.8</td>
<td>0.70</td>
<td>0.078</td>
<td>103%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>201</td>
<td>1690</td>
<td>7.7</td>
<td>100</td>
<td>0.300</td>
<td>7.8</td>
<td>0.66</td>
<td>0.078</td>
<td>103%</td>
<td></td>
</tr>
</tbody>
</table>

This table shows that there is a spread in the value for $\gamma$ depending on vehicle size segment, but that this (due to the assumption that the ACEA relations are independent of vehicle size of mass) does not translate into a spread in slope values. The table, however, shows that the slope of the line that determines the ratio between CO$_2$ increase and mass increase does strongly depend on fuel. This means that for diesel vehicles a lower limit function slope may be necessary to avoid perverse incentives than is the case for petrol vehicles. It is furthermore reasonable to assume that the impact of mass increase may be different for vehicles with the same mass but different power-to-weight ratios (e.g. comparing a “normal” sedan to a sports car in the same weight class) or for vehicles with different engine efficiencies.

As a means to further explore the sensitivity of the above determination of $\gamma$ the tables below show values of $\gamma$ derived for a $\pm 15\%$ variation in the value with which fuel consumption increases in response to a 100 kg mass increase. Clearly a variation in this relation leads to a variation in the value of $\gamma$ and in the slope $\Delta CO_2/\Delta m$ of the same order of magnitude. The slope values are calculated for 2002 baseline vehicles with average mass and CO$_2$ emissions based on 2002 sales statistics. The impacts of the variation in $\gamma$ on the slope for CO$_2$ as function of mass for vehicles closer to various 2012 target lines is explored further on.
Option 3 corresponds to upward market shifts. When vehicles of different mass, as offered in the market, are compared one finds $\gamma$ to be significantly higher than $0.65$, as heavier and larger vehicles on average have better performance (i.e. higher power-to-weight ratio) than smaller and lighter cars and consequently a lower power train efficiency under normal driving conditions (i.e. more part load driving) than lighter / smaller cars:

- A analysis of 2003 statistics of newly sold vehicles, as referred to in [TNO/IEEP/LAT 2006], yields a value for $\gamma$ of around 0.93;
- The unweighted least-squares fit through the 2006 data depicted in the graph below equals $CO_2 = 0.117 \times mass + 24.8$, and represents the general correlation between $CO_2$ and mass of all vehicle models available in the market. Combining this linear relation $CO_2 = a \times m + b$ with equation (1) the coefficient $\gamma$ can be written as: $\gamma = \frac{a \times m}{a \times m + b}$. For an average mass of around 1300 kg this equation yields a value for $\gamma$ of around 0.86. For mass values of 900 resp. 2000 kg the value for $\gamma$ ranges from 0.81 to 0.90.
- The weighted least-squares fit through the 2006 data depicted in the graph below equals $CO_2 = 0.0934 \times mass + 38.7$. For an average mass of around 1300 kg this equation yields a value for $\gamma$ of around 0.76. For mass values of 900 resp. 2000 kg the value for $\gamma$ ranges from 0.68 to 0.83.
Unweighted and sales-weighted least squares fits (a U + b) through the 2006 new vehicle sales plotted by CO\textsubscript{2} as function of mass for all vehicle models

\begin{center}
\begin{figure}
\centering
\includegraphics[width=\textwidth]{2006_CO2_vs_mass_graph}
\caption{2006 CO\textsubscript{2} vs mass}
\end{figure}
\end{center}

In the analysis presented below we focus on impact of slope values for a mass-based limit function in relation to gaming option 2. If the slope is chosen such that the perverse incentive described by option 2 is avoided, also option 3 will be avoided. Possibly option 1 can be avoided to some extent by tightening the requirements for type approval testing. A brief analysis of option 1 is included after the discussion on gaming option 2 below.

\textit{Translating the impacts of weight increase to limit-function slope values for the case of gaming option 2}

As mentioned above the formula used in the cost assessment model for calculating the effect on CO\textsubscript{2} emissions of autonomous mass increase is:

\[ \frac{\Delta \text{CO}_2}{\text{CO}_2} = 0.65 \times \frac{\Delta m}{m} \]  \hspace{1cm} (2)

This formula assumes that vehicle performance (acceleration, top speed, towing capability, etc.) is maintained through adjustment of the power-to-weight ratio when a vehicle “gains weight”. Formula (2) can be written as:

\[ \frac{\Delta \text{CO}_2}{\Delta m} = 0.65 \times \frac{\text{CO}_2}{m} \hspace{0.5cm} \text{or} \hspace{0.5cm} f'(x) = 0.65 \frac{f(x)}{x} \]  \hspace{1cm} (3)

Solving this differential equation gives:

\[ \text{CO}_2 = \text{const.} \times m^{0.65} \]  \hspace{1cm} (4)
where the constant can be tuned so that the function fits the CO\textsubscript{2} and mass of a given vehicle or vehicle class. Equation (4) shows that for all practical purposes this function is almost linear, as is also illustrated in the graph below. This means that for mass changes up to a few hundred kg the slope of the function in the point defined by a vehicle’s initial mass and CO\textsubscript{2} emission is a sufficiently good indicator of the impact of mass change on CO\textsubscript{2} for that vehicle.

The slope of the line indicating how CO\textsubscript{2} changes as a result of mass increase (accompanied by technical measures to the power train to maintain performance at the same level) obviously depends on the initial mass and CO\textsubscript{2} emission of the vehicle. For the average vehicle in 2006 the slope equals:

\[ a = \frac{\Delta \text{CO}_2}{\Delta \text{m}} = 0.65 \times \text{avg. CO}_2 / \text{avg. mass} = 0.65 \times \frac{159.2}{1289} = 0.0803 \]  

(5)

The formula (2) used for calculating the effect of autonomous mass increase on CO\textsubscript{2} emissions assumes that performance (acceleration, top speed, etc.) is maintained through adjustment of the power-to-weight ratio when a vehicle “gains weight”. When existing models are compared regarding CO\textsubscript{2} and mass one sees that CO\textsubscript{2} rises faster with mass as heavier / larger cars usually have a higher power-to-weight ratio and consequently better performance but lower power train efficiency under normal driving conditions (more part load driving) than lighter / smaller cars.

The graph below shows the slopes of two sets of mass variations:
- one set of three examples of vehicles that are on the line determined by the sales weighted fit of CO\textsubscript{2} against mass for all vehicles sold in 2006;
- one set of three examples of vehicles that are on the line determined by the 100% mass-based limit function that yields an average of 130 g/km in 2012.
The table below shows the slope (a) and offset (b) values of the lines (CO₂ = a x m + b) describing resp. the sales weighted least squares fit through the 2006 data, as well as for a range of mass-based limit functions with slopes ranging from 100% to 20%.

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 sales weighted least squares fit</td>
<td>0.0934</td>
<td>38.71</td>
</tr>
<tr>
<td>2012 100% limit function</td>
<td>0.0762</td>
<td>31.56</td>
</tr>
<tr>
<td>2012 80% limit function</td>
<td>0.0610</td>
<td>51.25</td>
</tr>
<tr>
<td>2012 60% limit function</td>
<td>0.0457</td>
<td>70.94</td>
</tr>
<tr>
<td>2012 40% limit function</td>
<td>0.0305</td>
<td>90.62</td>
</tr>
<tr>
<td>2012 20% limit function</td>
<td>0.0152</td>
<td>110.31</td>
</tr>
</tbody>
</table>

As one can see the slope of the lines indicating the effect of mass variation (formula (2)) is smaller than the average slope for CO₂ vs. mass in 2006 and smaller than the slope of the 100% variant of the mass based limit function for 2012. The latter means that mass increase (while maintaining the power-to-weight ratio to maintain performance) brings an individual vehicle closer to the target line. The 100% slope thus provides an incentive for mass increase. This is illustrated more schematically in the graphs below. The upper graph shows the effect of mass increase or reduction in relation to a mass-based limit function. The lower graph shows the effect of mass increase or reduction in case of a pan area (l x w) based limit function.
For the case of $\gamma = 0.65$ in formula (1), the table below shows the ratios of the CO$_2$ vs mass increase slopes (for points on the 2006 sales weighted least squares fit as well as on the 2012 limit functions for slopes ranging from 100% to 20%) compared to the 100% limit function slope. It is clear from this table that, under the assumption that formula (2) is valid (i.e. $\gamma = 0.65$), gaming option 2 does not bring vehicles closer to the target line for limit function slopes of 60% and lower. Only for very heavy vehicles (> 2000 kg) that are already close to the 60% line (which can only be the case after applying a significant amount of CO$_2$ reduction technology) mass increase accompanied by adjustment of power might reduce the need for application of the most expensive CO$_2$ reduction options.
A sensitivity analysis presented above with respect to variation of the impact of a 100 kg mass increase on fuel consumption, based on which the value of $\gamma$ in formula (2) is determined, shows that a 15% lower impact might lead to values for $\gamma$ in the range of 0.51 to 0.59 instead of 0.65. The table below shows the ratios of the CO$_2$ vs mass increase slopes (for points on the 2006 sales weighted least squares fit as well as on the 2012 limit functions for slopes ranging from 100% to 20%) compared to the 100% limit function slope for the case of $\gamma = 0.50$. To fully avoid perverse incentives for mass increase in this case the slope of the limit function would need to be somewhat below 60%.

<table>
<thead>
<tr>
<th></th>
<th>m [kg]</th>
<th>CO$_2$ [g/km]</th>
<th>$\gamma$</th>
<th>slope [g/km/kg]</th>
<th>relative slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 sales weighted least squares fit</td>
<td>900</td>
<td>122.8</td>
<td>0.65</td>
<td>0.0887</td>
<td>116%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>160.1</td>
<td>0.65</td>
<td>0.0801</td>
<td>105%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>225.5</td>
<td>0.65</td>
<td>0.0733</td>
<td>96%</td>
</tr>
<tr>
<td>2012 100% limit function</td>
<td>900</td>
<td>100.1</td>
<td>0.65</td>
<td>0.0723</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.6</td>
<td>0.65</td>
<td>0.0653</td>
<td>86%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>184.0</td>
<td>0.65</td>
<td>0.0598</td>
<td>78%</td>
</tr>
<tr>
<td>2012 80% limit function</td>
<td>900</td>
<td>106.1</td>
<td>0.65</td>
<td>0.0766</td>
<td>101%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.5</td>
<td>0.65</td>
<td>0.0652</td>
<td>86%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>173.2</td>
<td>0.65</td>
<td>0.0583</td>
<td>74%</td>
</tr>
<tr>
<td>2012 60% limit function</td>
<td>900</td>
<td>112.1</td>
<td>0.65</td>
<td>0.0810</td>
<td>106%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.4</td>
<td>0.65</td>
<td>0.0652</td>
<td>86%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>162.4</td>
<td>0.65</td>
<td>0.0528</td>
<td>69%</td>
</tr>
<tr>
<td>2012 40% limit function</td>
<td>900</td>
<td>118.1</td>
<td>0.65</td>
<td>0.0853</td>
<td>112%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.2</td>
<td>0.65</td>
<td>0.0651</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>151.6</td>
<td>0.65</td>
<td>0.0493</td>
<td>65%</td>
</tr>
<tr>
<td>2012 20% limit function</td>
<td>900</td>
<td>124.0</td>
<td>0.65</td>
<td>0.0896</td>
<td>118%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.1</td>
<td>0.65</td>
<td>0.0651</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>140.8</td>
<td>0.65</td>
<td>0.0458</td>
<td>60%</td>
</tr>
</tbody>
</table>
Translating the impacts of weight increase to limit-function slope values for the case of gaming option 1

For gaming option 1, adding mass without compensating the associated loss of performance, the value of $\gamma$ in formula (1) is around 0.35 instead of 0.65 for option 2. The table below shows the ratios of the CO$_2$ vs mass increase slopes (for points on the 2006 sales weighted least squares fit, the 2012 100% limit function and the 2012 60% limit function) compared to the 100% limit function slope for the case of $\gamma = 0.35$. It is clear that the smaller value of $\gamma$ results in smaller slope values for the effect of mass increase on CO$_2$. For most vehicles (2006 vehicles as well as 2012 vehicles) that are closer to the limit line, the slope is smaller than that of the 60% limit line proposed by the Commission. This means that gaming according to option 1 brings vehicles closer to the limit line and thus can in principle be used to reduce the CO$_2$ reduction effort that manufacturers have to make in order to meet the 2012 target. The effect appears especially strong for large/heavy vehicles.

<table>
<thead>
<tr>
<th></th>
<th>m [kg]</th>
<th>CO$_2$ [g/km]</th>
<th>$\gamma$</th>
<th>slope [g/km/kg]</th>
<th>relative slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 sales weighted least squares fit</td>
<td>900</td>
<td>122.8</td>
<td>0.35</td>
<td>0.0477</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>160.1</td>
<td>0.35</td>
<td>0.0431</td>
<td>57%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>225.5</td>
<td>0.35</td>
<td>0.0395</td>
<td>52%</td>
</tr>
<tr>
<td>2012 100% limit function</td>
<td>900</td>
<td>100.1</td>
<td>0.35</td>
<td>0.0389</td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.6</td>
<td>0.35</td>
<td>0.0352</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>184.0</td>
<td>0.35</td>
<td>0.0322</td>
<td>42%</td>
</tr>
<tr>
<td>2012 80% limit function</td>
<td>900</td>
<td>106.1</td>
<td>0.35</td>
<td>0.0413</td>
<td>54%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.5</td>
<td>0.35</td>
<td>0.0351</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>173.2</td>
<td>0.35</td>
<td>0.0303</td>
<td>40%</td>
</tr>
<tr>
<td>2012 60% limit function</td>
<td>900</td>
<td>112.1</td>
<td>0.35</td>
<td>0.0436</td>
<td>57%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.4</td>
<td>0.35</td>
<td>0.0351</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>162.4</td>
<td>0.35</td>
<td>0.0284</td>
<td>37%</td>
</tr>
<tr>
<td>2012 40% limit function</td>
<td>900</td>
<td>118.1</td>
<td>0.35</td>
<td>0.0459</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.2</td>
<td>0.35</td>
<td>0.0351</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>151.6</td>
<td>0.35</td>
<td>0.0265</td>
<td>35%</td>
</tr>
<tr>
<td>2012 20% limit function</td>
<td>900</td>
<td>124.0</td>
<td>0.35</td>
<td>0.0482</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>130.1</td>
<td>0.35</td>
<td>0.0350</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>140.8</td>
<td>0.35</td>
<td>0.0246</td>
<td>32%</td>
</tr>
</tbody>
</table>

Further evaluation would be necessary to find out to what extent mass can be increased before impacts on performance reach levels that would be unacceptable to the customer. This would require more detailed investigations on the design strategies of manufacturers as regards the engine power of new cars, and on the market acceptance of small (possibly imperceptible) reductions in acceleration. These aspects should be considered in the light of the development of vehicle prices, among other things as a result of the CO$_2$ reduction measures applied. It is generally difficult to sell cars with less added value to the consumer at a higher price.

Conclusions and discussion

From the analysis presented in this note it can be concluded that for most vehicles a mass-based limit function with a slope of 80% already largely eliminates perverse incentive to use mass increase, accompanied by increased power to maintain performance(option 2), as a means to reduce the required amount of CO$_2$ reduction through technical measures for a given vehicle model. For slopes lower than 80% the required reduction effort increases for
most vehicles if vehicle mass increases, with smaller slopes leading to an increasingly stronger disincentive for mass increase. To be more safe the slope, especially for large and heavy vehicles close to the target line, the slope needs to be below 60%.

Due to the higher value for $\gamma$ associated with mass increase resulting from market shifts, slopes below 80% also exclude the possibility that upward trends in the market (option 3: shifts towards larger and better performing cars) help manufacturers in attaining their sales averaged targets as set out by the mass-based limit function.

It should be noted here that the value of 0.65 for $\gamma$ in the case of gaming option 2 is an average value, which may not apply to all vehicle types and models in the same way. Depending on e.g. the already applied engine technology and the power-to-weight ratio or performance of a given vehicle model, one would expect a certain spread in the value of $\gamma$. Due to lack of data this spread cannot be evaluated at this moment. It does, however, seem safe to assume that the slope of the limit function needs to be well below 80% (eg 60%) to avoid perverse incentives for most vehicle models in the market. Further analysis would be necessary to assess whether the number of vehicles for which a 60% still poses an incentive with respect to gaming option 2 is sufficiently insignificant or not.

For the perverse incentive described by option 1 (the “brick in the boot” option, ie mass increase without compensating measures to maintain performance) the value for $\gamma$ in equation (1) is 0.35, leading to much lower slopes for the impact of mass increase than is the case for gaming option 2. For 2006 vehicles that are one the least squares fit through CO$_2$ as function of mass the slope varies between 52 and 63% (compared to the slope of the 100% mass-based limit function). For 2012 vehicles that are eg on the 60% mass-based limit line the slope varies between 37 and 57%. The 60% mass-based limit line, which appears safe with respect to gaming option 2, therefore does not fully exclude this gaming option 1. It is as yet, however, not clear to what extent this gaming option 1 is attractive to manufacturers.
Possible regulatory approaches to reducing CO₂ emissions from cars

Technical note 9: Quantitative analysis of various options with the updated model

1 Introduction

This note reports the results of the quantitative assessments performed in the context of the project “Possible regulatory approaches to reducing CO₂ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

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2 Policy options included in the model

2.1 Families of options

- The model contains the following three families of basic options:
  - uniform limit
    - applied per vehicle
    - applied to the sales weighted average in 2012 per manufacturer
    - applied to the sales weighted average in 2012 per manufacturer with trading
      - Note: in the results presented below the uniform limit is indicated as the 0% slope variant of the options with a utility based limit function.
  - utility based limit function
    - applied per vehicle
    - applied to the sales weighted average in 2012 per manufacturer
      - For each model sold by the manufacturer the CO₂ emission limit is calculated based on the vehicle’s utility value (see explanation further on). The target per manufacturer is then calculated as a sales-weighted average of the limit values per model.
      - This is identical to defining a sales-weighted average utility for the manufacturer and inserting that average utility value in the utility based limit function.
    - applied to define targets for 2012 based on the sales weighted average in 2006 per manufacturer
      - applied to the sales weighted average in 2012 per manufacturer with trading
  - percentage reduction
    - applied to the sales weighted average in 2012 per manufacturer
    - applied to the sales weighted average in 2012 per manufacturer with trading

- Application of a certain measure to the sales weighted average CO₂ emissions per manufacturer implies that manufacturers are allowed to perform internal averaging, i.e. the excess emission of one vehicle that emits more than the value allowed by the limit can be compensated by other vehicles that perform less than allowed if the limit were applied at the vehicle level. The model calculates the distribution of reductions per segment that yields the lowest overall costs for meeting the sales averaged target. This solution is characterised by equal marginal costs in all segments. Within each segment also internal averaging is included implicitly as all vehicles in the segment undergo CO₂ reduction up to the same level of marginal costs.
- Utility based limit functions assessed in this note are based on vehicle mass (m) or pan area (l x w) as utility parameters. Together with footprint (wheelbase x track width) these are the only options that are being seriously considered at this stage.
  - The available databases do not contain data on footprint. It is assumed that for the purpose of designing the measure and assessing distributional effects pan area (l x w) can be used as a proxy for footprint. The main purpose for using footprint instead of pan area is to avoid certain perverse effects.

Using mass as utility parameter limits the benefits of weight reduction as a means to reduce CO₂ emissions, as lighter vehicles also get a lower CO₂ limit. Depending on the slope of the

---

1 Results for this option are not presented here as this variant only gives interesting results when significant shifts in sales distributions over the various segments or in average utility values per segment are assumed.
utility-based limit function mass increase may bring vehicles closer to the CO\textsubscript{2} limit function. This could promote perverse effects (ie adding mass to the vehicle to reduce the required amount of technical reduction measures) and could stimulate the market trend to ever larger and heavier vehicles. Some considerations on the use of mass as a utility parameter are included in Annex D (see also separate note on utility parameters for a more elaborate discussion).

2.2 Baseline scenarios

- Cost for reaching various possible targets in 2012 are calculated relative to a 2012 baseline without the new CO\textsubscript{2} policy for passenger cars, and are expressed as the costs of technical reduction measures applied between 2006 and 2012 to comply with the assessed option in which the 130 g/km target for 2012 is applied.
  o As a baseline scenario for the 2006-2012 period two options are modelled:
    - \textbf{\textit{b0}}: manufacturers do not apply additional CO\textsubscript{2} reduction measures between 2006 and 2012 so that for each manufacturer in each segment the average CO\textsubscript{2} emission rises proportional to the autonomous mass increase that is assumed to occur between 2006 and 2012;
    - \textbf{\textit{b1}}: manufacturers apply CO\textsubscript{2} reduction measures between 2006 and 2012 to compensate the impact of autonomous mass increase (or other trends) on CO\textsubscript{2} and so maintain the average CO\textsubscript{2} emission in each segment at the 2006 level. The costs of these measures are subtracted from the costs for reaching the 2012 target.
  o See Technical Note 6 on model adaptations for further explanations.

2.3 Autonomous mass increase

- Four scenarios have been assessed for the autonomous mass increase that is assumed to occur between 2006 and 2012.
  o Scenario \textbf{\textit{a}} assumes an average autonomous mass increase of 0.82\% p.a. This value is derived from scenario \textbf{\textit{a}} in Table 3.27 of [TNO 2006] and has also been used as central estimate in the IA.
  o Scenario \textbf{\textit{b}} uses an autonomous mass increase of 1.5\% p.a., which was the baseline in the calculations for [TNO 2006].
  o Scenario \textbf{\textit{c}} assesses the costs for meeting the target under the assumption that there is no autonomous mass increase between 2006 and 2012 (AMI = 0.0\% p.a.).
  o Finally scenario \textbf{\textit{d}} explores the impacts of a more extreme assumption for the autonomous mass increase of 2.5\% p.a..
  o Data for the four scenarios are presented in the table below.

- The scenarios are labelled somewhat odd (ie not in order of increasing AMI). The labelling \textbf{\textit{a}}, \textbf{\textit{b}}, \textbf{\textit{c}}, \textbf{\textit{d}} is the chronological order in which the scenarios were assessed upon request by the Commission Services.
- In the case of using baseline \textbf{\textit{b1}} the costs for compensating autonomous mass increase are not attributed to the 130 g/km CO\textsubscript{2} policy. This reduces the impact of the assumption on autonomous mass increase. Costs for reaching 130 g/km will, however, still increase with increasing annual mass increase percentage as the measures taken to maintain CO\textsubscript{2} emissions in the baseline at the 2006 level push the additional measures for reaching 130 g/km further up the non-linear cost curve.
  o For scenario \textbf{\textit{e}} the baselines \textbf{\textit{b0}} and \textbf{\textit{b1}} are identical.
Table 1 Four scenarios for autonomous mass increase in the 2006-2012 period.

<table>
<thead>
<tr>
<th>new reference year</th>
<th>scenario a</th>
<th>scenario b</th>
<th>scenario c</th>
<th>scenario d</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>1.13%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2008</td>
<td>1.00%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2009</td>
<td>0.88%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2010</td>
<td>0.75%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2011</td>
<td>0.63%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>2012</td>
<td>0.50%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50%</td>
</tr>
<tr>
<td>average 2007-2012</td>
<td>0.82%</td>
<td>1.50%</td>
<td>0.00%</td>
<td>2.50% p.a.</td>
</tr>
</tbody>
</table>

2.4 Baseline data for 2006

- For 2006 the model contains data that are based on sales statistics which have been supplied to the Commission by AAA. Average values for CO\textsubscript{2} emissions, vehicle mass and pan area as well as total sales for 2006 for the various manufacturers / manufacturer groups are presented in the table below:

Table 2 Baseline data for 2006: averages and total sales per manufacturer.

<table>
<thead>
<tr>
<th>manufacturer</th>
<th>CO\textsubscript{2} [g/km]</th>
<th>mass [kg]</th>
<th>pan area [m\textsuperscript{2}]</th>
<th>sales [#]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSA</td>
<td>141.7</td>
<td>1201</td>
<td>7.12</td>
<td>1882210</td>
</tr>
<tr>
<td>Fiat</td>
<td>143.8</td>
<td>1112</td>
<td>6.75</td>
<td>1050885</td>
</tr>
<tr>
<td>Renault</td>
<td>147.5</td>
<td>1234</td>
<td>7.30</td>
<td>1232236</td>
</tr>
<tr>
<td>Toyota</td>
<td>151.9</td>
<td>1214</td>
<td>7.07</td>
<td>773329</td>
</tr>
<tr>
<td>Honda</td>
<td>153.5</td>
<td>1261</td>
<td>7.41</td>
<td>229791</td>
</tr>
<tr>
<td>GM</td>
<td>156.9</td>
<td>1257</td>
<td>7.34</td>
<td>1424783</td>
</tr>
<tr>
<td>Ford</td>
<td>161.6</td>
<td>1319</td>
<td>7.78</td>
<td>1490276</td>
</tr>
<tr>
<td>Nissan</td>
<td>164.2</td>
<td>1202</td>
<td>6.99</td>
<td>273893</td>
</tr>
<tr>
<td>Suzuki</td>
<td>164.4</td>
<td>1152</td>
<td>6.59</td>
<td>178614</td>
</tr>
<tr>
<td>Hyundai</td>
<td>164.8</td>
<td>1349</td>
<td>7.26</td>
<td>461880</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>165.0</td>
<td>1366</td>
<td>7.71</td>
<td>2744849</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>168.8</td>
<td>1245</td>
<td>7.19</td>
<td>101124</td>
</tr>
<tr>
<td>Mazda</td>
<td>173.2</td>
<td>1296</td>
<td>7.75</td>
<td>229135</td>
</tr>
<tr>
<td>BMW</td>
<td>182.2</td>
<td>1453</td>
<td>7.95</td>
<td>739993</td>
</tr>
<tr>
<td>DaimlerChrysler</td>
<td>183.9</td>
<td>1472</td>
<td>8.01</td>
<td>860816</td>
</tr>
<tr>
<td>Subaru</td>
<td>215.9</td>
<td>1384</td>
<td>7.77</td>
<td>31541</td>
</tr>
<tr>
<td>Porsche</td>
<td>282.1</td>
<td>1596</td>
<td>8.24</td>
<td>39069</td>
</tr>
<tr>
<td>Average</td>
<td>159.2</td>
<td>1289</td>
<td>7.43</td>
<td>13744424</td>
</tr>
</tbody>
</table>

- In the bar charts presented in the rest of this note manufacturers are listed from left to right based on increasing sales averaged 2006 CO\textsubscript{2} emissions.
- The two bubble graphs on the next page are derived from the table above and compare manufacturers with respect to average mass, average pan area, average CO\textsubscript{2} emissions and sales.
  - Separate graphs for the sales of petrol vehicles and diesel vehicles are included in Technical Note 7 on bubble graphs.
Figure 1 Average CO₂ emissions per manufacturer as function of average mass: size of bubbles indicates total sales (petrol + diesel vehicles)

Figure 2 Average CO₂ emissions per manufacturer as function of average pan area (l x w): size of bubbles indicates total sales (petrol + diesel vehicles)
2.5 Utility-based limit functions

2.5.1 Scenario a: autonomous mass increase 0.82% p.a.

- In the calculations presented in this note for the case of AMI = 0.82% p.a. the following basic range of options are assessed:

<table>
<thead>
<tr>
<th>utility-based limit function (a U + b)</th>
<th>mass</th>
<th>l x w</th>
</tr>
</thead>
<tbody>
<tr>
<td>least squares fit 2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 120%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 80%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 60%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 40%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- For this scenario only also the following intermediate slope values are assessed (grey fields in this table indicate that the impacts of a specific slope value were not assessed for that utility parameter):

<table>
<thead>
<tr>
<th>utility-based limit function (a U + b)</th>
<th>mass</th>
<th>l x w</th>
</tr>
</thead>
<tbody>
<tr>
<td>least squares fit 2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 70%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 65%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 68%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope 77%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Besides these straightforward slope variations also the following options have been investigated for the case of utility-based limit functions applied per manufacturer without trading:
  - a “cost optimised slope” for which the average costs per vehicle are minimal (in the per manufacturer - utility variant without trading);
  - a “weighted equalised distribution” and an “unweighted equalised distribution variant in which the slope is optimised for an even distribution of the burden over all manufacturers;
  - see Technical Note 8 on definition of limit functions for more explanation.
2.5.2 Scenario b: autonomous mass increase 1.5% p.a.

- In the calculations presented in this note for the case of AMI = 1.5% p.a. the same range of options are assessed, but for mass as utility parameter the higher autonomous mass increase leads to slightly different limit functions for meeting the 2012 goal of 130 g/km:

<table>
<thead>
<tr>
<th>utility-based limit function ( (a \cdot U + b) )</th>
<th>mass ( l \times w )</th>
<th>( a )</th>
<th>( b )</th>
<th>( a )</th>
<th>( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>least squares fit 2006</td>
<td></td>
<td>0.0934</td>
<td>38.7</td>
<td>22.70</td>
<td>-9.2</td>
</tr>
<tr>
<td>slope 120%</td>
<td></td>
<td>120%</td>
<td>0.0856</td>
<td>9.5</td>
<td>120%</td>
</tr>
<tr>
<td>slope 100%</td>
<td></td>
<td>100%</td>
<td>0.0713</td>
<td>29.5</td>
<td>100%</td>
</tr>
<tr>
<td>slope 80%</td>
<td></td>
<td>80%</td>
<td>0.0571</td>
<td>49.6</td>
<td>80%</td>
</tr>
<tr>
<td>slope 60%</td>
<td></td>
<td>60%</td>
<td>0.0428</td>
<td>69.7</td>
<td>60%</td>
</tr>
<tr>
<td>slope 40%</td>
<td></td>
<td>40%</td>
<td>0.0285</td>
<td>89.8</td>
<td>40%</td>
</tr>
<tr>
<td>slope 20%</td>
<td></td>
<td>20%</td>
<td>0.0143</td>
<td>109.9</td>
<td>20%</td>
</tr>
<tr>
<td>slope 0%</td>
<td></td>
<td>0%</td>
<td>0.0000</td>
<td>130.0</td>
<td>0%</td>
</tr>
</tbody>
</table>

- For this scenario only also the following intermediate slope values are assessed (grey fields in this table indicate that the impacts of a specific slope value were not assessed for that utility parameter):

<table>
<thead>
<tr>
<th>utility-based limit function ( (a \cdot U + b) )</th>
<th>mass ( l \times w )</th>
<th>( a )</th>
<th>( b )</th>
<th>( a )</th>
<th>( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>least squares fit 2006</td>
<td></td>
<td>0.0934</td>
<td>38.7</td>
<td>22.70</td>
<td>-9.2</td>
</tr>
<tr>
<td>slope 30%</td>
<td></td>
<td>30%</td>
<td>0.0214</td>
<td>99.9</td>
<td>30%</td>
</tr>
<tr>
<td>slope 50%</td>
<td></td>
<td>50%</td>
<td>0.0357</td>
<td>79.8</td>
<td>50%</td>
</tr>
<tr>
<td>slope 70%</td>
<td></td>
<td>70%</td>
<td>0.0499</td>
<td>59.7</td>
<td>70%</td>
</tr>
<tr>
<td>slope 65%</td>
<td></td>
<td>65%</td>
<td>0.0464</td>
<td>64.7</td>
<td>65%</td>
</tr>
<tr>
<td>slope 68%</td>
<td></td>
<td>68%</td>
<td>0.0485</td>
<td>61.7</td>
<td>68%</td>
</tr>
<tr>
<td>slope 77%</td>
<td></td>
<td>77%</td>
<td>0.0549</td>
<td>52.7</td>
<td>77%</td>
</tr>
</tbody>
</table>

- Also for this scenario a “cost optimised slope”, as well as a “weighted equalised distribution” and an “unweighted equalised distribution” variant (see section 2.5.1 and Technical Note 8 for more explanation) have been determined based on the case of utility-based limit functions applied per manufacturer without trading:

<table>
<thead>
<tr>
<th>utility-based limit function ( (a \cdot U + b) )</th>
<th>mass ( l \times w )</th>
<th>( a )</th>
<th>( b )</th>
<th>( a )</th>
<th>( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>cost optimised slope</td>
<td></td>
<td>123%</td>
<td>0.0880</td>
<td>6.0</td>
<td>123%</td>
</tr>
<tr>
<td>weighted equalised distribution</td>
<td></td>
<td>74%</td>
<td>0.0530</td>
<td>55.4</td>
<td>64%</td>
</tr>
<tr>
<td>unweighted equalised distribution</td>
<td></td>
<td>47%</td>
<td>0.0336</td>
<td>82.7</td>
<td>27%</td>
</tr>
</tbody>
</table>
### 2.5.3 Scenario c: autonomous mass increase 0.0% p.a.

- In the calculations presented in this note for the case of AMI = 0.0% p.a. the same range of options are assessed, but for mass as utility parameter the lower (ie zero) autonomous mass increase leads to different limit functions for meeting the 2012 goal of 130 g/km:

<table>
<thead>
<tr>
<th>utility-based limit function ( (aU + b) )</th>
<th>mass ( l \times w )</th>
<th>( a )</th>
<th>( b )</th>
<th>( a )</th>
<th>( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>least squares fit 2006</td>
<td></td>
<td>0.0934</td>
<td>38.7</td>
<td>22.70</td>
<td>-9.2</td>
</tr>
<tr>
<td>slope 120%</td>
<td></td>
<td>120%</td>
<td>0.0914</td>
<td>11.9</td>
<td>120%</td>
</tr>
<tr>
<td>slope 100%</td>
<td></td>
<td>100%</td>
<td>0.0762</td>
<td>31.6</td>
<td>100%</td>
</tr>
<tr>
<td>slope 80%</td>
<td></td>
<td>80%</td>
<td>0.0610</td>
<td>51.2</td>
<td>80%</td>
</tr>
<tr>
<td>slope 60%</td>
<td></td>
<td>60%</td>
<td>0.0457</td>
<td>70.9</td>
<td>60%</td>
</tr>
<tr>
<td>slope 40%</td>
<td></td>
<td>40%</td>
<td>0.0305</td>
<td>90.6</td>
<td>40%</td>
</tr>
<tr>
<td>slope 20%</td>
<td></td>
<td>20%</td>
<td>0.0152</td>
<td>110.3</td>
<td>20%</td>
</tr>
<tr>
<td>slope 0%</td>
<td></td>
<td>0%</td>
<td>0.0000</td>
<td>130.0</td>
<td>0%</td>
</tr>
</tbody>
</table>

- For this scenario only also the following intermediate slope values are assessed (grey fields in this table indicate that the impacts of a specific slope value were not assessed for that utility parameter):

<table>
<thead>
<tr>
<th>utility-based limit function ( (aU + b) )</th>
<th>mass ( l \times w )</th>
<th>( a )</th>
<th>( b )</th>
<th>( a )</th>
<th>( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>least squares fit 2006</td>
<td></td>
<td>0.0934</td>
<td>38.7</td>
<td>22.70</td>
<td>-9.2</td>
</tr>
<tr>
<td>slope 30%</td>
<td></td>
<td>30%</td>
<td>0.0229</td>
<td>100.5</td>
<td>30%</td>
</tr>
<tr>
<td>slope 50%</td>
<td></td>
<td>50%</td>
<td>0.0381</td>
<td>80.8</td>
<td>50%</td>
</tr>
<tr>
<td>slope 70%</td>
<td></td>
<td>70%</td>
<td>0.0533</td>
<td>61.1</td>
<td>70%</td>
</tr>
<tr>
<td>slope 65%</td>
<td></td>
<td>65%</td>
<td>0.0495</td>
<td>66.0</td>
<td>65%</td>
</tr>
<tr>
<td>slope 68%</td>
<td></td>
<td>68%</td>
<td>0.0518</td>
<td>63.1</td>
<td>68%</td>
</tr>
<tr>
<td>slope 77%</td>
<td></td>
<td>77%</td>
<td>0.0587</td>
<td>54.2</td>
<td>77%</td>
</tr>
</tbody>
</table>

- Also for this scenario a “cost optimised slope”, as well as a “weighted equalised distribution” and an “unweighted equalised distribution variant (see section 2.5.1 and Technical Note 8 for more explanation) have been determined based on the case of utility-based limit functions applied per manufacturer without trading:

<table>
<thead>
<tr>
<th>utility-based limit function ( (aU + b) )</th>
<th>mass ( l \times w )</th>
<th>( a )</th>
<th>( b )</th>
<th>( a )</th>
<th>( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>cost optimised slope</td>
<td></td>
<td>123%</td>
<td>0.0936</td>
<td>9.1</td>
<td>123%</td>
</tr>
<tr>
<td>weighted equalised distribution</td>
<td></td>
<td>80%</td>
<td>0.0606</td>
<td>51.7</td>
<td>67%</td>
</tr>
<tr>
<td>unweighted equalised distribution</td>
<td></td>
<td>39%</td>
<td>0.0295</td>
<td>91.8</td>
<td>18%</td>
</tr>
</tbody>
</table>
2.5.4 Scenario d: autonomous mass increase 2.5% p.a.

- In the calculations presented in this note for the case of AMI = 2.5% p.a. the same range of options are assessed, but for mass as utility parameter the higher autonomous mass increase leads to different limit functions for meeting the 2012 goal of 130 g/km:

<table>
<thead>
<tr>
<th>utility-based limit function (a U + b)</th>
<th>mass</th>
<th>l x w</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>least squares fit 2006</td>
<td></td>
<td></td>
<td>0.0934</td>
<td>38.7</td>
</tr>
<tr>
<td>slope 120%</td>
<td>120%</td>
<td>0.0821</td>
<td>8.0</td>
<td>22.17</td>
</tr>
<tr>
<td>slope 100%</td>
<td>100%</td>
<td>0.0884</td>
<td>28.3</td>
<td>18.48</td>
</tr>
<tr>
<td>slope 80%</td>
<td>80%</td>
<td>0.0547</td>
<td>48.7</td>
<td>14.78</td>
</tr>
<tr>
<td>slope 60%</td>
<td>60%</td>
<td>0.0411</td>
<td>69.0</td>
<td>11.09</td>
</tr>
<tr>
<td>slope 40%</td>
<td>40%</td>
<td>0.0274</td>
<td>89.3</td>
<td>7.39</td>
</tr>
<tr>
<td>slope 20%</td>
<td>20%</td>
<td>0.0137</td>
<td>109.7</td>
<td>3.70</td>
</tr>
<tr>
<td>slope 0%</td>
<td>0%</td>
<td>0.0000</td>
<td>130.0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

- For this scenario only also the following intermediate slope values are assessed (grey fields in this table indicate that the impacts of a specific slope value were not assessed for that utility parameter):

<table>
<thead>
<tr>
<th>utility-based limit function (a U + b)</th>
<th>mass</th>
<th>l x w</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>least squares fit 2006</td>
<td></td>
<td></td>
<td>0.0934</td>
<td>38.7</td>
</tr>
<tr>
<td>slope 30%</td>
<td>30%</td>
<td>0.0205</td>
<td>99.5</td>
<td>5.54</td>
</tr>
<tr>
<td>slope 50%</td>
<td>50%</td>
<td>0.0342</td>
<td>79.2</td>
<td>9.24</td>
</tr>
<tr>
<td>slope 70%</td>
<td>70%</td>
<td>0.0479</td>
<td>58.8</td>
<td>12.93</td>
</tr>
<tr>
<td>slope 65%</td>
<td>65%</td>
<td>0.0445</td>
<td>63.9</td>
<td>12.01</td>
</tr>
<tr>
<td>slope 68%</td>
<td>68%</td>
<td>0.0465</td>
<td>60.9</td>
<td>12.56</td>
</tr>
<tr>
<td>slope 77%</td>
<td>77%</td>
<td>0.0527</td>
<td>51.7</td>
<td>14.23</td>
</tr>
</tbody>
</table>

- Also for this scenario a “cost optimised slope”, as well as a “weighted equalised distribution” and an “unweighted equalised distribution” variant (see section 2.5.1 and technical Note 8 for more explanation) have been determined based on the case of utility-based limit functions applied per manufacturer without trading:

<table>
<thead>
<tr>
<th>utility-based limit function (a U + b)</th>
<th>mass</th>
<th>l x w</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>cost optimised slope</td>
<td>123%</td>
<td>0.0880</td>
<td>6.0</td>
<td>123%</td>
</tr>
<tr>
<td>weighted equalised distribution</td>
<td>68%</td>
<td>0.0468</td>
<td>60.5</td>
<td>56%</td>
</tr>
<tr>
<td>unweighted equalised distribution</td>
<td>35%</td>
<td>0.0237</td>
<td>94.8</td>
<td>11%</td>
</tr>
</tbody>
</table>

2.6 CO₂ reduction targets per manufacturer

- Applying the above described utility based limit functions to the sales averaged utility values per manufacturer leads to the following net reduction targets per manufacturer (2006 average minus 2012 target), also referred to as distance to target.
Table 3  CO₂ reduction targets per manufacturer for different values of the slope of the mass-based limit function and for the case of percentage reduction target for scenario a (AMI = 0.82%) and scenario c (AMI = 0.0%)  

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>2006-data</th>
<th>2006-2012 CO₂ emission reduction target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO₂ mass</td>
<td>mass pan are sales</td>
</tr>
<tr>
<td></td>
<td>[g/km]</td>
<td>[kg]</td>
</tr>
<tr>
<td><strong>Scenario a (AMI = 0.82%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>PSA</td>
<td>142</td>
<td>1201</td>
</tr>
<tr>
<td>Fiat</td>
<td>144</td>
<td>1112</td>
</tr>
<tr>
<td>Renault</td>
<td>147</td>
<td>1234</td>
</tr>
<tr>
<td>Toyota</td>
<td>152</td>
<td>1214</td>
</tr>
<tr>
<td>Honda</td>
<td>153</td>
<td>1261</td>
</tr>
<tr>
<td>GM</td>
<td>157</td>
<td>1257</td>
</tr>
<tr>
<td>Ford</td>
<td>162</td>
<td>1319</td>
</tr>
<tr>
<td><strong>Scenario c (AMI = 0.0%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>PSA</td>
<td>144</td>
<td>1201</td>
</tr>
<tr>
<td>Fiat</td>
<td>145</td>
<td>1112</td>
</tr>
<tr>
<td>Renault</td>
<td>148</td>
<td>1234</td>
</tr>
<tr>
<td>Toyota</td>
<td>153</td>
<td>1261</td>
</tr>
<tr>
<td>Honda</td>
<td>157</td>
<td>1257</td>
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<tr>
<td>GM</td>
<td>162</td>
<td>1319</td>
</tr>
<tr>
<td>Ford</td>
<td>167</td>
<td>1378</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>159</td>
<td>1289</td>
</tr>
</tbody>
</table>
Table 4 CO₂ reduction targets per manufacturer for different values of the slope of the \textit{pan area}-based limit function and for the case of percentage reduction target for scenario a (AMI = 0.82\%) and scenario c (AMI = 0.0\%)  

\textbf{scenario a (AMI = 0.82\%)}

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>2006-data</th>
<th>2006-2012 CO₂ emission reduction target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td></td>
<td>g/km</td>
<td>kg</td>
</tr>
<tr>
<td></td>
<td>m²</td>
<td>#</td>
</tr>
<tr>
<td></td>
<td>€</td>
<td></td>
</tr>
<tr>
<td>PSA</td>
<td>142</td>
<td>1201</td>
</tr>
<tr>
<td>Fiat</td>
<td>144</td>
<td>1112</td>
</tr>
<tr>
<td>Renault</td>
<td>147</td>
<td>1234</td>
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<tr>
<td>Toyota</td>
<td>152</td>
<td>1214</td>
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<tr>
<td>Honda</td>
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<tr>
<td>GM</td>
<td>157</td>
<td>1257</td>
</tr>
<tr>
<td>Ford</td>
<td>162</td>
<td>1319</td>
</tr>
<tr>
<td>Nissan</td>
<td>164</td>
<td>1202</td>
</tr>
<tr>
<td>Suzuki</td>
<td>165</td>
<td>1156</td>
</tr>
<tr>
<td>Hyundai</td>
<td>165</td>
<td>1349</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>165</td>
<td>1366</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>169</td>
<td>1245</td>
</tr>
<tr>
<td>Mazda</td>
<td>173</td>
<td>1296</td>
</tr>
<tr>
<td>BMW</td>
<td>182</td>
<td>1453</td>
</tr>
<tr>
<td>DaimlerChrysler</td>
<td>184</td>
<td>1472</td>
</tr>
<tr>
<td>Subaru</td>
<td>216</td>
<td>1384</td>
</tr>
<tr>
<td>Porsche</td>
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<td>1596</td>
</tr>
<tr>
<td>Average</td>
<td>159</td>
<td>1289</td>
</tr>
</tbody>
</table>

\textbf{scenario c (AMI = 0.0\%)}

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>2006-data</th>
<th>2006-2012 CO₂ emission reduction target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td></td>
<td>g/km</td>
<td>kg</td>
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<tr>
<td></td>
<td>m²</td>
<td>#</td>
</tr>
<tr>
<td></td>
<td>€</td>
<td></td>
</tr>
<tr>
<td>PSA</td>
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<td>1201</td>
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<tr>
<td>Fiat</td>
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<td>1112</td>
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<tr>
<td>Renault</td>
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<td>Toyota</td>
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<tr>
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<tr>
<td>GM</td>
<td>157</td>
<td>1257</td>
</tr>
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</tr>
<tr>
<td>Nissan</td>
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<td>1202</td>
</tr>
<tr>
<td>Suzuki</td>
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<tr>
<td>Hyundai</td>
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<tr>
<td>Volkswagen</td>
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<td>1366</td>
</tr>
<tr>
<td>Mitsubishi</td>
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<td>1245</td>
</tr>
<tr>
<td>Mazda</td>
<td>173</td>
<td>1296</td>
</tr>
<tr>
<td>BMW</td>
<td>182</td>
<td>1453</td>
</tr>
<tr>
<td>DaimlerChrysler</td>
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<td>1472</td>
</tr>
<tr>
<td>Subaru</td>
<td>216</td>
<td>1384</td>
</tr>
<tr>
<td>Porsche</td>
<td>282</td>
<td>1596</td>
</tr>
<tr>
<td>Average</td>
<td>159</td>
<td>1289</td>
</tr>
</tbody>
</table>
Figure 3  CO$_2$ reduction targets per manufacturer for different values of the slope of the mass-based limit function and for the case of percentage reduction target for scenario a (AMI = 0.82%)

Figure 4  CO$_2$ reduction targets per manufacturer for different values of the slope of the pan area-based limit function and for the case of percentage reduction target for scenario a (AMI = 0.82%)

- As is clear from Table 3 above the net reduction targets for mass-based limits are largely independent from the assumptions regarding autonomous mass increase. Comparing the distance to target for scenario a and c one can see that the difference is 0.1 g/km or less for all manufacturers. The reason for this insensitivity is that the overall impact of
autonomous mass increase is compensated for in the setting of the limit functions and that the 2012 targets per manufacturer are based on the average weight including autonomous mass increase. Depending on the distribution of sales of different mass classes detailed impacts may be slightly different per manufacturer but these differences appear negligible. For this reasons Figure 3 and Figure 4 only present results for scenario a (AMI = 0.82%).

- As can be seen from Table 4 autonomous mass increase does not affect the net reduction targets per manufacturer for limits based on pan area, but this is trivial.
- Autonomous mass increase obviously does affect the gross CO₂ reduction to be realised by technical reduction measures, which is equal to the difference between the 2012 target and the 2006 average plus the amount of additional CO₂ emission due to the mass increase between 2006 and 2012.

2.7 Lifetime fuel cost savings at the consumer level

- The net CO₂ emission reduction in the previous section can be translated into a net lifetime fuel cost saving (Net Present Value) on the basis of the following assumptions, most of which have also been used for assessing cost effectiveness in [TNO 2006]:
  - vehicle lifetime = 13 years
  - annual mileage = 16,000 km
  - conversion factor from Type Approval to Real World CO₂ reduction: 1.195
  - fuel retail price = 1.00 €/litre and 1.20 €/litre (incl. taxes)
  - discount factor = 4% (for NPV calculation)
- Given that the emission reduction targets per manufacturer hardly depend on the autonomous mass increase scenario, as shown in Table 3 and Table 4, the lifetime fuel cost savings are only calculated for scenario a (AMI = 0.82%). Values for scenario c (AMI = 0.0%) will not differ more than 1%.
Table 5  Average lifetime fuel cost savings (incl. tax) per manufacturer for different values of the slope of the mass-based limit function and for the case of percentage reduction target for scenario a (AMI = 0.82%) and fuel price = 1.00 €/litre

<table>
<thead>
<tr>
<th>manufacturer</th>
<th>mass (g/km)</th>
<th>mass (kg)</th>
<th>pan area (m²)</th>
<th>sales scenarios</th>
<th>lifetime fuel savings (NPV)</th>
<th>2006-data</th>
<th>lifetime fuel savings (NPV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACEA</td>
<td>average</td>
<td>average</td>
<td>average</td>
<td>average</td>
<td>2006-data</td>
<td>lifetime fuel savings (NPV)</td>
<td></td>
</tr>
<tr>
<td>BMW</td>
<td>152</td>
<td>1289</td>
<td>7.4</td>
<td>13744424</td>
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<td>2244</td>
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<tr>
<td>Daimler/Chrysler</td>
<td>152</td>
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<td>2244</td>
</tr>
<tr>
<td>Fiat</td>
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<td>7.4</td>
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<td>2244</td>
<td>2244</td>
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<tr>
<td>Ford</td>
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<td>1289</td>
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<td>2244</td>
<td>2244</td>
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<tr>
<td>GM</td>
<td>152</td>
<td>1289</td>
<td>7.4</td>
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<tr>
<td>Porsche</td>
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<td>2244</td>
<td>2244</td>
<td>2244</td>
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<tr>
<td>PSA</td>
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<td>1289</td>
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<td>2244</td>
<td>2244</td>
<td>2244</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>152</td>
<td>1289</td>
<td>7.4</td>
<td>13744424</td>
<td>2244</td>
<td>2244</td>
<td>2244</td>
</tr>
<tr>
<td>JAMA</td>
<td>Toyota</td>
<td>152</td>
<td>1289</td>
<td>7.4</td>
<td>13744424</td>
<td>2244</td>
<td>2244</td>
</tr>
<tr>
<td>Nissan</td>
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<td>7.4</td>
<td>13744424</td>
<td>2244</td>
<td>2244</td>
<td>2244</td>
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<tr>
<td>Mitsubishi</td>
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<td>1289</td>
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<td>13744424</td>
<td>2244</td>
<td>2244</td>
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<tr>
<td>Honda</td>
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<td>7.4</td>
<td>13744424</td>
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<td>2244</td>
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</tr>
<tr>
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<td>2244</td>
<td>2244</td>
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<tr>
<td>Subaru</td>
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<tr>
<td>JAMA</td>
<td>Toyota</td>
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<td>7.4</td>
<td>13744424</td>
<td>2244</td>
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<td>2244</td>
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<tr>
<td>Subaru</td>
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<td>13744424</td>
<td>2244</td>
<td>2244</td>
<td>2244</td>
</tr>
</tbody>
</table>

Table 6 Average lifetime fuel cost savings (incl. tax) per manufacturer for different values of the slope of the mass-based limit function and for the case of percentage reduction target for scenario a (AMI = 0.82%) and fuel price = 1.20 €/litre

<table>
<thead>
<tr>
<th>manufacturer</th>
<th>mass (g/km)</th>
<th>mass (kg)</th>
<th>pan area (m²)</th>
<th>sales scenarios</th>
<th>lifetime fuel savings (NPV)</th>
<th>2006-data</th>
<th>lifetime fuel savings (NPV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACEA</td>
<td>average</td>
<td>average</td>
<td>average</td>
<td>average</td>
<td>2006-data</td>
<td>lifetime fuel savings (NPV)</td>
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<tr>
<td>BMW</td>
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<td>7.4</td>
<td>13744424</td>
<td>2244</td>
<td>2244</td>
<td>2244</td>
</tr>
<tr>
<td>Daimler/Chrysler</td>
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<tr>
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<tr>
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TN 9: Quantitative analysis of various options with the updated model
Table 7  Average lifetime fuel cost savings (incl. tax) per manufacturer for different values of the slope of the pan area-based limit function and for the case of percentage reduction target for scenario a (AMI = 0.82%) and fuel price = 1.00 €/litre

| 2006-data | lifetime fuel savings (NPV) | manufacturer | g/km | kg | m² | [#] | [€] | average | average | average | total | per manuf. - utility - lxw - slope 0% | per manuf. - utility - lxw - slope 20% | per manuf. - utility - lxw - slope 30% | per manuf. - utility - lxw - slope 40% | per manuf. - utility - lxw - slope 50% | per manuf. - utility - lxw - slope 60% | per manuf. - utility - lxw - slope 70% | per manuf. - utility - lxw - slope 80% | per manuf. - utility - lxw - slope 90% | per manuf. - utility - lxw - slope 100% | per manuf. - utility - lxw - slope 120% | per manuf. - percentage red. | per manuf. - percentage red. | per manuf. - percentage red. | per manuf. - percentage red. |
|-----------|-----------------------------|--------------|------|----|-----|-----|-----|--------|--------|--------|-------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| ACEA       |                             |              |      |    |     |     |     |        |        |        |       |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                |                                | bacterial limit function and for the case of percentage reduction target for scenario a (AMI = 0.82%) and fuel price = 1.00 €/litre

Table 8  Average lifetime fuel cost savings (incl. tax) per manufacturer for different values of the slope of the pan area-based limit function and for the case of percentage reduction target for scenario a (AMI = 0.82%) and fuel price = 1.20 €/litre

| 2006-data | lifetime fuel savings (NPV) | manufacturer | g/km | kg | m² | [#] | [€] | average | average | average | total | per manuf. - utility - lxw - slope 0% | per manuf. - utility - lxw - slope 20% | per manuf. - utility - lxw - slope 30% | per manuf. - utility - lxw - slope 40% | per manuf. - utility - lxw - slope 50% | per manuf. - utility - lxw - slope 60% | per manuf. - utility - lxw - slope 70% | per manuf. - utility - lxw - slope 80% | per manuf. - utility - lxw - slope 90% | per manuf. - utility - lxw - slope 100% | per manuf. - utility - lxw - slope 120% | per manuf. - percentage red. | per manuf. - percentage red. | per manuf. - percentage red. | per manuf. - percentage red. |
|-----------|-----------------------------|--------------|------|----|-----|-----|-----|--------|--------|--------|-------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------| bacterial limit function and for the case of percentage reduction target for scenario a (AMI = 0.82%) and fuel price = 1.00 €/litre

TN 9: Quantitative analysis of various options with the updated model 140
3 Caveats

- The Polk 2002 and AAA 2006 databases are not entirely compatible in the coverage of models (main differences relate to coverage of van-based M1 vehicles). Assessment of the amount technical CO\textsubscript{2} reduction measures applied between 2002 and 2006 is influenced by possible inconsistencies in the data, but the applied methodology tries to take account of that as good as possible.

- Results for individual manufacturers should not be interpreted as predictions of the costs in 2012 for that manufacturer but should rather be seen as an estimate of the costs for a manufacturer with characteristics (in terms of sales distributions and CO\textsubscript{2} emissions per vehicle per segment) similar to that manufacturer.
Notes on graphs and analyses

- The following sections show general results for all combinations of baselines and assumptions on autonomous mass increase. For the combination a / b1 (autonomous mass increase = 0.82%, costs relative to baseline in which 2006 CO\textsubscript{2} values are maintained) more detailed analysis and additional graphs are presented.
  - Because the distributional effects are largely the same for all combinations of baselines and assumptions on autonomous mass increase, the conclusions drawn for the combination a / b1 are generally also valid for the other combinations.

- All costs presented are retail price increases relative to 2006, associated with the technical CO\textsubscript{2} reduction measures that need to be applied to reach the 2012 average target of 130 g/km.

- Results are presented for the 8 different combinations of baseline scenario and assumption on autonomous mass increase:
  - a / b0: AMI = 0.82%, baseline: CO\textsubscript{2} increases with AMI
  - a / b1: AMI = 0.82%, baseline: CO\textsubscript{2} per car maintained at 2006 level
  - b / b0: AMI = 1.5%, baseline: CO\textsubscript{2} increases with AMI
  - b / b1: AMI = 1.5%, baseline: CO\textsubscript{2} per car maintained at 2006 level
  - c / b0: AMI = 0.0%, baseline: CO\textsubscript{2} increases with AMI
  - c / b1: AMI = 0.0%, baseline: CO\textsubscript{2} per car maintained at 2006 level
    - CO\textsubscript{2} emissions remain the same between 2006 and 2012 if AMI = 0.0% p.a.. The results for scenario c therefore do not depend on the baseline scenario (b0 or b1).
  - d / b0: AMI = 2.5%, baseline: CO\textsubscript{2} increases with AMI
  - d / b1: AMI = 2.5%, baseline: CO\textsubscript{2} per car maintained at 2006 level

- The scenarios are labelled somewhat odd (ie not in order of increasing AMI). The labelling a, b, c, d is the chronological order in which the scenarios were assessed upon request by the Commission Services.

- For results presented relative to baseline b1, in which manufacturers apply CO\textsubscript{2} reduction measures between 2006 and 2012 to maintain the average CO\textsubscript{2} emission in each segment at the 2006 level, the costs of these reduction measures are subtracted from the costs for reaching the 2012 targets.

- All results per segment are calculated under the assumption that manufacturers apply direct and full cost pass through of the costs for CO\textsubscript{2} reduction measures to the retail price of the vehicles in which these measures are applied. In reality manufacturers obviously have the freedom to distribute the overall costs for meeting the 2012 target in a different way over the model spectrum that is offered.
5 Scenario a (AMI = 0.82% p.a.) / baseline b0

5.1 Per car – utility – mass (a / b0)

5.1.1 Graphs

Figure 5 Absolute retail price increase per manufacturer for utility based limits applied per car, U = mass, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)

![Absolute retail price increase per manufacturer](image)

Figure 6 Relative retail price increase per manufacturer for utility based limits applied per car, U = mass, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)

![Relative retail price increase per manufacturer](image)
Figure 7  Relative retail price increase per segment for utility based limits applied per car, U = mass, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)

5.1.2 Conclusions
- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case in which costs are presented relative to baseline b1.
  - Absolute and relative retail price increases are slightly higher.
  - For detailed conclusions see section 6.1.2 for the case a / b1.

5.1.3 Calculations based on individual vehicles
- Calculations based on individual vehicles, instead of averages per segment per manufacturer, have not been performed for this scenario (scenario a 0.82% AMI, relative to baseline b0). For results related to scenario a 0.82% AMI, relative to baseline b1 the reader is referred to section 6.1.3.
5.2 Per car – utility – pan area (l x w) (a / b0)

5.2.1 Graphs

Figure 8 Absolute retail price increase per manufacturer for utility based limits applied per car, U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)

Figure 9 Relative retail price increase per manufacturer for utility based limits applied per car, U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)
5.2.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case in which costs are presented relative to baseline \( b_1 \).
  - Absolute and relative retail price increases are slightly higher.
  - For detailed conclusions see section 6.2.2 for the case \( a / b_1 \).

5.2.3 Calculations based on individual vehicles

- Calculations based on individual vehicles, instead of averages per segment per manufacturer, have not been performed for this scenario (scenario \( a \ 0.82\% \ AMI, \ relative \ to \ baseline \ b_0 \)). For results related to scenario \( a \ 0.82\% \ AMI, \ relative \ to \ baseline \ b_1 \) the reader is referred to section 6.2.3.
5.3 Per manufacturer – utility – mass & per manufacturer – % reduction (a / b0)

5.3.1 Graphs

Figure 11 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer, \( U = \text{mass} \), scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)

![Absolute retail price increase per manufacturer](image)

Figure 12 Relative retail price increase per manufacturer for utility based limits applied per manufacturer, \( U = \text{mass} \), scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)

![Relative retail price increase per manufacturer](image)
Figure 13  Relative retail price increase per segment for utility based limits applied per manufacturer, U = mass, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)

Per manufacturer - utility - m - a / b0

Figure 14  Relative retail price increase per manufacturer for utility based limits applied per manufacturer, U = mass, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated), for specific slope variants

Per manufacturer - utility - m - a / b0

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers.
For further detail also the following intermediate slopes have been assessed:

Figure 15 Relative retail price increase per manufacturer for utility based limits applied per manufacturer, \(U = \text{mass}, \) scenario a (AMI = 0.82\% p.a.) and baseline b0 (AMI not compensated), with intermediate slope values

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Relative retail price increase [%]</th>
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<tr>
<td>PSA</td>
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<td>Fiat</td>
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<td>Subaru</td>
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<tr>
<td>Porsche</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
</tr>
</tbody>
</table>

5.3.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case in which costs are presented relative to baseline b1.
  - Absolute and relative retail price increases are slightly higher.
  - For detailed conclusions see section 6.3.2 for the case a / b1.
5.4 Per manufacturer – utility – pan area (l x w) & per manufacturer – % reduction (a / b0)

5.4.1 Graphs

Figure 16 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer, U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)
Figure 17  Relative retail price increase per manufacturer for utility based limits applied per manufacturer, U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)

Figure 18  Relative retail price increase per segment for utility based limits applied per manufacturer, U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)
Figure 19  Relative retail price increase per manufacturer for utility based limits applied per manufacturer, U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated), for specific slope variants

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers
For further detail also the following intermediate slopes have been assessed:

Figure 20  Relative retail price increase per manufacturer for utility based limits applied per manufacturer, \(U = \text{pan area},\) scenario \(a\) (AMI = 0.82\% p.a.) and baseline \(b0\) (AMI not compensated), with intermediate slope values

![Relative retail price increase per manufacturer for utility based limits applied per manufacturer](image)

5.4.2 Conclusions
- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case in which costs are presented relative to baseline \(b1\).
  - Absolute and relative retail price increases are slightly higher.
  - For detailed conclusions see section 6.4.2 for the case \(a / b1\).
5.5 Per manufacturer + trading – utility – mass & per manufacturer + trading – % reduction (a / b0)

5.5.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying credits to the amount that the achieved CO₂ emission is below or above the target for that segment.

Figure 21 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer + trading, U = mass, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)
Figure 22  Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading, $U = \text{mass}$, scenario $a$ ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline $b0$ ($\text{AMI} \text{ not compensated}$)

![Relative retail price increase per manufacturer](image1)

Figure 23  Absolute retail price increase per segment for utility based limits applied per manufacturer + trading, $U = \text{mass}$, scenario $a$ ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline $b0$ ($\text{AMI} \text{ not compensated}$)

![Absolute retail price increase per segment](image2)
5.5.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case in which costs are presented relative to baseline b1.
  - Absolute and relative retail price increases are slightly higher.
  - For detailed conclusions see section 6.5.2 for the case a / b1.
5.6 Per manufacturer + trading – utility – pan area (l x w) & per manufacturer + trading – % reduction (a / b0)

5.6.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying credits to the amount that the achieved CO₂ emission is below or above the target for that segment.

Figure 24 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer + trading, U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)
Figure 25  Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading, U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)

Figure 26  Relative retail price increase per segment for utility based limits applied per manufacturer + trading, U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b0 (AMI not compensated)
5.6.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case in which costs are presented relative to baseline b1.
  - Absolute and relative retail price increases are slightly higher.
  - For detailed conclusions see section 6.6.2 for the case a / b1.
6 Scenario a (AMI = 0.82% p.a.) / baseline b1

6.1 Per car – utility – mass (a/ b1)

6.1.1 Graphs

Figure 27 Absolute retail price increase per manufacturer for utility based limits applied per car for U = mass, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)

Figure 28 Relative retail price increase per manufacturer for utility based limits applied per car for U = mass, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)
6.1.2 Conclusions

- For small petrol vehicles the costs increase strongly with rising slope values.
- Medium sized petrol vehicles are almost insensitive to the slope of the limit value.
- For small and medium diesel vehicles the costs for meeting the target are generally lower than for the other segments.
- With limits set per vehicle most reductions are achieved in the three petrol vehicle segments and in large diesel vehicles.
- With small slopes no reductions are necessary for small diesel vehicles. These vehicles are even allowed to have an increase in CO$_2$ emissions relative to 2006. The associated negative costs result from the fact that costs are presented relative to a baseline in which CO$_2$ emissions per segment per manufacturer are kept constant (with CO$_2$ reduction measures applied to compensate effects of autonomous mass increase).
- For each manufacturer average costs per vehicle scale non-linearly with the slope of the limit function. For some manufacturer costs increase with increasing slope, for other manufacturers costs decrease with increasing slope and for several manufacturers costs even show a local minimum.
- Overall costs are sensitive to the slope of the utility based limit function but the sensitivity is limited: the highest value (for uniform slope) is only 38% higher than the lowest (for about 100% slope).
- Preferably the absolute and relative price increase should both increase with vehicle size and CO$_2$ emission. This is the case for slopes of 100% and smaller.
- Especially when looking at the relative cost increase some manufacturers will be faced with a higher burden than other manufacturers with similar average CO$_2$ emissions. The most notable “anomalies” can to a large extent be explained based on information in the bubble graphs depicted in annex B:
  - **Fiat**: For Fiat this is caused by the high share of small vehicles in the sales, and by the fact that these vehicles have above average (i.e. compared to the sales weighted fit of
CO₂ vs. utility) CO₂ emissions. The average Fiat is smaller and lighter than the average PSA vehicle, but average CO₂ emissions are somewhat higher. Effects are enhanced by the relatively low price of the vehicles from Fiat.

- **Suzuki**: The absolute costs for Suzuki are very similar to those of Nissan but the relative cost are much higher and much more sensitive to the slope of the limit function. 2006 CO₂ values for Suzuki and Nissan are almost the same but the average mass and l x w are smaller for Suzuki leading to tighter CO₂ limits values and thus to higher costs than is the case for Nissan. A further important difference is the fact that the average retail price for Suzuki is about 25% lower than for Nissan.

- **Mitsubishi**: The sensitivity of Mitsubishi is caused by a high share of heavy SUVs in the large diesel segment.

- **Subaru**: Subaru only sells petrol vehicles and its models generally have larger engines and better performance than other vehicles with the same utility value. 2006 CO₂ emissions are thus relatively high and all reductions have to be made in the petrol segments. Average mass and pan area of Subaru vehicles are also high compared to the petrol sales of other manufacturers. This gives a higher CO₂ target, but as the average CO₂ emissions for Subaru are so far above average (i.e. compared to the sales weighted fit of CO₂ vs. utility), this does not help significantly to reduce the costs of meeting the 2012 target.

- **Porsche**: Porsche only sells large petrol vehicles in 2006. For these sports vehicles and SUVs CO₂ emissions are above average for the segment and above average for their utility value. For 2012 it is assumed that the Cayenne will also be sold in a diesel version².

### 6.1.3 Calculations based on individual vehicles

- The graph on the next page shows the reductions required to meet the 100% mass-based utility limit based on calculations for each individual vehicle model.
- Almost all vehicles require application of CO₂ reduction measures to a significant extent. Of the 13585 models in the database 1369 would require reductions larger than the maximum values identified in the cost curves of [TNO 2006]. In this example these models are excluded from the market (models are represented in the graph using zero CO₂ values).
  - Excluded models obviously include all large sports vehicles (Ferrari, Porsche, etc.) but also a fair share of model variants of “normal” passenger cars of different sizes ranging from e.g. Audi A4 and Ford Focus to Daihatsu Cuore!
- Calculations can also be performed for a system with fines. In that case the limit function can be shifted upwards somewhat as the reductions applied to vehicles excluded in this example also contribute to reaching the target.

- As the option of setting targets at the vehicle level is currently not the preferred route, we do not further investigate this option.

² This is implemented using the same methodology used in the model to account for the petrol to diesel shift in general. In the 2012 sales, part of the expected petrol sales in a segment is shifted to the equivalent diesel segment. The 2006 baseline CO₂ emission for these vehicles is calculated as the 2006 baseline value for the petrol vehicles times a correction factor accounting for the average CO₂ benefit of diesels over petrol vehicles. This baseline CO₂ emission is then mixed in with that of the already existing diesel share (if any, which is not the case for Porsche) on the basis of sales weighted averaging.
Figure 30  2012 CO₂ emissions per vehicle model sold in EU-15 with and without reductions required to meet mass-based CO₂ limit function applied per car for scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)
6.2 Per car – utility – pan area (l x w) (a/ b1)

6.2.1 Graphs

Figure 31 Absolute retail price increase per manufacturer for utility based limits applied per car for U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)

Figure 32 Relative retail price increase per manufacturer for utility based limits applied per car for U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)
6.2.2 Conclusions

- The overall picture for \( l \times w \) is very similar to that of mass based utility functions applied per vehicle.
- The lowest retail price increase per car is achieved for a slope of 100 to 120%.
- The sensitivity of Suzuki to increased slopes is somewhat more enhanced when \( l \times w \) is used as utility parameter. This is explained by the fact that Suzuki has a relatively low average pan area. Especially for the diesel sales (small SUVs) the average pan area is very small (see Annex B).

6.2.3 Calculations based on individual vehicles

- The graph below shows the reductions required to meet the 100% \( l \times w \)-based utility limit.
- Almost all vehicles require application of CO\(_2\) reduction measures to a significant extent. Of the 13585 models in the database 2602 would require reductions larger than the maximum values identified in the cost curves of [TNO 2006]. In this examples these models are excluded from the market (models are represented in the graph using zero CO\(_2\) values).
- Calculations can also be performed for a system with fines. In that case the limit function can be shifted upwards somewhat as the reductions applied to vehicles excluded in this example also contribute to reaching the target.
Figure 34  2012 CO₂ emissions per vehicle model sold in EU-15 with and without reductions required to meet pan area-based CO₂ limit function applied per car for scenario a (AMI = 0.82% p.a.). 2012 CO₂ emissions values without reduction include impact of autonomous mass increase.

- As the option of setting targets at the vehicle level is currently not the preferred route, we do not further investigate this option.
6.3 Per manufacturer – utility – mass & per manufacturer – % reduction (a/ b1)

6.3.1 Graphs

Figure 35  Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)

Figure 36  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)
Figure 37  Relative retail price increase per segment for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline b1 (AMI compensated)

Figure 38  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline b1 (AMI compensated), for specific slope variants

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers.
Intermediate slope values

For further detail also the following intermediate slopes have been assessed:

Figure 39 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{mass} \), scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated), with intermediate slope values
Figure 40  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \ \text{p.a.}$) and baseline b1 (AMI compensated), with intermediate slope values

per manufacturer - utility - m - a / b1

Figure 41  Relative retail price increase per manufacturer as function of average mass per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \ \text{p.a.}$) and baseline b1 (AMI compensated), with slopes based on weighted and unweighted equalisation of the relative retail price increase per manufacturer

Note: Porsche and Subaru have been excluded from both equalisation approaches and are also not depicted in this graph.
6.3.2 Conclusions

• As to be expected the impact of slope on costs and on distributional effects (by manufacturer and by segment) is much less for the “per manufacturer” option than for the “per car” option.

• For each manufacturer average costs per vehicle scale linearly with the slope of the limit function. For manufacturer with a sales-averaged mass below the overall average mass the costs increase with increasing slope while for manufacturers with above-average mass the costs decrease with increasing slope. Sensitivity to changing slope is very different for the different manufacturers depending on the difference between the average mass of the manufacturer and the overall average mass.

• Overall average costs are sensitive to the slope of the utility based limit function but the sensitivity is limited: the highest value (for uniform slope) is only 10% higher than the lowest value. For slopes between 80% and 120% the costs can be considered almost independent of the slope. Lowest costs are achieved for the 123% slope.

• Optimisation of the slope to yield the lowest average retail price increase per vehicle leads to a very high value for the slope (123%), resulting in relatively low costs for large vehicle and high relative price increases for small cars.

• Preferably the absolute and relative price increase should both increase with vehicle size and CO₂ emission. This is generally achieved for slopes of 100% and smaller although the relative price increase for small petrol vehicle remains higher than for medium petrol vehicles.

• The slopes determined by minimising the squared distance for all manufacturers to the average relative retail price increase value (“weighted equalisation” and “unweighted equalisation”) still show a strong scatter in the absolute and relative retail price increase values per manufacturer.

  o Apparently a linear utility based limit function can not be tailored to equalise the burden per manufacturer.
  o The fact that the scatter plot of relative retail price increase against average mass for the “weighted equalisation” and “unweighted equalisation” slopes does not show any linear or non-linear correlation in the residue (i.e. remaining difference between relative retail price increase per manufacturer and the average relative retail price increase) proves that using a non-linear utility-based limit function will not improve the equalisation of the relative retail price increase over the manufacturers.

• The most equal distribution of absolute retail price increase over manufacturers is achieved by the percentage reduction option. As a consequence the relative costs strongly decrease with increasing car price, CO₂ value or utility, which is undesired.

  o Another undesired impact of the percentage reduction option is that it locks manufacturers into their present market positions, in the sense that they are discouraged from moving “up market”.

• Especially when looking at the relative cost increase some manufacturers will be faced with a higher burden than other manufacturers with similar average CO₂ emissions. The most notable “anomalies” can to a large extent be explained based on information in the bubble graphs depicted in annex B. In most cases the sensitivity is very similar to the case of the “per car” option.

  o Fiat: For Fiat the high costs are caused by the high share of small vehicles in the sales, and by the fact that these vehicles have above average (i.e. compared to the sales weighted fit of CO₂ vs. utility) CO₂ emissions. The average Fiat is smaller and
lighter than the average PSA vehicle, but average CO\(_2\) emissions are somewhat higher. Effects are enhanced by the relatively low price of the vehicles from Fiat.

- **Suzuki**: The absolute costs for Suzuki are very similar to those of Nissan but the relative cost are much higher and much more sensitive to the slope of the limit function. 2006 CO\(_2\) values for Suzuki and Nissan are almost the same but the average mass and l x w are smaller for Suzuki leading to tighter CO\(_2\) limits values and thus to higher costs than is the case for Nissan. A further important difference is the fact that the average retail price for Suzuki is about 25% lower than for Nissan.

- **Mitsubishi**: The sensitivity of Mitsubishi is caused by a high share of heavy SUVs in the large diesel segment. The average costs and sensitivity are greatly reduced when internal averaging is allowed. Relative price increase is still relatively high though.

- **Subaru**: Subaru only sells petrol vehicles and its models generally have larger engines and better performance than other vehicles with the same utility value. 2006 CO\(_2\) emissions are thus relatively high and all reductions have to be made in the petrol segments. Average mass and pan area of Subaru vehicles are also high compared to the petrol sales of other manufacturers. This gives a higher CO\(_2\) target, but as the average CO\(_2\) emissions for Subaru are so far above average (i.e. compared to the sales weighted fit of CO\(_2\) vs. utility), this does not help significantly to reduce the costs of meeting the 2012 target.

- **Porsche**: Porsche only sells large petrol vehicles in 2006. For these sports vehicles and SUVs CO\(_2\) emissions are above average for the segment and above average for their utility value. For 2012 it is assumed that the Cayenne will also be sold in a diesel version.
6.4 Per manufacturer – utility – pan area (l x w) & per manufacturer – % reduction (a/b1)

6.4.1 Graphs

Figure 42 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{pan area} \), scenario a \((\text{AMI} = 0.82\% \text{ p.a.})\) and baseline b1 \((\text{AMI compensated})\)

Figure 43 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{pan area} \), scenario a \((\text{AMI} = 0.82\% \text{ p.a.})\) and baseline b1 \((\text{AMI compensated})\)
Figure 44 Relative retail price increase per segment for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline b1 (AMI compensated) per manufacturer - utility - $l \times w$ - $a / b1$

![Graph showing relative retail price increase per segment for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline b1 (AMI compensated).]

Figure 45 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline b1 (AMI compensated), for specific slope values

![Graph showing relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline b1 (AMI compensated), for specific slope values.]

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers.
Intermediate slope values

For further detail also the following intermediate slopes have been assessed:

Figure 46 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated), with intermediate slope values

Figure 47 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated), with intermediate slopes
Figure 48  Relative retail price increase per manufacturer as function of average mass per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated), with slopes based on weighted and unweighted equalisation of the relative retail price increase per manufacturer

$$y = -0.0201x + 0.2191$$  $R^2 = 0.0688$

$$y = 0.0089x + 0.0029$$  $R^2 = 0.0162$

Note: Porsche and Subaru have been excluded from both equalisation approaches and are also not depicted in this graph.

6.4.2  Conclusions

- The overall picture for limits functions based on $l \times w$ and applied per manufacturer is very similar to that of mass based utility functions applied per manufacturer.
- Again for each manufacturer average costs per vehicle scale linearly with the slope of the limit function. For manufacturer with a sales-averaged pan area below the overall average mass the costs increase with increasing slope while for manufacturers with above-average pan area the costs decrease with increasing slope. Sensitivity to changing slope is very different for the different manufacturers depending on the difference between the average pan area of the manufacturer and the overall average pan area.
- Optimisation of the slope to yield the lowest average retail price increase per vehicle leads to a very high value for the slope (123%), resulting in relatively low costs for large vehicle and high relative price increases for small cars.
- Also for $l \times w$ the slopes determined by minimising the squared distance for all manufacturers to the average relative retail price increase value (“weighted equalisation” and “unweighted equalisation”) still show a strong scatter in the absolute and relative retail price increase values per manufacturer.
- Apparently a linear utility based limit function can not be tailored to equalise the burden per manufacturer.
- Compared to mass as utility parameter a somewhat more pronounced correlation between relative retail price increase and utility remains for l x w, but this correlation is not strong enough to suggest that using a non-linear utility-based limit function would improve the equalisation of the relative retail price increase over the manufacturers. The apparent upward trend for low l x w is caused by the specific sales of Suzuki (small SUVs with low l x w and high CO₂ emissions) and can certainly not be considered representative of a general trend.

- The sensitivity of Suzuki to increased slopes is significantly more enhanced when l x w is used as utility parameter.
  - This can be explained by the fact that for l x w Suzuki is further below the overall average than for mass (see bubble graphs in Annex B).
- For e.g. Ford, Nissan, and Mazda the sensitivity to the value of the slope is enhanced compared to the case of mass as utility parameter.
  - For l x w the average values for these manufacturers are further away from the overall average than for mass (see bubble graphs in Annex B).
- For Renault and Honda the sensitivity to the slope is reduced compared to the case of mass as utility parameter.
  - For l x w the average values for these manufacturers are closer to the overall average than for mass (see bubble graphs in Annex B).
- For Hyundai the sensitivity is completely reversed compared to the case of mass as utility parameter.
  - This is caused by the fact that the average pan area for Hyundai is below the overall average while for mass the average value for Hyundai is above the overall average (see bubble graphs in Annex B).
6.5 Per manufacturer + trading – utility – mass & per manufacturer + trading – % reduction (a/ b1)

6.5.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying credits to the amount that the achieved CO₂ emission is below or above the target for that segment.

Figure 49 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer + trading for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\%$ p.a.) and baseline b1 (AMI compensated)
Figure 50  Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \ p.a.$) and baseline b1 ($\text{AMI} \text{ compensated}$)

Figure 51  Absolute retail price increase per segment for utility based limits applied per manufacturer + trading for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \ p.a.$) and baseline b1 ($\text{AMI} \text{ compensated}$)
6.5.2 Conclusions

- Average costs are independent of the slope or other target definition (% red.) for measures with trading.
- Average costs are somewhat lower than for equivalent options “per manufacturer” without trading.
- Compared to the option “per manufacturer” without trading the sensitivity of relative retail price increase per segment to the slope of the limit function is strongly increased.
- Adding trading to the “per manufacturer” options leads to a more even distribution of relative retail price increase.
- Sensitivities per manufacturer, i.e. the change of costs as function of the slope of the limit function, are somewhat less then in the case without trading.
  - This is most pronounced for Subaru and Porsche. When trading is allowed Subaru and Porsche are faced with significantly lower costs per vehicle and costs are less sensitive to the slope of the limit function.
- Slopes below 100% lead to negative costs for small diesel vehicles. This is caused by the fact that manufacturers can earn money by reducing these vehicles beyond the target for this segment and to sell the additional reduction as CO₂ emission credits.
- The desired situation of costs increasing with vehicle size is achieved for slopes of 60% and lower. For 80% the costs per vehicle are about equal for the three petrol segments, but increase as function of size for the diesel segments.
- Traded volumes are a significant share (10 – 20%) of the total costs of reaching the 130 g/km target.
- Traded volumes are significant enough to justify the set-up of a trading system. The impact of trading on average or total costs is less than 10%. Impacts on costs per manufacturer seem of the same order of magnitude but need to be further analysed.
- The main benefit of a system with trading is that it makes life easier for a limited number of “specialised” manufacturers with sales distributions or model portfolios that strongly deviate from the average.
6.6 Per manufacturer + trading – utility – pan area (l x w) & per manufacturer + trading – % reduction (a/ b1)

6.6.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying credits to the amount that the achieved CO₂ emission is below or above the target for that segment.

Figure 53 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)
Figure 54  Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)

<table>
<thead>
<tr>
<th>Relative retail price increase [%]</th>
<th>PSA</th>
<th>Fiat</th>
<th>Renault</th>
<th>Toyota</th>
<th>Honda</th>
<th>GM</th>
<th>Ford</th>
<th>Nissan</th>
<th>Suzuki</th>
<th>Hyundai</th>
<th>Volkswagen</th>
<th>Mitsubishi</th>
<th>Mazda</th>
<th>BMW</th>
<th>DaimlerChrysler</th>
<th>Subaru</th>
<th>Porsche</th>
<th>Average</th>
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<tr>
<td>trading - utility - lxw - a / b1</td>
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</tbody>
</table>

Figure 55  Relative retail price increase per segment for utility based limits applied per manufacturer + trading for U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)

<table>
<thead>
<tr>
<th>Relative retail price increase [%]</th>
<th>p,S</th>
<th>p,M</th>
<th>p,L</th>
<th>d,S</th>
<th>d,M</th>
<th>d,L</th>
<th>average</th>
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<tr>
<td>trading - utility - lxw - a / b1</td>
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</tbody>
</table>

TN 9: Quantitative analysis of various options with the updated model 182
Figure 56  Volumes of traded CO₂ emission credits (in g/km and in monetary value) for utility based limits applied per manufacturer + trading for U = pan area, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated)

<table>
<thead>
<tr>
<th>slope</th>
<th>CO₂ cost [g/km]</th>
<th>CO₂ cost [€]</th>
<th>CO₂ cost [g/km]</th>
<th>CO₂ cost [€]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>5,63E+07</td>
<td>4,17E+09</td>
<td>2,97%</td>
<td>22,65%</td>
</tr>
<tr>
<td>20%</td>
<td>4,78E+07</td>
<td>3,55E+09</td>
<td>2,52%</td>
<td>19,25%</td>
</tr>
<tr>
<td>40%</td>
<td>3,96E+07</td>
<td>2,94E+09</td>
<td>2,09%</td>
<td>15,95%</td>
</tr>
<tr>
<td>60%</td>
<td>3,40E+07</td>
<td>2,52E+09</td>
<td>1,79%</td>
<td>13,68%</td>
</tr>
<tr>
<td>80%</td>
<td>3,08E+07</td>
<td>2,28E+09</td>
<td>1,62%</td>
<td>12,37%</td>
</tr>
<tr>
<td>100%</td>
<td>2,89E+07</td>
<td>2,14E+09</td>
<td>1,52%</td>
<td>11,61%</td>
</tr>
<tr>
<td>120%</td>
<td>2,78E+07</td>
<td>2,06E+09</td>
<td>1,47%</td>
<td>11,17%</td>
</tr>
<tr>
<td>percentage red.</td>
<td>1,87E+07</td>
<td>1,38E+09</td>
<td>0,98%</td>
<td>7,52%</td>
</tr>
</tbody>
</table>

### 6.6.2 Conclusions
- The overall picture for limits functions based on l x w and applied per manufacturer is very similar to that of mass based utility functions applied per manufacturer.
- Also for pan area adding trading to the “per manufacturer” options leads to a more even distribution of relative retail price increase.
- Sensitivities per manufacturer, i.e. the change of costs as function of the slope of the limit function, are somewhat less then in the case without trading.
  - This is most pronounced for Subaru and Porsche. When trading is allowed Subaru and Porsche are faced with significantly lower costs per vehicle and costs are less sensitive to the slope of the limit function.
- Impact of using l x w compared to mass is similar to the case without trading:
  - The sensitivity of Suzuki to increased slopes is significantly more enhanced when l x w is used as utility parameter.
  - For e.g. Ford, Nissan, and Mazda the sensitivity to the value of the slope is enhanced compared to the case of mass as utility parameter.
  - For Renault and Honda the sensitivity to the slope is reduced compared to the case of mass as utility parameter.
  - For Hyundai the sensitivity is completely reversed compared to the case of mass as utility parameter.
  - Explanations for these changes are the same as in the case of options per manufacturer without trading (see also bubble graphs in Annex B).
6.7 Additional analysis of distributional effects for utility-based limits per manufacturer without trading

6.7.1 Introduction
- The graphs below show additional analyses of the distributional effects for the utility-based limit functions applied per manufacturer without trading.
- In all graphs relative retail price increase per manufacturer is plotted as a function of the cumulative market share of manufacturers. For the different graphs manufacturers are listed in different orders:
  - Manufacturer are sorted a function of:
    - decreasing market share
    - increasing relative retail price increase for a given slope of the utility-based limit function.
- Analyses are presented separately for mass and pan area.
6.7.2 Mass and pan area based limits: manufacturers sorted by decreasing market share

Figure 57 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline b1 (AMI compensated)

Figure 58 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline b1 (AMI compensated)
6.7.3 Mass based limits: manufacturers sorted by increasing relative retail price increase

Figure 59 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \ p.a.$) and baseline b1 ($\text{AMI} \ \text{compensated}$), slope = 40%

![Graph showing relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \ p.a.$) and baseline b1 ($\text{AMI} \ \text{compensated}$), slope = 40%]

Figure 60 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \ p.a.$) and baseline b1 ($\text{AMI} \ \text{compensated}$), slope = 50%

![Graph showing relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \ p.a.$) and baseline b1 ($\text{AMI} \ \text{compensated}$), slope = 50%]
Figure 61  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated), slope = 60%

Figure 62  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated), slope = 70%
Figure 63 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.82\% \text{ p.a.}$) and baseline b1 (AMI compensated), slope = 80%
6.7.4 Pan area based limits: manufacturers sorted by increasing relative retail price increase

Figure 64 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a ($\text{AMI} = 0.82\%\ p.a.$) and baseline b1 (AMI compensated), slope = 40%

Figure 65 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a ($\text{AMI} = 0.82\%\ p.a.$) and baseline b1 (AMI compensated), slope = 50%
Figure 66 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated), slope = 60%

**Figure 66** Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated), slope = 60%

**Figure 67** Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario a (AMI = 0.82% p.a.) and baseline b1 (AMI compensated), slope = 70%
6.7.5 Conclusions

- For both mass and pan area and for all slopes between 40% and 80% it can be concluded that for 80% or more of the vehicles sold in Europe the average relative retail price increase per manufacturer is below or around the average value.
  - All graphs are based on averages per manufacturer. It can therefore not be concluded that the relative retail price increase is below or around the average for 80% of all vehicle models sold in Europe.
- This 80% market share includes all European “mainstream” manufacturers (PSA, Renault, Fiat, Ford, Volkswagen and BMW), as well as Japanese manufacturers Toyota and Honda.
- Whether GM and DaimlerChrysler are within the bandwidth of “below or around the average” relative retail price increase strongly depends on the utility parameter and the slope.
- For Porsche the relative retail price increase is a factor of 2 to 3 times the average depending on slope and utility parameter.
- For other Japanese manufacturers than Toyota and Honda and for the Korean manufacturer Hyundai the relative retail price increase tends to be significantly above average. For Hyundai this is more so for pan area as utility parameter than for mass.
### 6.8 Comparison of options w.r.t. absolute retail price increase

Table 9: Comparison of absolute retail price increases for various regulatory options under scenario a and relative to baseline b1 (AMI compensated)

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<tr>
<th>retail price increase</th>
<th>per car</th>
<th>per manuf.</th>
<th>trading</th>
<th>per car</th>
<th>per manuf.</th>
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<td>1263</td>
<td>1509</td>
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<td>1263</td>
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<td>slope 80%</td>
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<td>1263</td>
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<table>
<thead>
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<th>value divided by minimum of range for each option (column)</th>
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<th>per manuf.</th>
<th>trading</th>
<th>per car</th>
<th>per manuf.</th>
<th>trading</th>
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<td>100%</td>
<td>132%</td>
<td>110%</td>
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<td>slope 20%</td>
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<td>100%</td>
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<td>101%</td>
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<table>
<thead>
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<th>value divided by minimum of all utility based options</th>
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<th>per manuf.</th>
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<td>100%</td>
<td>149%</td>
<td>111%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 20%</td>
<td>135%</td>
<td>108%</td>
<td>100%</td>
<td>137%</td>
<td>109%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 40%</td>
<td>123%</td>
<td>106%</td>
<td>100%</td>
<td>127%</td>
<td>107%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 60%</td>
<td>115%</td>
<td>104%</td>
<td>100%</td>
<td>119%</td>
<td>105%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 80%</td>
<td>110%</td>
<td>103%</td>
<td>100%</td>
<td>115%</td>
<td>104%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 100%</td>
<td>108%</td>
<td>102%</td>
<td>100%</td>
<td>113%</td>
<td>104%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 120%</td>
<td>109%</td>
<td>102%</td>
<td>100%</td>
<td>113%</td>
<td>103%</td>
<td>100%</td>
</tr>
<tr>
<td>percentage reduction</td>
<td></td>
<td></td>
<td></td>
<td>101%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>per car value divided value for utility based limit per manufacturer</th>
<th>per car</th>
<th>per manuf.</th>
</tr>
</thead>
<tbody>
<tr>
<td>slope 0%</td>
<td>135%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 20%</td>
<td>124%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 40%</td>
<td>116%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 60%</td>
<td>110%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 80%</td>
<td>107%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 100%</td>
<td>106%</td>
<td>100%</td>
</tr>
<tr>
<td>slope 120%</td>
<td>107%</td>
<td>100%</td>
</tr>
</tbody>
</table>

- Depending on the slope, setting utility based targets per car leads to 6% to 35% higher costs per car than setting utility based targets per manufacturer.
- Options with trading are cheaper than options without trading but the difference is small (10% or less).
6.9 Early movers

- A criterion for the way in which the 130 g/km limit is to be applied is that “early movers” should at least not be punished and possibly even rewarded for their early action.
  - “Early movers” are manufacturers that already apply a lot of CO$_2$ reducing technologies or that for other reasons are already more energy efficient than their competitors.
- In the absence of detailed information on the technical state of the vehicles of various manufacturers or on the amount of CO$_2$ reduction applied e.g. in the context of the industry’s self commitment, one way of looking at this issue is to compare manufacturers based on the CO$_2$ reduction they achieved in the 2002-2006 period, based on data available in the model.
- Annex C explains how the cost assessment model estimates the amount of CO$_2$ emission reduction per manufacturer resulting from technical measures applied in the 2002-2006 period.
  - It should be noted that this estimate involves a high level of uncertainty as it has to be estimated on the basis of incomplete information.
- The table below shows a comparison per manufacturer of the estimated relative CO$_2$ reduction through technical measures in the 2002-2006 period and the average relative retail price increase for different utility parameters and slopes.
  - Pink cells indicate manufacturers for which the estimated CO$_2$ reduction in the 2002-2006 period is above average. These could be labelled as “early movers”.
  - Blue cells indicate manufacturers for which the average relative retail price increase for meeting the 2012 target is above average.
Table 10  Analysis of impacts on early movers by assessing possible correlations between the relative size of relative retail price increase per manufacturer for meeting the 2012 target and the relative size of the estimated CO\textsubscript{2} reductions already applied in the 2002-2006 period

<table>
<thead>
<tr>
<th>2002-2006 CO\textsubscript{2} reduction</th>
<th>relative retail price increase for meeting 2012 target</th>
</tr>
</thead>
<tbody>
<tr>
<td>[g/km]</td>
<td>[%]</td>
</tr>
<tr>
<td>2002-2006 CO\textsubscript{2} emissions</td>
<td>ACEA</td>
</tr>
<tr>
<td>[g/km]</td>
<td>182</td>
</tr>
<tr>
<td>[g/km]</td>
<td>0,3</td>
</tr>
<tr>
<td>[%]</td>
<td>0,2%</td>
</tr>
<tr>
<td>[%]</td>
<td>6,9%</td>
</tr>
<tr>
<td>[%]</td>
<td>5,8%</td>
</tr>
<tr>
<td>[%]</td>
<td>5,2%</td>
</tr>
<tr>
<td>[%]</td>
<td>4,1%</td>
</tr>
<tr>
<td>[%]</td>
<td>5,8%</td>
</tr>
<tr>
<td>[%]</td>
<td>6,3%</td>
</tr>
<tr>
<td>[%]</td>
<td>5,8%</td>
</tr>
<tr>
<td>[%]</td>
<td>5,3%</td>
</tr>
</tbody>
</table>

- The overall picture is quite mixed. Several of the manufacturers for which we estimated a high level of CO\textsubscript{2} reduction in the 2002-2006 period are still faced with a large reduction target an consequent high costs in the 2006-2016 period.

- Another valid comparison is to look at the relative efficiency of various manufacturers in relation to their average utility. The table below shows 2006 CO\textsubscript{2} emissions divided by mass and by pan area compared with the average relative retail price increase for different utility parameters and slopes.
  - The picture from this is more consistent: Manufacturers with CO\textsubscript{2} emissions per unit utility that are above the average are generally faced with above average relative retail price increases for meeting the 2012 target.
  - It should be noted, however, that this relative efficiency is not only determined by the relative efficiency of individual models compared to equivalent vehicles of other manufacturers, but also the product portfolio of a manufacturer (e.g. sales of SUVs in the large diesel segment).
Table 11 Analysis of impacts on early movers by assessing possible correlations between the relative size of relative retail price increase per manufacturer for meeting the 2012 target and the relative efficiency in 2006 expressed as CO₂ emissions per unit mass or per unit pan area

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>2006-2006 CO₂ reduction</th>
<th>relative retail price increase for meeting 2012 target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006 average CO₂</td>
<td>2006 average mass</td>
</tr>
<tr>
<td>ACEA</td>
<td>182 1453</td>
<td>0.125 7.95</td>
</tr>
<tr>
<td>BMW</td>
<td>184 1472</td>
<td>0.125 8.01</td>
</tr>
<tr>
<td>Fiat</td>
<td>144 111</td>
<td>0.129 6.75</td>
</tr>
<tr>
<td>Ford</td>
<td>162 1319</td>
<td>0.123 7.78</td>
</tr>
<tr>
<td>GM</td>
<td>157 1257</td>
<td>0.125 7.34</td>
</tr>
<tr>
<td>Porsche</td>
<td>282 1596</td>
<td>0.172 8.24</td>
</tr>
<tr>
<td>PSA</td>
<td>142 1201</td>
<td>0.118 7.12</td>
</tr>
<tr>
<td>Renault</td>
<td>147 1234</td>
<td>0.120 7.30</td>
</tr>
<tr>
<td>VW</td>
<td>165 1366</td>
<td>0.121 7.71</td>
</tr>
<tr>
<td>JAMA</td>
<td>182 1443</td>
<td>0.125 7.95</td>
</tr>
<tr>
<td>Toyota</td>
<td>152 1214</td>
<td>0.125 7.07</td>
</tr>
<tr>
<td>Nissan</td>
<td>164 1202</td>
<td>0.137 6.59</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>169 1245</td>
<td>0.136 7.19</td>
</tr>
<tr>
<td>Honda</td>
<td>153 1281</td>
<td>0.122 7.41</td>
</tr>
<tr>
<td>Mazda</td>
<td>173 1296</td>
<td>0.134 7.75</td>
</tr>
<tr>
<td>Suzuki</td>
<td>164 1152</td>
<td>0.143 6.59</td>
</tr>
<tr>
<td>Subaru</td>
<td>216 1384</td>
<td>0.156 7.77</td>
</tr>
<tr>
<td>Hyundai</td>
<td>165 1349</td>
<td>0.122 7.26</td>
</tr>
<tr>
<td>average</td>
<td>159 1289</td>
<td>0.124 7.43</td>
</tr>
</tbody>
</table>
7 Scenario b (AMI = 1.5% p.a.) / baseline b0
7.1 Per car – utility – mass (b/ b0)
7.1.1 Graphs

Figure 69 Absolute retail price increase per manufacturer for utility based limits applied per car for $U = \text{mass}$, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated)

Figure 70 Relative retail price increase per manufacturer for utility based limits applied per car for $U = \text{mass}$, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated)
7.1.2 Conclusions
- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for of scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.1.2 for the case a / b1.

7.1.3 Calculations based on individual vehicles
- Calculations based on individual vehicles, instead of averages per segment per manufacturer, have not been performed for this scenario (scenario b 1.5% AMI, relative to baseline b0). For results related to scenario a 0.82% AMI, relative to baseline b1 the reader is referred to section 6.1.3.
7.2 Per car – utility – pan area (l x w) (b/ b0)

7.2.1 Graphs

Figure 72 Absolute retail price increase per manufacturer for utility based limits applied per car for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated)

Figure 73 Relative retail price increase per manufacturer for utility based limits applied per car for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated)
7.2.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario $a$ with AMI = 0.82% p.a. and costs presented relative to baseline $b_1$.
  - Absolute and relative retail price increases are significantly higher than for of scenario $a$ with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.2.2 for the case $a / b_1$.

7.2.3 Calculations based on individual vehicles

- Calculations based on individual vehicles, instead of averages per segment per manufacturer, have not been performed for this scenario (scenario $b$ 1.5% AMI, relative to baseline $b_0$). For results related to scenario $a$ 0.82% AMI, relative to baseline $b_1$ the reader is referred to section 6.1.3.
7.3 Per manufacturer – utility – mass & per manufacturer – % reduction (b/ b0)

7.3.1 Graphs

Figure 75 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{mass} \), scenario \( b \) (AMI = 1.5% p.a.) and baseline \( b_0 \) (AMI not compensated)

Figure 76 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{mass} \), scenario \( b \) (AMI = 1.5% p.a.) and baseline \( b_0 \) (AMI not compensated)
Figure 77  Relative retail price increase per segment for utility based limits applied per manufacturer for $U = \text{mass}$, scenario b ($\text{AMI} = 1.5\% \text{ p.a.}$) and baseline b0 ($\text{AMI}$ not compensated)

Figure 78  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario b ($\text{AMI} = 1.5\% \text{ p.a.}$) and baseline b0 ($\text{AMI}$ not compensated), for specific slope variants

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers.
The following intermediate slopes have been assessed for more detailed analysis:

Figure 79  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{mass} \), scenario \( b \) (AMI = 1.5% p.a.) and baseline \( b_0 \) (AMI not compensated), with intermediate slope values

7.3.2  Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario \( a \) with AMI = 0.82% p.a. and costs presented relative to baseline \( b_1 \).
  - Absolute and relative retail price increases are significantly higher than for of scenario \( a \) with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.3.2 for the case \( a / b_1 \).
7.4 Per manufacturer – utility – pan area (l x w) & per manufacturer – % reduction (b/b0)

7.4.1 Graphs

Figure 80 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated)

Figure 81 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated)
Figure 82  Relative retail price increase per segment for utility based limits applied per manufacturer for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated) per manufacturer - utility - l x w - b / b0

Figure 83  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated), for specific slope variants

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers.
The following intermediate slopes have been assessed for more detailed analysis:

**Figure 84** Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario $b$ (AMI = 1.5% p.a.) and baseline $b_0$ (AMI not compensated), with intermediate slope values

The diagram shows the relative retail price increase per manufacturer for different utility based limits applied per manufacturer and varying slopes.

### 7.4.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario $a$ with AMI = 0.82% p.a. and costs presented relative to baseline $b_1$.
  - Absolute and relative retail price increases are significantly higher than for scenario $a$ with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.4.2 for the case $a / b_1$. 

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7.5 Per manufacturer + trading – utility – mass & per manufacturer + trading – % reduction (b/b0)

7.5.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying credits to the amount that the achieved CO₂ emission is below or above the target for that segment.

Figure 85 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated)
Figure 86  Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated)

Figure 87  Relative retail price increase per segment for utility based limits applied per manufacturer + trading for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not compensated)
7.5.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.5.2 for the case a / b1.
7.6 Per manufacturer + trading – utility – pan area (l x w) & per manufacturer +
trading – % reduction (b/ b0)

7.6.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying
credits to the amount that the achieved CO₂ emission is below or above the target for that
segment.

Figure 88 Absolute retail price increase per manufacturer for utility based limits applied per
manufacturer + trading for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b0 (AMI not
compensated)
Figure 89 Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading for \( U = \text{pan area} \), scenario b (AMI = 1.5\% p.a.) and baseline b0 (AMI not compensated)

![Relative retail price increase chart for manufacturers](chart1.png)

Figure 90 Relative retail price increase per segment for utility based limits applied per manufacturer + trading for \( U = \text{pan area} \), scenario b (AMI = 1.5\% p.a.) and baseline b0 (AMI not compensated)

![Relative retail price increase chart for segments](chart2.png)
7.6.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.6.2 for the case a / b1.
8 Scenario b (AMI = 1.5% p.a.) / baseline b1

8.1 Per car – utility – mass (b/ b1)

8.1.1 Graphs

Figure 91 Absolute retail price increase per manufacturer for utility based limits applied per car for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)

Figure 92 Relative retail price increase per manufacturer for utility based limits applied per car for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)
8.1.2 Conclusions regarding “per car – utility – mass”

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.1.2 for the case a / b1.

8.1.3 Calculations based on individual vehicles

- Calculations based on individual vehicles, instead of averages per segment per manufacturer, have not been performed for this scenario (scenario b 1.5% AMI, relative to baseline b1). For results related to scenario a 0.82% AMI, relative to baseline b1 the reader is referred to section 6.1.3.
8.2 Per car – utility – pan area (l x w) (b/ b1)

8.2.1 Graphs

Figure 94 Absolute retail price increase per manufacturer for utility based limits applied per car for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)

Figure 95 Relative retail price increase per manufacturer for utility based limits applied per car for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)
8.2.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.2.2 for the case a / b1.

8.2.3 Calculations based on individual vehicles

- Calculations based on individual vehicles, instead of averages per segment per manufacturer, have not been performed for this scenario (scenario b 1.5% AMI, relative to baseline b1). For results related to scenario a 0.82% AMI, relative to baseline b1 the reader is referred to section 6.1.3.
8.3 Per manufacturer – utility – mass & per manufacturer – % reduction (b/ b1)

8.3.1 Graphs

Figure 97 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)

Figure 98 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)
Figure 99  Relative retail price increase per segment for utility based limits applied per manufacturer for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)

Figure 100  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated), for specific slope variants

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers.
The following intermediate slopes have been assessed for more detailed analysis:

Figure 101  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated), with intermediate slope values

8.3.2  Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.3.2 for the case a / b1.
8.4 Per manufacturer – utility – pan area (l x w) & per manufacturer – % reduction (b/ b1)

8.4.1 Graphs

Figure 102 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)

Figure 103 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)
Figure 104  Relative retail price increase per segment for utility based limits applied per manufacturer for \(U = \) pan area, scenario b (AMI = 1.5\% p.a.) and baseline b1 (AMI compensated)

Figure 105  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for \(U = \) pan area, scenario b (AMI = 1.5\% p.a.) and baseline b1 (AMI compensated), for specific slope variants

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers.
The following intermediate slopes have been assessed for more detailed analysis:

Figure 106  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated), with intermediate slope values per manufacturer - utility - l x w - b / b1

8.4.2 Conclusions
- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.4.2 for the case a / b1.
8.5 Per manufacturer + trading – utility – mass & per manufacturer + trading – % reduction (b/ b1)

8.5.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying credits to the amount that the achieved CO₂ emission is below or above the target for that segment.

Figure 107 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)
Figure 108  Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading for $U = \text{mass}$, scenario b ($\text{AMI} = 1.5\% \ \text{p.a.}$) and baseline b1 (AMI compensated)

Figure 109  Relative retail price increase per segment for utility based limits applied per manufacturer + trading for $U = \text{mass}$, scenario b ($\text{AMI} = 1.5\% \ \text{p.a.}$) and baseline b1 (AMI compensated)
8.5.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.5.2 for the case a / b1.
8.6 Per manufacturer + trading – utility – pan area (l x w) & per manufacturer + trading – % reduction (b / b1)

8.6.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying credits to the amount that the achieved CO$_2$ emission is below or above the target for that segment.

Figure 110 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = pan area, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)

![Graph showing absolute retail price increase per manufacturer for utility based limits](image-url)
Figure 111  Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading for $U = \text{pan area}$, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)

Figure 112  Relative retail price increase per segment for utility based limits applied per manufacturer + trading for $U = \text{pan area}$, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated)
8.6.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.6.2 for the case a / b1.

8.7 Additional analysis of distributional effects for utility-based limits per manufacturer without trading

8.7.1 Introduction

- The graphs below show additional analyses of the distributional effects for the utility-based limit functions applied per manufacturer without trading.
- In all graphs relative retail price increase per manufacturer is plotted as a function of the cumulative market share of manufacturers. For the different graphs manufacturers are listed in different orders:
  - Manufacturer are sorted a function of:
    - decreasing market share
    - increasing relative retail price increase for a given slope of the utility-based limit function.
- Analyses are presented separately for mass and pan area.

8.7.2 Mass based limits: manufacturers sorted by increasing relative retail price increase

Figure 113 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated), slope = 40%
Figure 114 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated), slope = 50%

Figure 115 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario b (AMI = 1.5% p.a.) and baseline b1 (AMI compensated), slope = 60%
Figure 116  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U =$ mass, scenario a ($AMI = 1.5\% \text{ p.a.}$) and baseline b1 (AMI compensated), slope = 70$\%$

Figure 117  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U =$ mass, scenario b ($AMI = 1.5\% \text{ p.a.}$) and baseline b1 (AMI compensated), slope = 80$\%$
9 Scenario c (AMI = 0.0% p.a.) / baseline b0

9.1 Per car – utility – mass (c/ b0)

9.1.1 Graphs

Figure 118 Absolute retail price increase per manufacturer for utility based limits applied per car for $U = \text{mass}$, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)

Figure 119 Relative retail price increase per manufacturer for utility based limits applied per car for $U = \text{mass}$, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)
9.1.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario \( a \) with AMI = 0.82% p.a. and costs presented relative to baseline \( b_1 \).
  - Absolute and relative retail price increases are significantly lower than for scenario \( a \) with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.1.2 for the case \( a / b_1 \).

9.1.3 Calculations based on individual vehicles

- Calculations based on individual vehicles, instead of averages per segment per manufacturer, have not been performed for this scenario (scenario \( c \) 0.0% AMI, relative to baseline \( b_0 \)). For results related to scenario \( a \) 0.82% AMI, relative to baseline \( b_1 \) the reader is referred to section 6.1.3.
9.2 Per car – utility – pan area (l x w) (c/ b0)

9.2.1 Graphs

Figure 121 Absolute retail price increase per manufacturer for utility based limits applied per car for U = pan area, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)

Figure 122 Relative retail price increase per manufacturer for utility based limits applied per car for U = pan area, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)
Figure 123  Relative retail price increase per segment for utility based limits applied per car for $U = \text{pan area}$, scenario $c$ (AMI = 0.0% p.a.) and baseline $b0$ (AMI not compensated)

9.2.2  Conclusions
- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario $a$ with AMI = 0.82% p.a. and costs presented relative to baseline $b1$.
  - Absolute and relative retail price increases are significantly lower than for scenario $a$ with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.2.2 for the case $a / b1$.

9.2.3  Calculations based on individual vehicles
- Calculations based on individual vehicles, instead of averages per segment per manufacturer, have not been performed for this scenario (scenario $c$ 0.0% AMI, relative to baseline $b0$). For results related to scenario $a$ 0.82% AMI, relative to baseline $b1$ the reader is referred to section 6.1.3.
9.3 Per manufacturer – utility – mass & per manufacturer – % reduction (c/ b0)

9.3.1 Graphs

Figure 124 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)

Figure 125 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)
Figure 126  Relative retail price increase per segment for utility based limits applied per manufacturer for U = mass, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)

per manufacturer - utility - m - c / b0

Figure 127  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated), for specific slope variants

per manufacturer - utility - m - c / b0

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers.
The following intermediate slopes have been assessed for more detailed analysis:

**Figure 128** Relative retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{mass} \), scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated), with intermediate slope values

![Graph showing relative retail price increase per manufacturer](image)

### 9.3.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly lower than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.3.2 for the case a / b1.
9.4 Per manufacturer – utility – pan area (l x w) & per manufacturer – % reduction (c/b0)

9.4.1 Graphs

Figure 129 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)

Figure 130 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)
Figure 131 Relative retail price increase per segment for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario c ($\text{AMI} = 0.0\% \text{ p.a.}$) and baseline $b_0$ ($\text{AMI}$ not compensated)

Figure 132 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{pan area}$, scenario c ($\text{AMI} = 0.0\% \text{ p.a.}$) and baseline $b_0$ ($\text{AMI}$ not compensated), for specific slope variants

Note: Porsche and Subaru have been excluded from both equalisation approaches and therefore retail price increases are relatively high for these manufacturers.
The following intermediate slopes have been assessed for more detailed analysis:

Figure 133 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated), with intermediate slope values per manufacturer - utility - l x w - c / b0

9.4.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly lower than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.4.2 for the case a / b1.
9.5 Per manufacturer + trading – utility – mass & per manufacturer + trading – % reduction (c/ b0)

9.5.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying credits to the amount that the achieved CO₂ emission is below or above the target for that segment.

Figure 134 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = mass, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)
Figure 135  Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = mass, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)

Figure 136  Relative retail price increase per segment for utility based limits applied per manufacturer + trading for U = mass, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)
9.5.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario \textit{a} with AMI = 0.82\% p.a. and costs presented relative to baseline \textit{b1}.
  - Absolute and relative retail price increases are significantly lower than for scenario \textit{a} with AMI = 0.82\% p.a..
  - For detailed conclusions see section 6.5.2 for the case \textit{a} / \textit{b1}.
9.6 Per manufacturer + trading – utility – pan area (l x w) & per manufacturer + trading – % reduction (c/ b0)

9.6.1 Graphs

Note: average costs per car include the revenues or costs associated with selling or buying credits to the amount that the achieved CO₂ emission is below or above the target for that segment.

Figure 137 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = pan area, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)
Figure 138  Relative retail price increase per manufacturer for utility based limits applied per manufacturer + trading for U = pan area, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)

Figure 139  Relative retail price increase per segment for utility based limits applied per manufacturer + trading for U = pan area, scenario c (AMI = 0.0% p.a.) and baseline b0 (AMI not compensated)
9.6.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly lower than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.6.2 for the case a / b1.
10 Scenario c (AMI = 0.0% p.a.) / baseline b1

In the absence of autonomous mass increase (AMI = 0.0% p.a.) the CO₂ emissions of vehicles do not change between 2006 and 2012. As a consequence no costs need to be made for maintaining emissions at the 2006 level in baseline b1. For this reason the results for scenario c are the same for the baselines b0 and b1.

In this chapter we therefore only present the results of the analysis using graphs in which manufacturers are sorted by increasing relative retail price increase as function of the cumulative sales. For the case of scenario c this analysis has only been done for mass based limits.

10.1 Additional analysis of distributional effects for utility-based limits per manufacturer without trading

10.1.1 Introduction

- The graphs below show additional analyses of the distributional effects for the utility-based limit functions applied per manufacturer without trading.
- In all graphs relative retail price increase per manufacturer is plotted as a function of the cumulative market share of manufacturers. For the different graphs manufacturers are listed in different orders:
  - Manufacturer are sorted a function of:
    - decreasing market share
    - increasing relative retail price increase for a given slope of the utility-based limit function.
- Analyses are presented for mass only.
10.1.2 Mass based limits: manufacturers sorted by increasing relative retail price increase

Figure 140  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario a (AMI = 0.0% p.a.) and baseline b0=b1, slope = 40%

Figure 141  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario a (AMI = 0.0% p.a.) and baseline b0=b1, slope = 50%
Figure 142  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{mass} \), scenario a (AMI = 0.0\% p.a.) and baseline \( b_0 = b_1 \), slope = 60\%

**per manufacturer - utility - m - c / b_0 = b_1**

![Graph showing relative retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{mass} \), scenario a (AMI = 0.0\% p.a.) and baseline \( b_0 = b_1 \), slope = 60\%]

Figure 143  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{mass} \), scenario a (AMI = 0.0\% p.a.) and baseline \( b_0 = b_1 \), slope = 70\%

**per manufacturer - utility - m - c / b_0 = b_1**

![Graph showing relative retail price increase per manufacturer for utility based limits applied per manufacturer for \( U = \text{mass} \), scenario a (AMI = 0.0\% p.a.) and baseline \( b_0 = b_1 \), slope = 70\%]
Figure 144  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.0\% \text{ p.a.}$) and baseline $b_0=b_1$, slope = 80%

![Relative retail price increase per manufacturer for utility based limits applied per manufacturer for $U = \text{mass}$, scenario a ($\text{AMI} = 0.0\% \text{ p.a.}$) and baseline $b_0=b_1$, slope = 80%](image_url)
11 Scenario d (AMI = 2.5% p.a.) / baseline b0

For scenario d (AMI = 2.5% p.a.) only the option of applying a sales weighted target per manufacturer without trading (“per manufacturer – utility”) has been assessed. Furthermore for the utility-based limit functions results are only given for slopes between 30% and 80%.

11.1 Per manufacturer – utility – mass & per manufacturer – % reduction (d/ b0)

11.1.1 Graphs

Figure 145 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario d (AMI = 2.5% p.a.) and baseline b0 (AMI not compensated)
Figure 146  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario d (AMI = 2.5% p.a.) and baseline b0 (AMI not compensated)

Figure 147  Relative retail price increase per segment for utility based limits applied per manufacturer for U = mass, scenario d (AMI = 2.5% p.a.) and baseline b0 (AMI not compensated)
11.1.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.3.2 for the case a / b1.
11.2 Per manufacturer – utility – pan area (l x w) & per manufacturer – % reduction (d/ b0)

11.2.1 Graphs

Figure 148 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario d (AMI = 2.5% p.a.) and baseline b0 (AMI not compensated)

Figure 149 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario d (AMI = 2.5% p.a.) and baseline b0 (AMI not compensated)
11.2.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for of scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.4.2 for the case a / b1.
12 Scenario d (AMI = 2.5% p.a.) / baseline b1

For scenario d (AMI = 2.5% p.a.) only the option of applying a sales weighted target per manufacturer without trading (“per manufacturer – utility”) has been assessed. Furthermore for the utility-based limit functions results are only given for slopes between 30% and 80%.

12.1 Per manufacturer – utility – mass (d/ b1)

12.1.1 Graphs

Figure 151 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario d (AMI = 2.5% p.a.) and baseline b1 (AMI compensated)
Figure 152  Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = mass, scenario d (AMI = 2.5% p.a.) and baseline b1 (AMI compensated)

Figure 153  Relative retail price increase per segment for utility based limits applied per manufacturer for U = mass, scenario d (AMI = 2.5% p.a.) and baseline b1 (AMI compensated)
12.1.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.3.2 for the case a / b1.
12.2 Per manufacturer – utility – pan area (l x w) & per manufacturer – % reduction (d/ b1)

12.2.1 Graphs

Figure 154 Absolute retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario d (AMI = 2.5% p.a.) and baseline b1 (AMI compensated)

Figure 155 Relative retail price increase per manufacturer for utility based limits applied per manufacturer for U = pan area, scenario d (AMI = 2.5% p.a.) and baseline b1 (AMI compensated)
12.2.2 Conclusions

- Overall conclusions and conclusions per segment and per manufacturer are the same as for the case of scenario a with AMI = 0.82% p.a. and costs presented relative to baseline b1.
  - Absolute and relative retail price increases are significantly higher than for scenario a with AMI = 0.82% p.a..
  - For detailed conclusions see section 6.4.2 for the case a / b1.
13 General conclusions

13.1 Average costs vs. distributional effects

- The average additional retail price increase associated with meeting the 130 g/km target is not strongly variable according to the range of assumptions and detailed design parameters for the CO$_2$ legislation.
- The absolute retail price increase per car between 2006 and 2012 to be attributed to the CO$_2$ legislation is of the order of € 1050 to € 2400, depending on assumed autonomous mass increase (0.0%, 0.82%, 1.5% or 2.5% p.a.) and baseline scenario. This is equivalent to 5 to 11% relative retail price increase.
- Differences in distributional effects between the different options analysed are much larger than differences in impact on average cost per vehicle.
  - In fact, the impact of different slopes of the utility based limit function on overall costs is always limited to several tens of percents.
    - A 10% difference in absolute retail price increase correspond to about 130 €/vehicle, which still equals 1.8 billion Euro p.a. for a total EU 15 sales of around 14 million p.a.. This is 0.6 to 0.8% of the total turnover (incl. taxes) of the automobile sales in Europe.
    - For the “per manufacturer” options the difference in costs for the 60% and the 100% slope are about 40 €/car, which equals 0.6 billion Euro p.a. for a total EU 15 sales of around 14 million p.a..
  - Accepting these additional costs as “relatively insignificant” allows optimisation with respect to other criteria than overall cost effectiveness.

13.2 Applying a uniform limit or utility-based limit function per vehicle

- Applying a CO$_2$ limit at the vehicle level leads to the most pronounced differences in additional (absolute and relative) retail price increases per manufacturer, especially for a uniform limit or low values of the slope of a utility-based limit function.
- To meet the 130 g/km average almost all models in the market in 2006 will have to undergo significant CO$_2$ reductions. A significant amount of models will require larger reductions than available according to the cost curves. This not only includes sports cars and SUVs but also model variants of small and medium size “normal” vehicles.
  - To avoid that these models have to be excluded a penalty has to be introduced at the level of the marginal costs of the highest available level of CO$_2$ reduction. This has to be accompanied by a further tightening of the limit (function) to assure that the 130 g/km is met in 2012.
- A limit or limit function per vehicle is very inflexible as there is no possibility to compensate for less efficient cars by extra CO$_2$ reduction on other models. This leads to higher average costs than applying a limit function at the level of the sales averaged CO$_2$ emission per manufacturer (internal averaging).

13.3 Determination of the optimal slope of a utility-based limit function applied per manufacturer

13.3.1 General remarks
- Only linear utility-based limit functions, with mass and pan area as utility parameters, have been investigated. Different slopes of the linear limit function lead to different
distributions of the burden of meeting the 130 g/km target over the different manufacturer groups.

- Analysis discussed further on in this section proves that using a non-linear utility-based limit function will not improve the equalisation of the relative retail price increase over the manufacturers.

- It should be emphasised that the same percentage value of the slope has different distributional effects and average costs for different utility parameters (in this case mass and pan area). The choice of the slope is thus not entirely independent of the choice of utility parameter.
  - The distribution of costs over the segments is not very sensitive to the slopes of the utility function.

Table 12 Comparison of absolute and relative retail price increases per segment for two slope values of utility based limit functions under scenario a (AMI = 0.82% p.a.) relative to baseline b1 (AMI compensated)

<table>
<thead>
<tr>
<th>scenario a (a.w.i. = 0.82% p.a.)</th>
<th>absolute retail price increase compared to baseline b1 [€/car]</th>
<th>relative retail price increase compared to baseline b1 [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p,S</td>
<td>p,M</td>
</tr>
<tr>
<td>40% slope - lxw - per manufacturer</td>
<td>1365</td>
<td>1943</td>
</tr>
<tr>
<td>40% slope - m - per manufacturer</td>
<td>1363</td>
<td>1948</td>
</tr>
<tr>
<td>100% slope - lxw - per manufacturer</td>
<td>1485</td>
<td>1840</td>
</tr>
<tr>
<td>100% slope - m - per manufacturer</td>
<td>1484</td>
<td>1854</td>
</tr>
</tbody>
</table>

- However, the distribution of costs over manufacturers is depending on the utility parameter for a given slope %, as is indicated by the different slope values for which maximum equalisation is realised for mass and pan area. The “evenness” distribution achieved by a 48% slope for a mass based limit is reached at a 28% slope for pan area. Specific distributional effects for individual manufacturers will be different at the same level of “evenness” as manufacturers have significantly different ratios of sales averaged mass and pan area.

- The table above shows that petrol vehicles in general show a larger retail price increase than diesel vehicles for the per manufacturer options. This is not due to the lower efficiency of petrol vehicles but to the differences in cost curves. Under cost optimisation per manufacturer all segments deliver CO₂ reductions up to the same marginal costs. For petrol vehicles a given level of marginal costs represents a higher reduction and higher associated costs than for an equivalent diesel vehicle.

- All results presented per segment in this assessment assume full and linear cost pass through within each segment. In reality manufacturers can distribute the total costs of meeting the target over their total sales in very different ways.
Figure 157  Comparison of distributional impacts of the unweighted equalised slope for mass and pan area as utility parameters, for the case of scenario 1 (AMI = 0.82% p.a.) relative to baseline b1 (AMI compensated)

For 40% slope and utility parameter ‘mass’, the relative cost per manufacturer varies between 2.5% and 21%. For 40% slope and utility ‘pan area’(l x w) the relative cost per manufacturer varies between 2.5% and 23%. For the slopes
corresponding with an optimised distribution of relative retail price increase (28% for pan area, 48% for mass), the relative costs vary between 2.5% and 11%.

13.3.2 Impact of slope in relation to various assessment criteria

- For the case of mass or pan area (l x w) as utility parameter and a utility-based limit function applied to the sales averaged CO₂ emissions per manufacturer (without trading) the following conclusions can be drawn regarding the optimal slope of the limit function in relation to various assessment criteria:
  - Overall cost effectiveness:
    - For both utility parameters the lowest average retail price increase per car is reached for a slope of 123%. Average costs increase with decreasing slope.
  - Disincentives for perverse effects and unwanted market trends:
    - In the case of mass as utility parameter, for slopes above 80% mass increase (accompanied by measures applied to the powertrain to maintain performance) brings a vehicle closer to the 2012 target (as the target increases faster with mass than the vehicle’s CO₂ emissions), as is explained in Technical Note 4. To avoid stimulation of perverse effects or market trends which cause the 2012 average CO₂ emissions to increase above 130 g/km the slope of a mass-based limit function should thus be significantly below 80%.
    - For a slope of around 80% a mass-based limit function excludes weight reduction as a technical option for meeting the target set per manufacturer. The CO₂ reduction resulting from weight reduction is about the same as the tightening of the limit that is associated with weight reduction under an 80% slope.
  - Obviously weight reduction always leads to net CO₂ reduction and as such helps to meet the 130 g/km target.
  - Impacts on consumers:
    - For petrol vehicles there is no slope that meets the criterion that the relative retail price increase should not be lower for larger vehicles than for small vehicles. For a 0% slope the relative retail price increase for small vehicles is about the same as that for large vehicles, but still larger than that for medium-sized vehicles. For diesel vehicles this condition is met for all slopes between 0% and 120%, with cost increasing more pronounced with vehicle size class for the lower slope values.
    - The lifetime fuel cost savings at the consumer level (i.e. incl. taxes) is around €2240, which is higher than the vehicle retail price increase for all scenarios except the one assuming an autonomous mass increase of 2.5% p.a.. As a consequence the 130 g/km legislation is largely cost effective at the consumer level.
  - Distribution of the burden over various manufacturers:
    - Excluding Porsche and Subaru (which are characterised by selling only petrol vehicles with above average CO₂ emissions) from the analysis, the most even distribution of relative retail price increase per car is achieved for slopes between about 50% and 80% for mass as utility parameter and between about 30% and 70% for pan area as utility parameter. Nevertheless the scatter of relative retail price increase per manufacturer is ±4% around the average value of about 6%.
    - Higher slopes than those for which equalisation of relative retail price increase per car is achieved lead to decreasing relative retail price increase per car with increasing average utility (mass or pan area). For lower slopes the relative retail price increase per car will generally increase with increasing average utility.
    - A linear utility based limit function can not be tailored to fully equalise the burden per manufacturer in terms of relative retail price increase.
The scatter plot of relative retail price increase against average mass for the “weighted equalisation” and “unweighted equalisation” slopes does not show any linear or non-linear correlation in the residue (i.e. remaining difference between relative retail price increase per manufacturer and the average relative retail price increase). This proves that using a non-linear utility-based limit function will not improve the equalisation of the relative retail price increase over the manufacturers.

In general, however, it seems that a linear limit function leads to higher costs for manufacturers producing vehicles that are less efficient than the average for a given utility value.

For both mass and pan area and for both the 40% and the 80% slope it can be concluded that for 80% or more of the vehicles sold in Europe the average relative retail price increase per manufacturer is below or around the average value.

- It can not be concluded that the relative retail price increase is below or around the average for 80% of all vehicle models sold in Europe.
- This 80% market share includes all European “mainstream” manufacturers (PSA, Renault, Fiat, Ford, Volkswagen and GM), as well as Japanese manufacturers Toyota and Honda.
- Whether BMW and DaimlerChrysler are within the bandwidth of “below or around the average” relative retail price increase strongly depends on the utility parameter and the slope.
- For Porsche the relative retail price increase is a factor of 2 to 3 times the average depending on slope and utility parameter.
- For other Japanese manufacturers than Toyota and Honda and for the Korean manufacturer Hyundai the relative retail price increase tends to be significantly above average. For Hyundai this is more so for pan area as utility parameter than for mass.

Some more analysis is necessary to see if the remaining differences in relative retail price increase for the case of the “weighted equalisation” and “unweighted equalisation” slopes can be considered “fair” in the sense that early movers or manufacturers that sell relatively efficient vehicles (in terms of CO₂ per unit utility) bear lower costs for meeting the target than manufacturers of relatively inefficient vehicles.

For the utility parameter and slope value that are chosen in the end as basis for the CO₂ legislation, there will always be several manufacturers that are faced with costs per car that are markedly higher or lower than the average costs per car, independent of the utility parameter and slope value that are chosen. A plausible motivation must be provided for why the Commission considers it fair for other reasons acceptable that these manufacturers face higher or lower costs than average.

- In principle higher (or lower) costs than average are fair if a manufacturer produces vehicles that are less (or more) efficient than comparable models from other manufacturers. The difference in efficiency may be partly related to differences in mass. It can also be considered fair that the absolute and relative retail price increase is higher for manufacturers of sports vehicles, other high performance vehicles or luxury vehicles. This is consistent with the “polluter pays” principle.
- Specific attention should be paid to manufacturers for which high costs are caused by either a high share of large SUVs (with high mass, relatively low pan area, and relatively high CO₂ emissions) in the sales or a high share of
van-based vehicles that fall in the M1 category. Large SUVs are not all “Chelsea tractors” (e.g. BMW X5, Range Rover Freelander) but also include 4x4 off-road vehicles which are often used professionally e.g. in forestry (e.g. Toyota Land Cruiser and Land Rover). These SUVs and van-based vehicles serve practical functions which are clearly not correctly covered by mass or pan area as utility parameter.
  o An example of this is Mitsubishi which sells SUVs in the large diesel segment with very high mass and CO₂ emissions.

• For those cases where it is difficult to fully motivate the fairness of the impact of a given manufacturer (i.e. where meeting other evaluation criteria leads to a relatively unfair situation for a few manufacturers) one could consider the option of fines as a safety valve or explore whether there is an easy way for this manufacturer to avoid the specific unfair impacts.
  o Subaru and Porsche can reduce the impact of the CO₂ legislation by either offering diesel versions of the available models, or by “teaming up” with another manufacturer for the manufacturer average. Porsche could e.g. share the target with the Volkswagen group with which it already has close connections. And Subaru with Toyota, which has already a 30% stake in Subaru.

13.3.3 Conclusions

• For mass as utility parameter a slope of 40 to 60% seems optimal as it avoids incentives for perverse effects or market trends towards higher mass and leads to a relative retail price increase that on average increases with the average mass per manufacturer, and at least for diesel vehicles also increases with size segment.
• For pan area as utility parameter a slope of 30 to 40% seems optimal as it leads to a relative retail price increase that on average stays equal or increases with the average pan area per manufacturer, and at least for diesel vehicles also increases with size segment.

13.4 Impact of trading on costs and distributional effects

• Adding trading to the “per manufacturer” options leads to a more even distribution of relative retail price increase.
• Sensitivities per manufacturer, i.e. the change of costs as function of the slope of the limit function, are somewhat less then in the case without trading.
• Slopes below 100% lead to negative costs for small diesel vehicles. This is caused by the fact that manufacturers can earn money by reducing these vehicles beyond the target for this segment and to sell the additional reduction as CO₂ emission credits.
• The desired situation of costs increasing with vehicle size is achieved for slopes of 60% and lower. For 80% the costs per vehicle are about equal for the three petrol segments, but increase as function of size for the diesel segments.
• Traded amounts of CO₂ credits (in g/km) are relatively small (1 - 3%) compared to the total reduction (reduction per car times total sales), but traded volumes are a significant share (10 – 20%) of the total costs of reaching the 130 g/km target.
• Traded volumes are significant enough to justify the set-up of a trading system. The impact of trading on average or total costs is less than 10%. Impacts on costs per manufacturer seem of the same order of magnitude but need to be further analysed.
• The main benefit of a system with trading is that it reduces excessive burdens for a limited number of “specialised” manufacturers with sales distributions or model portfolios that strongly deviate from the average.

13.5 Applying a percentage reduction target per manufacturer

• With a percentage reduction target the goal of 130 g/km is met at lower average costs per car than for a utility-based limit function.
• A percentage reduction target leads to a seemingly even distribution of the relative retail price increase per car over all manufacturers. The distribution, however, should be considered unfair as the relative retail price increase per car is higher for manufacturers of small / light / low CO$_2$ emitting cars than for manufacturers of large / heavy / high CO$_2$ emitting cars.
• An important drawback of the percentage reduction option is that it locks the manufacturers of small / efficient vehicles in their present market position, while manufacturers of large / inefficient vehicles can meet their target by increasing their market share in the small and medium size vehicle segments.
• A percentage reduction target leads to higher costs for early movers as they have to climb further on the cost curve to meet the target.

13.6 Conclusions w.r.t. other criteria

• It is difficult to assess to what extent a specific measure or slope value treats early movers appropriately. This is mainly caused by the fact that it is difficult to point out which manufacturers are early movers. Overall, however, the condition seems to be generally met that manufacturers of relatively inefficient vehicles (based on CO$_2$ emissions per unit utility) are faced with above average costs for meeting the 130 g/km.
• It should be noted here, however, that it is dangerous to label high CO$_2$ in general or per unit utility as “inefficient”. Differences in average CO$_2$ emissions between manufacturers for a given size segment may be caused by differences in efficiency of comparable vehicle models offered by these manufacturers, but also to differences in the product portfolio within a size segment. This is especially the case for manufacturers which sell substantial amounts of sports vehicles (low mass per unit pan area) or SUVs (high mass per unit pan area).

13.7 Conclusions with regards to choice of utility parameter

• Mass and pan area have been assessed as candidate utility parameters. In the absence of data on footprint (wheelbase x track width) results on pan area can also be seen as a proxy for the impact of using footprint.
• As can be seen from Table 13, the assessed overall costs per vehicle are slightly higher when pan area is used as utility parameter.
  o For the options per manufacturer and intermediate slope values the difference is of the order of 1% or less. This is certainly below the accuracy of the cost assessment methodology used here, taking into account e.g. uncertainties in the definition of cost curves and the assumptions involved concerning the strategy that manufacturers choose to meet the targets set by the legislation.
  o Furthermore it should be emphasized that for the assessment of limit functions based on mass and pan area the same cost curves have been used. However, the use of mass as a utility parameter limits the effectiveness of weight reduction as a means to reduce...
CO₂ emissions and thus generally increases the costs per g/km for weight reduction. In principle this could lead to higher costs for reaching a given CO₂ reduction target. In paragraph 3.2.1. of Note 4 it has been argued that for the average CO₂ reduction levels involved to reach 130 g/km this cost increase is insubstantial, but it could very well be of the same order of magnitude as the cost advantage identified for mass in Table 13.

- Overall it should thus be concluded that the small difference in the assessed average costs for meeting the 2012 target between mass-based limit functions and limit functions based on pan are should be considered not significant.
- Overall distributional effects are very similar for mass and pan area.
  - For a limited number of manufacturers the burden strongly depends on the choice of utility parameter, depending on their average utility value for both parameters compared to the overall EU sales average.
- Mass as utility parameter reduces the contribution of weight reduction as a technical measure to reach emission reduction targets at the vehicle or manufacturer level.
- Mass as utility parameter has the risk of promoting perverse effects and stimulating market trends towards heavier cars. However, for slopes below 80% mass increase does not help manufacturers to reach their target (which increases with increasing vehicle mass) more easily.
- For both mass and pan area market trends towards heavier and or larger cars will lead to not meeting the target of 130 g/km in 2012, if this trend exceeds the amount of assumed autonomous trend which is factored into the setting of the limit function for 2012.
- Pan area accentuates the impact of the CO₂ legislation on certain vehicle classes, especially for SUVs which have relatively high mass and relatively low pan area.

13.8 Impact on costs and distributional effects of different assumptions on autonomous mass increase

- Different assumptions on autonomous mass increase have negligible impact on the distributional effects of a given measure.
- The impact of autonomous mass increase on the average costs per car is significant:
  - Absolute retail price increases for the different measures and combinations of AMI scenarios and baselines are presented in the table below.
  - When costs are compared to baseline b₀, scenario b with 1.5% p.a. autonomous mass increase leads to an average retail price increase that is 19 to 24% higher than for the case of scenario a with 0.82% p.a. autonomous mass increase.
  - When costs are compared to baseline b₁, scenario b with 1.5% p.a. autonomous mass increase leads to an average retail price increase that is 14 to 16% higher than for the case of scenario a with 0.82% p.a. autonomous mass increase.
  - Scenario c with 0.0% p.a. autonomous mass increase leads to costs that are 14 to 17% resp. 20 to 24% lower than for the case of scenario a with 0.82% p.a. autonomous mass increase for the baselines b₀ and b₁.
  - Scenario d with 2.5% p.a. autonomous mass increase leads to an additional retail price increase of around € 2400 for baseline b₀, and of around € 1900 for baseline b₁.
- Impacts are the same for mass and pan area as utility parameters.
Table 13 Overview of absolute retail price increases for all assessed regulatory options, all scenarios and baselines, and slopes between 0 and 120%

<table>
<thead>
<tr>
<th>2006-2012 average absolute retail price increase [€/veh.]</th>
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<tbody>
<tr>
<td>option</td>
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<td>per car</td>
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<tr>
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<tr>
<td>per manufacturer with trading</td>
</tr>
</tbody>
</table>

Note: for scenario d (a.w.i. = 2.5% p.a.) only the options per manufacturer without trading have been analysed.
13.9 Impact on costs and distributional effects of different assumptions on baseline for 2006-2012 without CO₂ emission legislation

- Different assumptions on autonomous development of CO₂ emissions at the vehicle level have negligible impact on the distributional effects of a given measure.
- The impact of assumptions on autonomous development of CO₂ emissions at the vehicle level on the average costs per car is significant:
  - Absolute retail price increases for the different measures and combinations of AMI scenarios and baselines are presented in the table above.
  - When costs are compared to baseline b₀, the costs for meeting 130 g/km in scenario a with 0.82% p.a. autonomous mass increase are about € 125 higher than in the case when costs are calculated relative to baseline b₁.
  - When costs are compared to baseline b₀, the costs for meeting 130 g/km in scenario b with 1.5% p.a. autonomous mass increase are about € 250 higher than in the case when costs are calculated relative to baseline b₁.
  - For scenario c with 0.0% p.a. autonomous mass increase the baselines b₀ and b₁ are identical so that costs compared to both= scenarios are the same.
- Impacts are the same for mass and pan area as utility parameters.
Possible regulatory approaches to reducing CO₂ emissions from cars

Technical note 10: Analysis of pooling for Volkswagen and Porsche

1 Introduction

This note reports the results of the quantitative analysis of various options with the assumption of pooling of target for Volkswagen and Porsche, performed in the context of the project “Possible regulatory approaches to reducing CO₂ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

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2 Results for VW and Porsche pooling targets

For utility-based limit functions applied per manufacturer (without trading) additional assessments have been made under the assumption that Volkswagen and Porsche pool their CO₂ reduction targets into a single sales-averaged CO₂ target.

- Assessments have been made for both mass and pan area as utility parameters.
- Assessments have only been made for the combination of scenario a (autonomous weight increase = 0.82% p.a.) and baseline b1 (without CO₂ legislation industry maintains the 2006 CO₂ levels per vehicle so costs of compensating effects of autonomous weight increase are not part of the costs of the CO₂ legislation). Distributional effects are not dependent on the assumptions regarding autonomous weight increase or baseline.
- Results can be compared with paragraphs 6.3, 6.4 and 6.7 of Technical Note 9 on quantitative analysis of various options with updated model.

2.1 Input data

For this assessment the model has been adapted, by uniting the data for VW and Porsche into data for a single manufacturer group “VW + Porsche”. Sales numbers have been added and
combined figures for CO\textsubscript{2} emissions, mass and pan area have been derived by means of sales-weighted averaging.

### Volkswagen

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### Volkswagen + Porsche

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2.2 Per manufacturer – utility – mass & per manufacturer – % reduction

2.2.1 Graphs

Note: The vertical scale of the graphs with absolute costs has been reduced to 0 - 8,000 € instead of 0 - 18,000 € which is used in paragraphs 6.3 and 6.4 of the “Annex on quantitative analysis of various options with updated model”, updated version dated 25/09/2007.
Intermediate slope values

per manufacturer - utility - m - a / b1

Absolute retail price increase [€]

PSA Fiat Renault Toyota Honda GM Ford Nissan Suzuki Hyundai VW + Porsche Mitsubishi Mazda BMW DaimlerChrysler Subaru Average

Absolute retail price increase [%]

Relative retail price increase [%]

Relative retail price increase [%]
### 2.3 Per manufacturer – utility – pan area (l x w) & per manufacturer – % reduction

#### 2.3.1 Graphs

Note: The vertical scale of the graphs with absolute costs has been reduced to 0 - 8,000 € instead of 0 - 18,000 € which is used in paragraphs 6.3 and 6.4 of the “Annex on quantitative analysis of various options with updated model”, updated version dated 25/09/2007.

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<th>Manufacturer</th>
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</tr>
</tbody>
</table>

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TN 10: Analysis of pooling for Volkswagen and Porsche 275
per manufacturer - utility - l x w - a / b₁

Relative retail price increase [%]

0% 5% 10% 15% 20% 25%

p,S  p,M  p,L  d,S  d,M  d,L  average

- per manuf. - utility - l x w - slope 0%
- per manuf. - utility - l x w - slope 20%
- per manuf. - utility - l x w - slope 40%
- per manuf. - utility - l x w - slope 60%
- per manuf. - utility - l x w - slope 80%
- per manuf. - utility - l x w - slope 100%
- per manuf. - utility - l x w - slope 120%
- per manuf. - percentage red.
Intermediate slope values

**per manufacturer - utility - l x w - a / b1**

![Graph showing absolute retail price increase in euros by manufacturer and utility for different slope values.]

**per manufacturer - utility - l x w - slope 40%**

![Graph showing absolute retail price increase in percentage by manufacturer and utility for different slope values.]

**per manufacturer - utility - l x w - slope 50%**

**per manufacturer - utility - l x w - slope 60%**

**per manufacturer - utility - l x w - slope 70%**

**per manufacturer - utility - l x w - slope 80%**

---

TN 10: Analysis of pooling for Volkswagen and Porsche
2.4 Additional analysis of distributional effects for utility-based limits per manufacturer without trading with VW and Porsche pooling targets

2.4.1 Introduction

- The graphs below show additional analyses of the distributional effects for the utility-based limit functions applied per manufacturer without trading.
- In all graphs relative retail price increase per manufacturer is plotted as a function of the cumulative market share of manufacturers. For the different graphs manufacturers are listed in different orders:
  - Manufacturer are sorted a function of:
    - decreasing market share
    - increasing relative retail price increase for a given slope of the utility-based limit function.
- Analyses are presented separately for weight and pan area.
2.4.2 Mass and pan area: manufacturers sorted by decreasing market share

**per manufacturer - utility - mass**

Manufacturers listed in order of decreasing market share

**per manufacturer - utility - pan area**

Manufacturers listed in order of decreasing market share
2.4.3 Mass based limits: manufacturers sorted by increasing relative retail price increase

**Per manufacturer - utility - m - a / b1**

- Manufacturers listed in order of increasing relative retail price increase for 40% slope.
- Manufacturers listed in order of increasing relative retail price increase for 50% slope.

**Cumulative Share of Sales (%) vs Relative Retail Price Increase (%)**

The diagrams illustrate the cumulative share of sales against the relative retail price increase for Volkswagen (VW) and Porsche, and for Fiat, Renault, Toyota, Fiat, BMW, Ford, and GM, in order of increasing relative retail price increase for 60% and 70% slopes.

The diagrams show the cumulative share of sales on the y-axis and the relative retail price increase on the x-axis. The data points represent different manufacturers, with lines connecting them to show the trend. The manufacturers listed are in order of increasing relative retail price increase for both 60% and 70% slopes.

For the 60% slope, the manufacturers listed in order of increasing relative retail price increase are VW + Porsche, Fiat, Renault, Toyota, Fiat, BMW, Ford, GM, Nissan, DC, Mitsubishi, Suzuki, Mazda, Honda, Hyundai, Subaru, and Nissan.

For the 70% slope, the manufacturers listed in order of increasing relative retail price increase are VW + Porsche, Fiat, Renault, Toyota, Fiat, BMW, Ford, GM, Nissan, DC, Mitsubishi, Suzuki, Mazda, Honda, Hyundai, Subaru, and Nissan.

The diagrams also highlight the average trend for all manufacturers combined.
2.4.4 Pan area based limits: manufacturers sorted by increasing relative retail price increase
per manufacturer - utility - l x w - a / b1

Manufacturers listed in order of increasing relative retail price increase for 70% slope

per manufacturer - utility - l x w - a / b1

Manufacturers listed in order of increasing relative retail price increase for 80% slope

TN 10: Analysis of pooling for Volkswagen and Porsche
3 Conclusions

- The effect of pooling the CO₂ reduction targets for Volkswagen and Porsche is very limited for VW but significant for Porsche. The absolute and relative retail price increase per car for VW + Porsche are slightly higher (about 6%) than for Volkswagen alone. This is to be expected based on the ratio between the sales numbers of VW and Porsche. The relative retail price increase per car for the VW + Porsche group is close to the overall average for all manufacturer together for all values of the slope of the utility-based limit function.

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<tr>
<td>U = m</td>
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- The overall average costs for meeting the 130 g/km target are about 1.5% lower for the case of a pooled target for VW and Porsche compared to the case of separate targets. As expected pooling increases the potential for cost optimisation.

- The option of pooling is also possible for Toyota and Subaru. Due to the smaller ratio of sales numbers the effect on the retail price increase per car for Toyota + Subaru is expected to be markedly higher.
**Technical note 11: Analysis of specific impacts on DaimlerChrysler**

1 **Introduction**

This note reports the results of the analysis of specific impacts on DaimlerChrysler performed in the context of the project “Possible regulatory approaches to reducing CO$_2$ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

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2. Analysis of specific impacts on DaimlerChrysler........................................................................................................................287
   2.1 Impact of excluding Chrysler brands...................................................................................................................................287
   2.2 Impact of utility-based limits on Smart.......................................................................................................................................289

2 **Analysis of specific impacts on DaimlerChrysler**

In this note two specific analyses are reporting with respect to the impacts of the 130 g/km legislation of DaimlerChrysler. The first analysis concerns the impacts of excluding all Chrysler brands from the target for DaimlerChrysler. The second analysis concerns detailed assessment of the impact of utility-based limits on models marketed under the Smart brand.

2.1 **Impact of excluding Chrysler brands**

- In the 2006 data the Chrysler brands Chrysler, Dodge and Jeep are still part of Daimler Chrysler. In the model calculations it has been assumed that these brands remain part of DaimlerChrysler. However, Daimler has recently sold 80% of its Chrysler shares to Cerberus Capital Management. Chrysler is to continue as a stand alone company so that in 2012 Chrysler sales (and the CO$_2$ emissions of these vehicles) no longer count for the total and average of Daimler.
- Table 1 below shows the share of Chrysler sales in the 2006 sales of DaimlerChrysler and the average CO$_2$ emission, average mass and average pan area of Daimler, DaimlerChrysler and the individual brands.
It is clear from Table 1 that vehicles from Chrysler brands (Chrysler, Dodge and Jeep) sold in Europe are some 29% heavier than vehicles from the European brands of Daimler (Mercedes (incl. Maybach) and Smart), and also have 10% higher pan area.

Excluding the Chrysler brands from the 2006 sales leads to a sales averaged CO₂ emissions for Daimler that is 3.3% lower than for DaimlerChrysler.

Table 2 below shows the impact of excluding the Chrysler sales for determining the utility-based limit value. Weight-based limits are based on extrapolated 2012 weight values under scenario a, ie assuming a 0.82% p.a. average autonomous weight increase between 2006 and 2012.

The impact of excluding sales under Chrysler brands in determining the utility-based CO₂ limit for Daimler obviously depends on the slope of the limit function. For all slopes of 120% and less the reduction in target is smaller than the reduction in 2006 average CO₂ emissions so that excluding the Chrysler brands from DaimlerChrysler makes it somewhat easier for Daimler to meet a 2012 utility based sales-weighted limit value.
2.2 Impact of utility-based limits on Smart

- Vehicles from the Smart brand are characterised by very small pan area (especially the Smart ForTwo), low weight and low CO$_2$ emissions (although not necessarily lower than other small vehicles in the same class).
- Table shows the impact of various slopes of the mass or pan area based limit functions on the reductions required for various Smart models, under the assumption that the target set by the limit function needs to be met at the vehicle model level.
  o Results are averaged over the different variants within each model.
  o Costs in the table are absolute retail price increases associated with the measures to be implemented to reduce CO$_2$ emissions from the 2012 baseline values in baseline b0 (effects of autonomous weight increase not compensated) to the 2012 target. For autonomous weight increase scenario a (a.w.i. = 0.82% p.a.) is assumed.
- As is to be expected retail price increases are always higher for the petrol variants than for the diesel variants.
- For the Smart ForTwo a pan area based limit functions lead to higher costs than mass based limit functions. For the ForFour and Roadster this is the other way around.
- For the Smart ForTwo a pan area based limit function with a slope $\geq 80\%$ leads to unacceptably high values for the retail price increase.
- For both mass and pan area slopes $\leq 60\%$ lead to costs for both petrol and diesel variants of all models that seem acceptable. Cost for diesel variants are very limited or zero in some cases. Costs for petrol vehicles are still significant, but this seems justified as the 2006 variants of these models are relatively inefficient compared to small models of other brands. This is especially the case for the ForFour.
- If the slope of the limit function is chosen $\leq 60\%$ the reductions required on Smart models do not pose a problem and would not require a floor in the limit function to avoid that vehicles with CO$_2$ emissions below e.g. 95 g/km are required to undergo further, costly emission reductions.
Table 3

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Technical note 12: Policy options for light duty commercial (N1) vehicles

1 Introduction

This note reports the results of the analysis of policy options for light duty commercial (N1) performed in the context of the project “Possible regulatory approaches to reducing CO$_2$ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

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3 Technical Potential for CO$_2$ Reductions .................................................................................... 292
4 Characteristics of the N1 market .................................................................................................. 293
5 Considerations in incorporating N1s into the regulatory system .................................................. 293
6 Considerations on utility parameters and segments for N1s .......................................................... 295
7 Considerations on alternative options .......................................................................................... 297
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Annex 1: Data on vehicle models, sales, mass and CO$_2$ emissions available from [TNO 2004]
Annex 2: Definition of N1 classes

2 Background

In the Commission’s updated Strategy on CO$_2$ from light duty vehicles (COM(2007)19), light commercial vehicles are expected to provide part of the CO$_2$ emission reduction required to bridge the gap between the proposed 130 g/km average for new passenger cars and the overall EU target of 120 g/km (equivalent) in 2012. The objective for N1 vehicles mentioned in COM(2007)19 is to reach a new vehicle sales averaged CO$_2$ emission of 175 g/km by 2012 and 160 g/km by 2015.

According to [TNO 2006] the 2002 average CO$_2$ emission of N1 vehicles is 201 g/km. The baseline value (without policy aimed at efficiency improvement in N1s) for 2012 is expected to be around 190 g/km based on autonomous efficiency improvements stemming in part at least from technology improvements diffusing into light vans from equivalent passenger cars. A reduction to 175 g/km by 2012 thus equals a net CO$_2$ reduction through direct application of additional technical measures of 15 g/km, equal to a 7% reduction compared to current level (estimated for 2006 at 195 g/km). For comparison, M1 vehicles will be required to reduce by 21% from 2006 to 2012, so it can be seen that this first objective is a far less demanding requirement than that imposed on passenger cars.

The authors of this study have previously carried out analysis of the technical possibilities for CO$_2$ reduction in N1 vehicles (see References). However, detailed analysis as performed for M1s in this study has not be undertaken for N1s due to lack of available vehicle statistics (sales, CO$_2$, mass, size, etc. per model). In default of such information, data from [TNO 2004] for the top 33 most sold models have been analysed and are summarised in Annex 1 to
this note. This represents partial data on sales, CO₂ emissions and mass, while information on
other potentially-useful vehicle parameters is completely absent.

Inquiries in the course of this study suggest that a full database of the required parameters for
N1 vehicles is still not available. Directive 2004/3 now requires CO₂ emissions data to be
measured and recorded for vans as it is for cars, but the requirements will not be fully
applicable to Class II and Class III vans until 2008 at the earliest. As a result, it can be
anticipated that the necessary data could in principle be available in a year or two.

As a consequence possible utility-based limit functions cannot be investigated with any
certainty. Earlier work suggested that reference mass gives a reasonably good ‘fit’ to CO₂
emissions, but in the absence of a full dataset this cannot yet be regarded as a firm
conclusion. Beyond this, distributional effects can not be analysed. From the analysis for M1
vehicles it is clear that the most favourable slope for the limit function is especially
determined by the impacts on distribution of the burden over different manufacturers, and this
cannot yet be determined. Further discussion of possible utility functions is however included
below.

According to [TNO 2006] the gap between 130 and 120 g/km in Mtonnes CO₂ p.a. to be
bridged by the accompanying measures is 7.6 Mtonnes p.a. in 2012 and 32.7 Mtonnes p.a. in
2020. The contribution of a 15 g/km reduction of the Type Approval CO₂ emissions of N1
vehicles contributes 1.2 Mtonnes p.a. in 2012 and 2.2 Mtonnes p.a. in 2020 to the net CO₂
reduction associated with the additional 10 g/km measures. The reduction of CO₂ from N1
vehicles thus contributes (1.2/7.6=) 16% to the additional CO₂ reduction requirement.

### Annual WTW GHG-emission reduction (in Mtonnes CO₂-eq. p.a.) for EU-15 resulting from technical
measures applied to light duty commercial vehicles (N₁-vehicles) in order to reach an average 2012
Type Approval CO₂-emission value which is 15, 30, 45 or 60 g/km lower than the average for 2002
[TNO 2006].

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<th>WTW GHG emission reduction [Mtonnes/y]</th>
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<td>60 g/km TA</td>
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3 Technical Potential for CO₂ Reductions

The technical options available to reduce the CO₂ emissions of vans, as identified in [TNO
2006], are largely of the same types as for passenger cars. Costs and reduction potentials for
application in N₁s are in many cases slightly different than for application in M₁s, however.
In principle, the timeframe in which such measures can be implemented is also the same as
that for CO₂ reduction in M₁ vehicles.

According to [TNO 2006] the measures that would be required to reach a first step of 15
g/km reduction are cost effective from a societal cost perspective (i.e. excluding taxes) for
fuel costs of 0.25 €/l (excl. tax) and above. As the share of tax in the fuel retail price is
generally higher than the share of tax in the vehicle retail price, the measures required to
reach this 15 g/km reduction are certainly cost effective from an end-user’s point of view, and
can therefore be considered as ‘low-hanging fruit’ that are relatively cheap to implement.
The total potential of technical measures identified in [TNO 2006] is about 60 g/km. This level of reduction does involve significant positive CO₂ abatement costs. However, due to the higher vehicle lifetime and higher annual mileage compared to M1 vehicles, the lifetime fuel cost savings associated with a 60 g/km CO₂ reduction in N1s are higher than for the same reduction in M1s, and roughly equate to the increase in vehicle retail price.

Note that, as the diesel penetration of the van market is already high (and has reached virtual saturation in some countries) the scope for improvements simply through further dieselisation is relatively limited compared to the car market.

4 Characteristics of the N1 market

The market for N1 vehicles is somewhat different to that for passenger cars, and these factors have some bearing on a possible choice of instrument and overall policy design to regulate CO₂ emissions from N1s. Key features are as follows:

- fewer brands than for M1s (9 compared with 17)
- fewer models than for M1s (around 100 compared to over 300)
- larger product diversity within a model (vehicle body variants and engine variants) than for M1s (typically around 10 variants compared to 5)
- smaller sales volumes overall than for M1 (1.7 million compared to 14 million)
- three main classes (Class I, II and III), also used for exhaust gas emission legislation – these are objectively determined classes (based on reference weight – see Annex 2) that are generally accepted and understood as a form of segmentation of the fleet.
- significantly higher average CO₂ emissions, but
- lower power-to-weight ratios especially compared to large M1 vehicles; so although there is a trend towards higher specific power in the N1 market there is likely to be less variation in CO₂ for a given utility value (ie no ‘sports car’ effect)
- a large share of diesels in the new vehicles sales (around 70% according to [TNO 2006]);
- likelihood of significant variations in the average CO₂ emissions from each brand or manufacturer, as some specialise more in M1-based vans (Class I) while some focus more on the larger (Class II and III) vans.

5 Considerations in incorporating N1s into the regulatory system

Clearly there is some preference in terms of policy coherence that the legislation for N1s be based on the same methodology as the legislation for M1s. More practically, there are likely to be some benefits in terms of cost and effort needed from combining some elements of the system for cars and vans. Obvious examples of the latter might be the monitoring and reporting requirements or sanctions chosen.

As against this, however, the differences between cars and vans suggest that some differences between the two are inevitable. For example, there are as yet separate targets for the two, and analysis below suggests that there is little prospect of developing a unified utility curve for cars and vans in the near future.

As discussed below, a utility-based limit function is a strong prospect for N1s as it is for cars, but even here there are possibilities of using another utility parameter because utility is a
rather different concept in relation to vans than to cars, and there may be a more suitable choice such as loading capacity or payload.

However the following policy options appear to be available for \( CO_2 \) legislation for N1 vehicles:

- single limit value applied to all manufacturers or all vehicles
- percentage reduction applied to the sales averaged \( CO_2 \) emission per manufacturer
- utility-based limit function
  - applied per vehicle, or
  - applied to the sales averaged utility value per manufacturer.
- alternative options:
  - uniform limit per class (class I, II and III); possibly determined on the basis of a utility based limit function and the average utility values per class, or
  - determined on the basis of the overall cost optimal division of \( CO_2 \) reduction efforts over the three classes;
  - with the option of internal averaging by manufacturers;
  - option of internal averaging between M1 & N1 vehicles
  - possibly accompanied by trading among manufacturers

Here we present some tentative conclusions on choice of instrument based on our existing knowledge of the van sector and our experience from the detailed evaluation of the car sector, but also bearing in mind the points made above regarding the differences between the car and van sectors. Ideally these conclusions should be tested through a fuller analysis once a comprehensive database of van models and the relevant sales data, \( CO_2 \) performance and other parameters become available.

- Given the expected wide range of \( CO_2 \) emissions between vans of different classes and between the sales-weighted averages of the range of vans offered by different manufacturer groups, applying single limit values to each vehicle or manufacturer does not appear to be any more promising an option for vans than for cars.
- Similarly, a percentage reduction applied to the sales averaged \( CO_2 \) emissions per manufacturer appears to be a possibility, but there is no immediate reason to suppose that this approach would not suffer from some of the same drawbacks as such a measure applied to passenger cars. There might on the other hand be less of an issue of punishing early movers, as there have not been strong policy signals in this sector up to now, and in principle all manufacturers are likely to have been under similar commercial pressures to offer better fuel economy historically – however strong or weak such signals might have been. Also, since the required effort is relatively small, issues of ‘fairness’ may not weigh as heavily in this case as they clearly do for passenger cars.
- There are clearly good possibilities to apply a utility function to vans as to cars. These are discussed below. Several options seem very attractive in principle, but there are nonetheless some drawbacks in practice.
- An important distinction between cars and vans is that for vans a simple and fairly meaningful market segmentation is available, and the variation in \( CO_2 \) performance within each class is (at least on the basis of the evidence so far available to us) likely to be smaller than is the case for cars. This option is addressed in greater detail below.
- In principle trading between M1s and N1s could reduce the costs of overall compliance, as the marginal abatement cost is likely to differ between vans and cars, and might for
example encourage extra effort to be made in relation to vans to reduce the effort on cars. However, since they have separate targets, this could cause one of the two targets to be missed, and might present other problems. Also, the relationship between test cycle and ‘real world’ emissions is likely to be different for cars and vans, so trading between them might have unpredictable consequences in terms of total emissions.

- As with cars, trading between manufacturers of N1s is in principle possible and should reduce the overall cost of compliance. However, it seems unlikely that the manufacturers of vans will be any more enthusiastic about trading with competitors than carmakers appear to be.

6 Considerations on utility parameters and segments for N1s

It is well known that car buyers weigh up a large range of factors in choosing a new car, and many of these have little bearing on either the CO₂ performance or an objective measure of the ‘utility’ of the vehicle chosen. In contrast, N1s are to a much greater extent ‘utility vehicles’ by definition, and can be supposed to be chosen and used in a more rational way. As a result, the utility of the vehicles may be expected to more closely match the demand for utility set by the purpose for which they are to be used than is the case for passenger cars. This makes to option of applying a utility parameter conceptually attractive.

Furthermore, since the utility of a van (primarily for carrying goods) is well understood, it is easier to propose a set of valid potential measures of utility. One complicating factor, however, is that different categories of goods impose different demands on the vehicle in which they are to be carried:

- Bulky goods require a large volume of carrying space
- Heavy goods demand a high payload potential
- Some classes of goods (eg rigid sheet materials or long lengths) impose specific dimensional demands for long or high carrying spaces
- Other specialist goods (eg refrigerated foodstuffs) have other, very specific demands.

Reflecting this, [TNO 2004] already undertook a brief analysis of options regarding utility parameters. Options shortlisted as candidates for (continuous) utility parameters were:

- mass
- maximum payload (= GVW – empty mass)
- composite of pan area and mass (defined as l × w × mass)
- external capacity (l × w × h, outer dimensions)
- composite of payload and volume

Other options might be:

- gross vehicle weight (GVW)
- pan area (l × w)
- footprint (in definition of track width × wheel base, as discussed for cars)
- loading volume (internal capacity)

As with cars, important criteria for selecting a utility parameter are:

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1 Note that in [TNO 2004] this parameter combination was referred to as ‘footprint’, hence a different usage of the term to that applied in this report to passenger cars
Below are presented some of the main considerations, some derived from [TNO 2004] and some added through later insights, regarding the application of these criteria to the various utility options proposed above:

- Maximum payload and internal loading volume are conceptually the best representations of the utility of a light commercial vehicle for most typical purposes. Selection of a vehicle is in general based on one of the two, depending on the type of goods to be transported. A combination of the two might therefore be a good overall solution.
- GVW is strictly speaking not a measurable parameter. The maximum payload is defined by the manufacturer based on partly quantitative engineering principles. This value can thus not be independently verified and can easily be manipulated, although it is bound by the physical limitations of the vehicle and warranty issues.
- As a consequence also maximum payload (= GVW – empty mass) is not a measurable parameter. This is an important drawback that militates heavily against its use in practice, in spite of its other attractions. Instead, vehicle mass would have to be preferred, even though it has significant drawbacks as a utility parameter for vans, similar to the ones stated elsewhere for cars.
- Loading volume is difficult to measure exactly (due to the complex shape of vehicle interior), and can, in the design phase of the vehicle, be increased without significant adverse effects on vehicle price or fuel consumption to achieve a less stringent CO2 limit for the vehicle. As a proxy for loading volume one could however use the dimensions of the largest rectangular box that fits into the freight compartment of the vehicle. This gives less room for manipulation and focuses on useful loading volume.
- Any option referring to the body or ‘box’ of the van itself (eg loading capacity) must also take account of the fact that some vans are certified and sold on a ‘chassis-only’ basis, ie without external bodywork, to have specialist bodies added by a third party. In these cases exception rules would be needed to deal with these.
- With this in mind, ‘footprint’ defined as l x w x reference mass should be considered an attractive composite parameter, i.e. pan area x mass. Loading volume x reference mass appears the best alternative if the relevant data were available.

In conclusion, therefore, it can be seen that there are conceptually good possibilities for applying a utility function to N1s, but there remain some practical issues to be overcome in doing so.

One simple utility function that could be applied to both cars and vans is of course vehicle mass, and this suggests the possibility of eventually applying a combined utility function to cars and vans under a single measure. However, our initial assessment\(^2\) is that this is not in

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\(^2\) Initial estimation of sales weighted average mass for N1 vehicles (based on top 25 vehicles) is 1700 kg (compared to 1300 kg for M1), so a separate weight-based utility function should thus be turned around the pivot point (1700 kg, 175 g/km CO\(_2\), compared with 1300 kg, 130 g/km for M1). Combining N1 & M1 vehicles, (with a limit line through both pivot points) would result in a slope of 0,11 = 150%. This is not realistic, and
fact a practical proposition, as it would distort the slope of the utility function and significantly shift the burden of improvements and costs between car manufacturers, while bringing little benefit.

7 Considerations on alternative options

Given the smaller size of the van fleet and the relatively limited range of vehicles within each class, a class-based system for vans might be considered as an attractive alternative, at least until more data become available and/or more stringent targets are to be set in the future.

- A uniform limit value per class can probably not be met by all vehicles in a given class, and should therefore preferably be accompanied by either internal averaging per manufacturer or by trading between manufacturers.
- Internal averaging per manufacturer could be allowed within a class or for the total N1 sales over the three classes. Given the smaller number of models and smaller sales internal averaging per class probably does not provide enough flexibility for meeting the target and as a consequence might lead to unwanted distributional impacts (affecting competitiveness of individual manufacturers). Internal averaging over all classes is therefore preferred, whereby the target per manufacturer is defined as the average of the targets per Class weighted by the sales of vehicles per class by that manufacturer in 2012.
- There does not seem to be any disadvantage to allow averaging over the three N1 classes to optimise the manufacturer’s response and reduce cost. There is in principal no reason to set different limits per class. However, there is a strong suspicion that a single value could lead to significant distributional effects, and so separate targets for each class based on utility (and for which we have a reasonable analytical foundation) appear to be preferred as they should help to minimise these.
- Vehicle classes are based on ‘reference mass’ (see Annex 2). As reference mass is not at all a function of payload weight but a direct function of vehicle mass, it can only be manipulated or gamed by increasing actual vehicle weight, which is unlikely to be an attractive option except possibly at or near to the class boundary.

The table below is based on Table 8.8 from [TNO 2006]. CO₂ reductions per class for meeting an overall average of 175 g/km have been assessed by determining the cost optimal division of reductions over the various classes (and fuel types) for reaching the overall target. Cost optimisation is based on total EU-15 sales (all manufacturers) and therefore does not take into account possible sub-optimisations that would arise from cost optimisation per manufacturer. Using the sales shares of the fuel types per class, overall CO₂ targets per class can be defined as the sales weighted average of the cost optimal 2012 CO₂ emission per class / fuel type for 2012.

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reflects the fact that the relationship of mass to emissions is significantly different for cars and vans, and that the target of 175 g/km CO₂ for N1s is a less stringent target than 130 g/km for M1s.
8 Conclusions and possible ways forward

The analysis presented above illustrates that our knowledge of the van sector is not yet sufficient to undertake the full analysis of instrument designs that has been done for passenger cars. Therefore, if it is thought desirable to proceed now with designing an instrument for this sector, then two approaches appear possible:

1. The analysis illustrated above suggests that van classes offer a viable and fairly robust segmentation of the van market. Also, for the market as a whole, the weighted averages set out in the table above reflect fairly robust estimates of the reductions that would be needed for each segment to achieve the 175 g/km target. Any shift in segment shares should in principle be fairly limited in the case of a weight-based segmentation approach, and in any case the reductions required are relatively modest for each segment, so neither the total cost nor the distributional impacts should be large.

2. Alternatively, there is no strong reason to assume that, in most respects, a similar framework to that for cars should not be used. Further analysis could be undertaken on the basis of current or limited additional information (eg more recent data) but this would not be ideal. If time allowed, a more robust assessment (eg of a suitable utility parameter and optimum slope) would be deferred until more data became available. Detailed design of the CO\textsubscript{2} legislation for N1s could then be organised in a separate project. This exercise would entail:
   - Setting up a data collection programme to collect the required vehicle statistics (sales, CO\textsubscript{2}, mass, size, etc. per model) that are necessary to determine the exact design of the legislation (selection of utility parameter, slope of limit function, etc.);
   - Detailed assessment using a model similar to that used for M1s;
   - Develop detailed proposal for design of the CO\textsubscript{2} legislation for N1s, utilising elements of the framework for M1s as far as these were demonstrated to be suitable.

In either case, it will be highly desirable that better data are collected as of 2008. This might involve incorporating vans into the Monitoring Mechanism, but also seeking ways to obtain more detailed information on the individual models and variants sold, for example by incorporating N1s fully into the commercial monitoring systems already available. These data should include numbers of sales and the certified CO\textsubscript{2} values, but also the possible utility parameters (weight and dimensions) discussed above.
References


[TNO 2006]  Review and analysis of the reduction potential and costs of technological and other measures to reduce CO₂-emissions from passenger cars, study for DG Enterprise carried out by TNO, IEEP and LAT/AUTH, Contract nr. SI2.408212, October 2006
## Annex 1: Data on vehicle models, sales, mass and CO₂ emissions available from [TNO 2004]

### Data for top 33 sales of vehicle models (incl. variants per model)

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Annex 2: Definition of N1 classes

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<tr>
<td>II</td>
<td>( 1250 \text{ kg} \leq 1700 \text{ kg} )</td>
</tr>
<tr>
<td>III</td>
<td>( &gt; 1700 \text{ kg} )</td>
</tr>
</tbody>
</table>

with reference mass defined in 80/1268/EEC as:

6.2.1. Reference mass

Mass of the vehicle in running order less the uniform mass of the driver of 75 kg and increased by a uniform mass of 100 kg.

with ‘mass of the vehicle in running order’ defined in Directive 70/156/EEC (Annex I, section 2.6) as:

\[ \text{Reference mass} = \text{empty mass} + 100 \text{ kg}. \]

From this we can conclude that:

- reference mass is not at all a function of payload weight and therefore can only be manipulated or gamed by increasing actual vehicle weight, which is unlikely to be an attractive option except possibly at or near to the class boundary
- the type approval process does indeed allow approval of chassis-only, but only for specific models which are not sold with body-on, so presumably this refers to a limited number of options.

\(^1\) Note that slightly different reference mass thresholds (1305 kg and 1760kg respectively) are used in Directive 2004/3/EC
Possible regulatory approaches to reducing CO₂ emissions from cars

Technical note 13: Analysis of impacts on employment

1 Introduction

This note reports a discussion of the impacts on employment of the reduction of CO₂ from cars, performed in the context of the project “Possible regulatory approaches to reducing CO₂ emissions from cars” (contr.nr. 070402/2006/452236/MAR/C3).

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2 Background – EU Car Manufacturing and Employment

Europe accounted for 42% of all global car production in 2002 - by far the largest regional industry and virtually twice the size of the US. In 2001, Germany exported USD 105bn of automotive goods, of which the largest share was cars, and the majority of which went to other EU Member States. This made it the world’s largest exporter in this field, with well over 20% world market shares of both cars and buses. Japan was the second largest exporter, with France fifth at USD 38.9bn.

The European automotive industry is a major component of Europe’s manufacturing base. It contributes about 6% of manufacturing employment and 7% of manufacturing output. It is nonetheless less than 2% of total GDP, and 1.5% of total employment. The value added in EU 15 was estimated at €120 billion in 2003.

Table 1 Employment in the production of vehicles by region (thousands)

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU 15</td>
<td>1,901</td>
<td>1,944</td>
<td>1,933</td>
<td>1,907</td>
</tr>
<tr>
<td>USA</td>
<td>1,312</td>
<td>1,313</td>
<td>1,212</td>
<td>1,151</td>
</tr>
<tr>
<td>Japan</td>
<td>705</td>
<td>683</td>
<td>664</td>
<td>646</td>
</tr>
</tbody>
</table>

From this table it can be seen that employment in the motor industry (including buses and trucks) is, at around 2 million, of a similar order of magnitude for the EU 15 as for the USA and Japan combined. In all three regions there was a slight decline in employment during the years 2000-2002. However, as a percentage of total industry employment, the automotive industry employment grew at an average of 1.9% between 1995 and 2003 at the EU 15 level. The industry is also estimated to provide indirect employment to 10 – 11 million people. Taking a longer view, however, Nieuwenhuis (2007) emphasises the long term decline of jobs in the EU motor industry, particularly of indirect white-collar jobs.

The industry is highly concentrated within the EU 15, with nearly half the value added taking place in Germany alone. Next in order are France, UK, Italy, Spain and Sweden; and these six together account for over 90% of production in the EU 15. The automotive industry accounted for 11% of manufacturing jobs in Germany, and 10% in Sweden in 2002. Moreover, in 2003, most of the employed workers in the EU 15 automotive industry were in Germany (more than 40%), and to a lesser extent in France (16%), the UK (13%), Spain (11%) and Italy (7%).

Several are of the newer Member States are also increasing in importance in terms of their automotive output - notably the Czech Republic, Poland, Slovakia and Hungary. The latter are seen as an important opportunity for further growth in EU's automotive production, with relatively low cost and qualified labour and large inward investments in new capacity, not least from the major manufacturers of the EU 15.

The automotive industry is also a major driver of new technologies, with almost 20% of manufacturing R&D undertaken by carmakers (ca. €24 billion).
3 The Theoretical Framework on Environmental Measures and Employment

The Commission staff working paper on the links between employment and environment policies – SEC(2005)1530 - highlights the importance of the Lisbon strategy aim for more and better jobs [emphasis added].

It also cites OECD studies that the net impact on employment of environmental policies has so far been either neutral or slightly positive. At the level of specific policies and mechanisms, it notes that the positive employment effects (eg employing extra people to provide better technology or environmental services) has to be balanced against the potential depressing effect on employment if cost increases suppress demand, either damaging the competitive position of a specific firm or product, or suppressing demand overall through an increase in average price.

It also stresses the need to examine both upstream and downstream impacts of any change - for example, new requirements may cause an increase or decrease in demand in upstream suppliers, and may change impact on consumers through higher prices.

Furthermore, indirect effects such as substitution and crowding out of investments will tend to offset the impact of the direct effect upon employment, whether the latter be positive or negative.

Even within a company adversely affected by the costs of environmental policies, a number of potential countervailing effects were noted, for example:

- Evidence supporting the Porter Hypothesis that new regulation can drive firms to find cheaper ways of achieving a given end, which has a larger benefit to them in the long run; and
- Broader evidence supporting the hypothesis that companies with a good environmental performance are not constrained over all by the apparent extra cost of this, but tend on average to be more profitable than others.

Regarding environmental technologies, the working paper also highlighted the first mover advantage as a broader factor that could be expected to improve the competitive and employment position of companies that embrace tighter standards and innovative technology. In future companies offering the cleanest goods in class might also benefit from a range of policy measures such as public procurement and others identified in the Environmental Technology Action Plan (ETAP).

The sections which follow use this framework to assess the likely effects of changing prices through tougher regulation on employment in the industry.
4 Supply and Demand – Effects on Employment

The net effect of a higher price of vehicles on employment in the EU is determined by the increase of the amount of labour within the EU per vehicle, due to the application of additional or more expensive components, and the change in vehicle sales, due to the higher price. The latter is determined by the price elasticity. As noted in the Commission working paper, the balance of these two elements is critical to the direct impacts on employment.

First and foremost, the impact on demand will depend on the extent to which carmakers can and will pass on their additional costs to the customers, and this is not known. As reported elsewhere, the extra costs are in most cases more than compensated for by the money saved through fuel efficiency over the life of the vehicle. From this perspective it is possible that consumers will be willing to accept some additional up-front cost in exchange for savings later; however, car buyers are notoriously myopic with respect to future costs, so it cannot by any means be assumed that these costs will be accepted by the consumer without question.

Therefore for the purposes of this analysis, it is assumed that higher prices would have a negative impact on demand. Hence:

\[
\Delta \text{Total labour} = \frac{(1 + \Delta \text{labour per car}) \times (1 + \Delta \text{sales}) \times \text{Total sales} \times \text{Total labour per car}}{\text{Total sales} \times \text{Total labour per car}}
\]

The price elasticity for new car sales with regard to the price of new cars is a very specific type of elasticity. Precise values are not well known because data on the ‘real’ price trend of new cars are difficult to derive, and other variables such as income are very important. In general, however, price elasticities for car ownership as function of fuel price, income etc are between 0 and -1 (ie fairly inelastic), so that one can expect that this is also the case for price elasticity for new car sales with regard to the price of new cars.

If the price elasticity for new car sales with regard to the price of new cars is between 0 and -1 as argued, a 6% price increase (reflecting the cost of measures as calculated, and assuming a full pass-through to the consumer which gives the biggest price effect) will lead to less than 6% reduction in sales - ie the total value of sales will rise slightly. If e.g. for the 6% price increase the amount of labour per car within the EU increases by 5% while sales decrease by 3%, then the CO\(_2\) emission legislation results in a 1.85% increase in employment.

In principle, therefore, lower vehicle sales within the EU thus do not necessarily lead to loss of jobs in the automobile industry within the EU, and could easily lead to a rise in direct employment depending on what share of extra costs were to go into extra labour. In either case, the direct impact seems likely to be relatively marginal.
5 Upstream and Downstream: Value Chain and Employment Impacts

Upstream Services

The automotive industry itself can be conceived of as having four levels, although definitions vary slightly:

- **Original Equipment Manufacturers (OEMs)** are the major manufacturers whom we address primarily in this report.
- **Tier 1 Suppliers** work closely with manufacturers to deliver major component elements of the vehicle, such as drive train assemblies. They in turn purchase components from Tier 2 and Tier 3 suppliers.
- **Tier 2 Suppliers** these manufacture minor subassemblies that are supplied to and assembled by the Tier 1 suppliers.
- **Tier 3 Suppliers** to supply the raw materials to the component manufacturers.

These suppliers play an increasing role in the value chain over time, often accounting for ‘the lion’s share’ of added value. In Germany, the share of manufacturers in total added value declined from 18% in 1995 to 12.1% in 2001 as a result of pressures of innovation and more sophisticated vehicle design, and similar declines were witnessed in most EU manufacturing countries. Increased vehicle value, eg through innovation in electronics, is cited as a key avenue for future growth in the supplier industry. This is a key possible growth area in relation to reducing CO$_2$, and Europe is well represented with specialist suppliers.

Thus a focus on carmakers can mask the vital contribution of domestic upstream inputs to the industry, which is estimated to provide more than twice the value added as that which is added within the automotive industry itself. Hence every euro spent in the industry generates a further two euros in upstream activity. A further 25% of the added value is accounted for by imports to the EU – ie a further euro is added elsewhere. Combining this with the calculation above, it seems clear that higher prices should produce a strong positive multiplier effect higher up the supply chain, and some at least of this should be translated into extra employment. Nieuwenhuis (2007) is emphatic on this point:

“… it is not clear how the need for additional technology will lead to a reduction in the number of jobs. It seems more likely to lead to an overall increase in the number of jobs, as new technology will require more engineering input, hence more engineers and then more production staff to make the equipment …”

He also cites the benefits of the requirement for catalytic converters on the fortunes of the major exhaust abatement technology manufacturers Johnson Matthey and Engelhardt.
Thus we would expect a net increase in costs to OEMs to result in a larger increase in value further up the supply chain. For example, if cars on the European market cars become on average 6% more expensive compared to 2006 (a fairly central estimate from our analysis);

- The additional costs to manufacturers are built up from:
  - material costs for own production of CO2 reducing technologies and purchase costs for components purchased from suppliers
  - tooling costs
  - labour costs
- Overall tooling costs and purchase costs are again built up from the same three costs types but then at the level of suppliers.
- Overall therefore a large share of the additional costs can be translated into labour costs, and hence more employment. Remaining costs are costs of materials and components imported from outside the EU. Except maybe for electric motors and batteries used in hybrids the share of these import costs is probably limited.

**Downstream Services**

Downstream services also comprise a very substantial component of the automotive industry as a whole, as they are required throughout the lifetime of a vehicle. These include accessories and spare parts, repairs and maintenance, in-service testing, fuel and other consumable supplies, finance and insurance, etc. In 2000, the annual global profits of the automotive value chain has been estimated as follows: aftersales, 57%; suppliers, 20%; retailers (new cars), 5% and OEMs, 18%. (Nieuwenhuis & Wells, 2002).

In particular, in the context of these proposals, improved fuel consumption would lead to a decrease in the aggregate demand for fuel. As against this, higher prices could lead to an increase in turnover for finance and insurance industries, while the use of more complex technologies could lead to more activities in relation to parts and maintenance.

6 **Substitution and Other Indirect Effects**

Consumers have many possible ways to react to higher car prices, primarily the following categories:

- They will buy fewer cars (or at least delay the purchase of a new car);
- They might drive fewer kilometres in aggregate (and possibly use other modes more); but those who have purchased a more efficient car might be tempted to drive further owing to lower running costs (the rebound effect); and
- They will save on other expenses elsewhere to offset the higher price that they have paid.

It is not possible to predict accurately which of the above behaviours will predominate, and all three are likely to occur to one extent or another. However in
any case consumers can not spend the resulting net price increase of their passenger car transport on other goods or services so more expensive cars may lead to less consumption elsewhere. Employment impacts of that depend on whether these are products and services from within the EU or products imported from outside the EU.

The fact that higher vehicle costs are at least partly earned back by lower fuel costs means that costs of imported oil are replaced with vehicle purchase costs. The costs of fuel represent a only small fraction of labour within the EU, while the additional vehicle costs represent a high share of labour in the EU, so that this shift from fuel costs to vehicle costs probably leads to a net employment increase in Europe. There is a relevant example of this effect in the aerogenerator industry in Germany and Denmark. The societal costs of windpower are higher than those of conventional energy (positive abatement costs), so that this technology needs to be subsidised, but as imported fossil energy is replaced by labour costs within the country, this leads to net benefits for employment in Germany and Denmark.

In a global market, relocation of manufacturing capacity outside Europe in response to higher costs is clearly a concern from the employment perspective. Whether or not costs are passed on to the purchaser, it is clear that a significant increase in the cost of making cars owing to regulation will increase the pressure on OEMs to cut their costs. One means of doing this would be to relocate manufacturing to cheaper locations – particularly out of the EU 15 countries, either to the EU 12 or elsewhere.

However the 2004 Competitiveness Report reflects evidence that when German automotive suppliers sought new manufacturing locations during 1997-2002, only 17.3% of new sites were in Germany, but 60% remained within the EU. Of the remainder, South America was the most favoured choice, followed by the US and Asia. Labour costs in the EU automotive industry in 2001 were on average on a par with those of the USA or Japan. Most countries had labour costs below those of the US or Japan, but Germany's were substantially above. This is partly offset by higher productivity, however.

In general meeting the CO₂ legislation will require advanced technologies and will stimulate innovation. Production of advanced components is the strength of the European supply industry so advanced components for fuel efficient vehicles will more likely come from European suppliers than from suppliers outside the EU. This should inhibit relocation of important parts of the supply chain out of Europe. It therefore seems probable that European CO₂ legislation will stimulate R&D and innovation within the EU. Increased R&D may have positive impacts on labour and may also have spin-offs in other applications / markets that may in turn lead to further positive labour effects.

The 2004 Competitiveness Report concludes that “worldwide demands for safer and more environment-friendly vehicles will continue” and that these demands will drive research and innovation. Such trends are not argued to be likely to damage the competitive position of EU manufacturers overall, but it is noted that R&D efforts need to be directed towards manufacturing cleaner vehicles.
Research and innovation are seen as strengths of the European market, with market demand in Germany in particular for high-quality products seen as an important driver.

The key weaknesses of the European automotive industry are identified to include a number of structural features of the industry and economy, such as low productivity and overcapacity; high labour costs and inflexible market regulation; and fragmentation of the single market due not least to variations in vehicle and fuel taxation. Environmental regulation was not cited as a major threat, but cleaner cars were seen as an opportunity.

7 Competitive Positions in the EU and Overseas Markets

7.1. Competition between European Manufacturers

The vehicle cost data presented elsewhere in this analysis clearly illustrate that the various options under consideration have differential impacts upon the average costs of the various manufacturers. Depending on if and how these costs are passed on to consumers, these could have an impact on the sales or profitability of the manufacturers, and there will be some ‘winners and losers’. However to a first approximation, aggregate employment levels should not be affected if some sales switch from one manufacturer to another. More important impacts might be felt if either:

- The total volume of sales changes significantly, or
- European manufacturers as a whole lose out significantly to those elsewhere in terms of future sales.

The first of these two possibilities is discussed above; the second is addressed in the sections that follow. In this section a distinction is made between the European market place and competition between European brands and other brands on markets outside Europe. The focus however is obviously on employment within Europe as it is affected by this.

7.2. Competition in the European Market

The European market is by far the largest single market for cars in the world, and regulation at EU level has conferred important benefits upon EU manufacturers. The EU automotive industry has traditionally enjoyed a trade surplus – the latest for passenger cars was at €36 billion, with €68 billion export value.

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2 The data included in this section is mainly extracted by Eurostat/ Comext, 2007.
### Table 2 EU 27 automobile trade in 2006 (in million €)

<table>
<thead>
<tr>
<th></th>
<th>Import</th>
<th>Export</th>
<th>Trade balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor cars and other motor vehicles</td>
<td>31,960</td>
<td>68,126</td>
<td>36,166</td>
</tr>
<tr>
<td>principally designed for the transport of persons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor vehicles for the transport of &gt;= 10 persons</td>
<td>679</td>
<td>790</td>
<td>111</td>
</tr>
<tr>
<td>Motor vehicles for the transport of goods</td>
<td>4,354</td>
<td>7,066</td>
<td>2,712</td>
</tr>
<tr>
<td>Special purpose motor vehicles (other than those principally designed for the transport of persons or goods)</td>
<td>183</td>
<td>2,572</td>
<td>2,388</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>37,177</strong></td>
<td><strong>78,554</strong></td>
<td><strong>41,377</strong></td>
</tr>
</tbody>
</table>

Source: Eurostat/ Comext, 2007

The EU market is also still dominated by sales of European brands. National brand loyalty is also still a salient feature of the French and German car markets. This is less so now in the UK and Italy, but even here there is still a strong preference for European brands. Most of the exports from EU manufacturing countries are accounted for by sales within the EU, as is illustrated in the table below. In 2006 the value of trade within Europe for the 27 Member States was €165 billion, against the value of imports which amounted to €31 billion (Eurostat/Comext, 2007). The main country to export in the EU 27 was Germany, with 33% of the total EU 27 share, followed by France and Belgium representing respectively 14%.
Table 3 Exports of passenger cars per Member State outside and within the EU 27 (in million €)

<table>
<thead>
<tr>
<th>Member State</th>
<th>Exports outside the EU 27</th>
<th>Exports within the EU 27</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>38,900.37</td>
<td>54,890.31</td>
<td>93,790.68</td>
</tr>
<tr>
<td>France</td>
<td>3,710.62</td>
<td>20,737.72</td>
<td>24,448.33</td>
</tr>
<tr>
<td>Belgium</td>
<td>3,221.00</td>
<td>20,865.29</td>
<td>24,086.29</td>
</tr>
<tr>
<td>Spain</td>
<td>2,022.92</td>
<td>17,059.59</td>
<td>19,082.51</td>
</tr>
<tr>
<td>UK</td>
<td>7,732.39</td>
<td>11,029.75</td>
<td>18,762.14</td>
</tr>
<tr>
<td>Italy</td>
<td>1,656.20</td>
<td>5,977.63</td>
<td>7,633.83</td>
</tr>
<tr>
<td>Sweden</td>
<td>3,093.97</td>
<td>4,262.93</td>
<td>7,356.90</td>
</tr>
<tr>
<td>Austria</td>
<td>2,342.55</td>
<td>4,678.75</td>
<td>7,021.31</td>
</tr>
<tr>
<td>Czech Rep.</td>
<td>691.00</td>
<td>6,128.41</td>
<td>6,819.41</td>
</tr>
<tr>
<td>Poland</td>
<td>751.25</td>
<td>4,894.48</td>
<td>5,645.73</td>
</tr>
<tr>
<td>Slovakia</td>
<td>1,545.03</td>
<td>3,555.69</td>
<td>5,100.72</td>
</tr>
<tr>
<td>Netherlands</td>
<td>316.02</td>
<td>2,792.07</td>
<td>3,108.09</td>
</tr>
<tr>
<td>Hungary</td>
<td>322.05</td>
<td>2,503.15</td>
<td>2,825.20</td>
</tr>
<tr>
<td>Portugal</td>
<td>63.02</td>
<td>2,346.73</td>
<td>2,409.75</td>
</tr>
<tr>
<td>Finland</td>
<td>809.91</td>
<td>1,124.61</td>
<td>1,934.52</td>
</tr>
<tr>
<td>Slovenia</td>
<td>246.96</td>
<td>1,511.37</td>
<td>1,758.34</td>
</tr>
</tbody>
</table>

Source: Eurostat/ Comext, 2007

Figure 2 Exports of passenger cars per Member State outside and within the EU 27 (in million €)

In Europe, the share of Japanese brands is much smaller (36% of imports), and of Korean ones smaller still (22% of imports). Also, the share of imports from Japan is not growing significantly, while Korean imports have doubled between 2000 and 2006, albeit from a much lower base. US manufacturers sell ‘European’ models through their European brands such as Opel; a few American models are directly imported, but in relatively small numbers.
All manufacturers (from the EU and outside) have to obey the same legislation, such as that under consideration here. If under the specific legislation the burden is distributed evenly (i.e., the legislation is designed so as not to discriminate arbitrarily between two manufacturers in a similar position, as it is in this case) there is in principle no change in competitive position between European manufacturers and those from outside Europe (except to the extent discussed above and as quantified in Technical Note 9). In reality, however, the general competitive position of European manufacturers on the home market is likely to improve compared to Japanese and Korean manufacturers for several reasons:

- For the options currently under study the burden is not evenly distributed: except for Toyota and Honda the relative retail price increase tends to be higher for Japanese and Korean manufacturers;
- The European sales of Japanese and Korean manufacturers are a relatively small share of their world-wide sales. CO₂ legislation in other markets is absent or less stringent than the proposed EU legislation. This means that it will be relatively expensive for them to develop dedicated vehicles for the EU market and that vehicles developed for the EU market can not easily be sold in other markets;³ and
- Stringent regulation is also likely to deter new market entrants who might compete with European manufacturers on price, but have much less access to the advanced technology needed for low CO₂ emissions. Nieuwenhuis (2007) argues in particular that Chinese importers will find it harder to compete in a tightly-regulated European market owing to their lack of sophisticated technology.

It is further argued in the 2004 Competitiveness Report that EU enlargement will be an important driver of aggregate demand, as car ownership levels in the EU 10 are currently relatively low and often met through second-hand car sales. Thus new car sales in EU 10 are projected to increase, whereas the market in EU 15 is mature and largely saturated. Owing to their strong position in manufacture and sales in EU 10 as in EU 15, it is the European manufacturers who should be best placed to exploit this developing new car market.

### 7.3. Main Markets outside Europe

The value of EU27 exports was € 68 billion in 2006. The main destinations of the EU27 exports is the US with exports worth € 27 billion, followed by Russia and Japan at above €4 billion respectively, China €2.2 and Canada €2.1 billion. The table below illustrates the breakdown of main exports destinations by main exporting Member States. Germany is the biggest exporting country, representing

---

³ The 2004 Competitiveness report confirms this effect, noting that “A large home market enables domestic firms to achieve economies of scale and scope. Hence, they benefit early in the product life cycle from learning curve effects and increasing expertise in production. In turn this leads to diminishing unit costs that make the domestic products more competitive on foreign markets. Furthermore, a large domestic customer base provides invaluable feedback for innovative products.” It also confirms that unit costs of meeting domestic standards are lower for home producers because this is their mass-market.
more than 64% of EU27 exports in these countries. It is followed by the UK at quite a distance (12%).

Table 4 Principal destinations of European passenger cars’ exports (in million €)

<table>
<thead>
<tr>
<th>Member State</th>
<th>US</th>
<th>Russia</th>
<th>Japan</th>
<th>China</th>
<th>Canada</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>17,719.77</td>
<td>1,549.58</td>
<td>2,932.04</td>
<td>1,817.14</td>
<td>1,306.21</td>
<td>25,324.74</td>
</tr>
<tr>
<td>UK</td>
<td>4,044.80</td>
<td>586.56</td>
<td>519.69</td>
<td>146.95</td>
<td>212.75</td>
<td>5,510.74</td>
</tr>
<tr>
<td>Sweden</td>
<td>1,492.14</td>
<td>231.83</td>
<td>99.71</td>
<td>47.21</td>
<td>168.26</td>
<td>2,039.15</td>
</tr>
<tr>
<td>Austria</td>
<td>1,262.43</td>
<td>80.58</td>
<td>177.28</td>
<td>52.26</td>
<td>143.23</td>
<td>1,715.79</td>
</tr>
<tr>
<td>Belgium</td>
<td>1,162.55</td>
<td>244.09</td>
<td>129.58</td>
<td>5.78</td>
<td>115.28</td>
<td>1,657.27</td>
</tr>
<tr>
<td>Slovakia</td>
<td>727.07</td>
<td>75.79</td>
<td>67.62</td>
<td>93.35</td>
<td>48.52</td>
<td>1,012.35</td>
</tr>
<tr>
<td>Italy</td>
<td>562.75</td>
<td>21.08</td>
<td>170.01</td>
<td>26.19</td>
<td>13.72</td>
<td>793.75</td>
</tr>
<tr>
<td>Finland</td>
<td>0.22</td>
<td>751.84</td>
<td>0.49</td>
<td>0.12</td>
<td>21.12</td>
<td>773.79</td>
</tr>
<tr>
<td>France</td>
<td>75.54</td>
<td>261.15</td>
<td>102.55</td>
<td>32.86</td>
<td>71.19</td>
<td>543.28</td>
</tr>
<tr>
<td>Latvia</td>
<td>0.05</td>
<td>164.39</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>164.47</td>
</tr>
<tr>
<td>Spain</td>
<td>2.11</td>
<td>102.46</td>
<td>20.16</td>
<td>21.21</td>
<td>2.11</td>
<td>148.05</td>
</tr>
<tr>
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Source: Eurostat/ Comext, 2007

Figure 3 Principal destinations of passenger cars’ exports per Member State – selection of first seven (in million €)

Source: Eurostat/ Comext, 2007
An important parameter in assessing the competitive position of EU manufacturers in other major markets is the size of their sales outside the EU. If a manufacturer has relatively low sales on non-EU markets then it is probably too expensive for that manufacturer to differentiate models for the different markets. On the other hand most global car makers already produce different models or different model versions for different markets.

Japanese brands completely dominate the Japanese markets, so it cannot be foreseen that a change in regulation will have a significant impact (positive or negative) on sales in this market, and hence on employment opportunities.

In contrast, the US market is more diverse. Home grown brands still dominate, but here the German brands hold the third-largest market share and US sales make an important contribution to their total sales and income. Specifically Porsche, BMW, Mercedes and to a lesser extent Volkswagen have large sales in the US, especially in the high end part of the market (with high margins). In general this appears likely to continue, as this particular part of the market appears not to be very sensitive to the envisaged price increases. The 2004 Competitiveness Report notes that demand in the domestic market also tends to translate into success abroad, in that purchasers of European cars in the US tend to be of significantly higher average income than buyers of Asian or American brands, reflecting the ‘luxury’ status of many of the European cars sold there. Indeed, higher prices would in some cases be offset by reduced fines paid under the US CAFE system if these vehicles were to become more fuel-efficient.

A further question, however, is whether selling more fuel efficient vehicles in e.g. California may give them a competitive advantage. McManus (2006) documents how fuel price rises in the US have damaged sales of the largest gas guzzling vehicles. This in turn has adversely affected the profitability of the three big US car makers, all of which are in serious financial difficulties, while Japanese and European manufacturers have benefited. Thus fuel economy has given imported models an important competitive advantage in recent years.

Foreign direct investment by European companies has historically lagged behind that of the US, but is growing significantly and is now a similar order of magnitude. This too should improve their competitive position.

7.4. Emerging Markets

The Chinese market is growing rapidly, and some European manufacturers are already positioning themselves there. Quotas were scheduled to be eliminated in 2006 under WTO agreements, and as noted, China is one of the countries that has already said fuel economy standards owing to its concerns over oil imports. Already most European car models are capable of meeting future Chinese standards, and will in future have a competitive advantage over US companies, many of whose models will be excluded.

The Russian car market is also expanding, and domestic producers are technologically backward. Currently much of the market in Russia is the second-
hand cars, but the market for new cars is likely to increase, and European manufacturers will be well placed owing to their proximity and long land borders. In particular, EU 10 countries are well positioned to serve the Russian market, to which most of their exports are indeed currently directed.

Although some manufacturers are present in other markets in South America, Middle East, Asia and Africa, the models sold in these markets are generally not as advanced as those sold in the EU (older models or older Euro-standard) and that these vehicles are usually assembled in local factories to reduce costs. Furthermore these markets are still small compared with the others discussed above. In this case the CO$_2$ legislation for the EU market does not directly influence the competitive position of European manufacturers in these markets.
References


Nieuwenhuis P, 2007, *Car CO₂ Reduction Feasibility Assessment; is 130g/km Possible?* Centre for Business Relationships, Accountability, Sustainability and Society, Cardiff.

