EU Transport GHG: Routes to 2050?

Regulation for vehicles and energy carriers

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Executive Summary

This paper is one of four policy papers drafted under the project “*EU Transport GHG: Routes to 2050?”*. These papers review the policy instruments that could be used to stimulate the application and take up of technical and non-technical options that contribute to reducing transport’s greenhouse gas (GHG) emissions, both up to 2020 and in the period from 2020 to 2050. This paper reviews and discusses regulatory instruments of which the main options are:

- CO_2 emission limits or targets for road vehicles and other modes;
- efficiency standards for components of vehicles and
- well-to-wheel emission regulation for energy carriers.

Over the last decades regulation has proven a very effective policy instrument in reducing noxious emissions (air pollutants) from road vehicles. Since end of 2008 European regulation is in place for the CO_2 emissions of passenger cars, setting a sales-averaged target of 130 g/km for new vehicles in 2015. This regulation is already now having its effect, with fuel-efficient vehicles using advanced CO_2 reduction technologies coming to the market at a higher pace then even deemed possible at the time the Regulation was designed. Besides for road transport, regulation may also be considered for other modes such as non-road mobile machinery, rail, inland and maritime shipping and aviation. Especially for other modes than road transport regulation of GHG emissions per unit of transport function (e.g. g/pass-km or g/tonkm) may become relevant.

As a policy instrument, regulation can be considered an alternative to fiscal or other economic instruments. It can, however, also be used as a complementary instrument augmenting the effectiveness of a cap and trade system or CO_2 tax by making sure that sufficient technological options come to the market which enable users to respond to the incentives set by the fiscal or economic instrument. In such a combination the target level for the regulation needs to be carefully coordinated with the overall target at which the economic instrument is aiming.

Currently all existing CO_2 regulation is based on tank-to-wheel (TTW) emissions as measured on a type approval test. Due to changes that can be expected in vehicles and energy use, the nature of GHG emission regulation for transport may need to change to take better account of well-to-tank (WTT) or well-to-wheel (WTW) energy emissions, as well as the embedded energy in vehicles and emissions occurring in production and recycling. An alternative to a WTW-based regulation for vehicles would be a coordinated development of TTW regulation for vehicles and WTT regulation for fuels and other energy carriers, to ensure that a transition to powertrains using other energy carriers brings the desired net WTW GHG emission reductions. In the longer run a regulation of the life cycle impacts of vehicle production and decommissioning could also be considered.

An important prerequisite for setting emission standards or regulatory targets / limit values is the availability of appropriate test procedures. These are also relevant for other, flanking measures such as labelling and CO_2 differentiation of taxes. An important issue for further development of these test procedures is to improve the correlation between reduction measured on the type approval test and effects on emission under real-world driving conditions.

In addition to or as an alternative for regulating emission at the vehicle level it may be useful to introduce efficiency regulations for a number of relevant vehicle components. This can be done for powertrain components, but is especially relevant for energy consuming auxiliaries. The impact of these systems on real-world energy consumption and CO_2 emissions is generally difficult to simulate in type approval testing at the vehicle level.

In general a regulatory framework for reducing CO_2 emissions from road vehicles should as much as possible be technology neutral, allow flexibility for manufacturers to comply with the targets in the most cost effective way, avoid undesired market distortions, maintain of even promote the industry’s global competitiveness, and support the required transition towards sustainable vehicles and energy carriers.

In terms of GHG emission reduction from the energy chain, CO_2 regulation of the fuels seems a suitable way increase the production efficiency for current fuels, to reduce flaring, and to promote the introduction of low-carbon fuels in the future. It would also help to counteract the trend towards higher WTT emissions in the production chain for conventional fuels. An alternative for regulating the WTW emissions of energy carriers would be a renewable energy target. If such a target is designed flexibly, allowing many different types of renewable energy to count towards the target (as is the case in the current RED directive), the market will be stimulated to find the most cost effective renewable energy solution for transport. Together with the CO_2 regulation of the fuels, this can be expected to result in a drive for low carbon renewable energy. Both types of regulation can be accompanied by additional sustainability criteria besides WTW GHG emissions.

If electric transport increases in the future, the policies for the power sector come into play: the ETS sets a cap on CO_2 emissions, and various member states have implemented renewable energy policies. Further greening of the power sector will then also reduce GHG emissions of the transport sector.

Overall it is concluded that an integral set of policy instruments is necessary to regulate WTT and TTW emissions in such a way that the introduction of clean technologies, relevant for realising ambitious long term emission reduction levels, are stimulated without creating loopholes or even adverse impacts on WTW GHG emissions in the intermediate timeframe. In the long term a level playing field needs to be created in which improved conventional technologies and new options compete on the basis of cost effectiveness towards meeting environmental targets on the one hand and market attractiveness on the other hand.

Combining an energy efficiency target at the vehicle level (rather than a CO_2 emission target) with a WTW GHG emission target at the level of energy carriers appears an option, but requires more research to investigate whether it provides better safeguards for realising net WTW emission reductions and against loopholes;

Overarching regulatory measures may be considered as a means to reinforce the effects of other policy instruments. A combination of vehicle regulation and measures targeting in-use parameters incentivises application of fuel efficient vehicles and optimal use of the vehicles. Therefore not only efforts in setting regulatory vehicle standards, but also in in-use standards for e.g. logistics or public transport may be useful.

1 Introduction

1.1 Topic of this paper

This paper is one of four policy papers drafted under the project "*EU Transport GHG: Routes to 2050?"*. These papers review the policy instruments that could be used to stimulate the application and take up of technical and non-technical options that could contribute to reducing transport's GHG emissions, both up to 2020 and in the period from 2020 to 2050. The papers aim to provide a high-level summary of the evidence based on existing studies.

This paper focuses on regulatory instruments and so covers issues such as CO_2 emission limits or targets for road vehicles and other modes, efficiency standards for components and emission regulation for energy carriers.

1.2 Background to project and its objectives

The context of the *EU Transport GHG: Routes to 2050* is the Commission's long-term objective for tackling climate change, which entails limiting global warming to 2^{o}C and includes the definition of a strategic target for 2050. In 2009 the Commission's President Barosso underlined the importance of the transport sector in this respect be noting that the next Commission "needs to maintain the momentum towards a low carbon economy, and in particular towards decarbonising our electricity supply and the transport sector"[1]. There are various recent policy measures that are aimed at controlling emissions from the transport sector, but these measures are not part of a broad strategy or overarching goal. Hence, the key objective of this project is to provide guidance and evidence on the broader policy framework for controlling GHG emissions from the transport sector. Hence, the project's objectives are defined as to:

- Begin to consider long-term transport policy framework in context of need to reduce greenhouse gas (GHG) emissions economy-wide.
- Deal with medium- to longer-term (post 2020; to 2050), i.e. moving beyond recent focus on short-term policy measures.
- Identify what we know about reducing transport's GHG emissions; and what we do not.
- Identify by when we need to take action and what this action should be.

Given the timescales being considered, the project will take a qualitative and, where possible, a quantitative approach. The project has three Parts, as follows:

- Part I ('Review of the available information') has collated the relevant evidence for options to reduce transport's GHG emissions, which was presented in a series of Papers (1 to 5), and is in the process of developing four policy papers (Papers 6 to 9) that outline the evidence for these instruments to stimulate the application and up take of the options.
- Part II ('In depth assessment and creation of framework for policy making') involves bringing the work of Part I together to develop a long-term policy framework for reducing transport's GHG emissions.
- Part III ('Ongoing tasks') covers the stakeholder engagement and the development of additional papers on subjects not covered elsewhere in the project.

As noted under Part III, stakeholder engagement is an important element of the project. A large stakeholder meeting was held in March 2009 at which the project was presented. This has been followed in July by a series of stakeholder meetings (or Technical Focus Groups) on the technical and non-technical options for reducing transport's GHG emissions. A series of stakeholder meetings will be held in September/October (see below), which will be followed by a further large stakeholder meeting in November and a final meeting probably in February 2010.

[1] http://ec.europa.eu/commission_barroso/president/pdf/press_20090903_EN.pdf

1.3 Background and purpose of the paper

This paper is one of four policy papers (Papers 6 to 9) being developed under the *EU Transport GHG: Routes to 2050* project. The aim of these papers is to review the policy instruments that could be used to stimulate the application and take up of the technical and non-technical options that could contribute to reducing transport's GHG emissions, both up to 2020 and in the period from 2020 to 2050. For the purpose of the project, we are using the following definitions:

- **Options** deliver GHG emissions reductions in transport – these can be technical, operational or modal shift.
- **Policy instruments** may be implemented to promote the application of these options.

The options were reviewed in a series of papers developed earlier in the project, i.e.:

1. Technical options for fossil fuel based road transport;
2. Alternative energy carriers and powertrains;
3. Technical options for non-road transport modes;
4. Operational options for all modes;
5. Modal split and decoupling.

These "options" papers have been revised to take into account comments received at an earlier set of stakeholder meetings (in early July 2009), as well as any additional evidence that has been supplied by stakeholders since those meetings.

This paper is the first of a series of "policy" papers that review the policy instruments for reducing CO_2 emissions from transport between 2010 and 2050. These papers cover:

6. Regulation of vehicles and energy carriers;
7. Economic instruments;
8. Infrastructure and spatial policy, speed and traffic management;
9. Information, R&D, pilots, voluntary agreements.

All of these papers use evidence from existing studies to assess each of these instruments against a number of key criteria.

This paper has been presented and discussed in draft form to a Technical Focus Group meeting (with stakeholders present) held on 23 September 2009. After this meeting, the paper has been the subject of consultation on the project's website. In finalising the paper, we have included the results of the Technical Focus Group meeting and other comments and additional evidence provided by stakeholders.

1.4 Structure of the paper

This paper is structured in the following way:
- Chapter 2 presents a brief overview of existing regulation in Europe and introduces a number of general issues that are relevant for the design of further regulatory measures for the 2010 – 2050 timeframe;
- Chapter 3 focuses on regulatory measures for road vehicles, highlighting regulations for light duty vehicles in Europe and elsewhere, sets out a general framework for designing CO_2 regulation for road vehicles and explores options for regulating heavy duty vehicles;
- In chapter 4 possibilities for regulating efficiency at the component level are explored;
- Options for regulating the well-to-tank GHG emissions from energy carriers are discussed in chapter 5;
- Chapter 6 looks at regulatory options for other transport modes, including aviation and shipping;
- In chapter 7 some possible overarching regulatory options are discussed;
- Chapter 8 summarizes the conclusions from the foregoing chapters.

2 Introduction and overall issues

2.1 Overview of existing regulations in Europe

In the EU legislation for regulating GHG emissions from road vehicles for the period until 2020 has partly been agreed and is partly in the process of preparation. The purpose of this paper is to look beyond this 2020 time horizon. Nevertheless a summary of the present status and developments for the period until 2020 is useful, as this may serve as a starting point for further developments.

2.1.1 CO_2 legislation for vehicles

Passenger cars

In December 2008 the European Parliament and Council have reached agreement through a co-decision procedure on the details of the CO_2 legislation for passenger cars, laid down in Regulation No 443/2009[2]. Some important elements of the agreement, relevant to issues discussed in this paper, are:

- Limit value curve: the fleet average to be achieved in 2015 by all cars registered in the EU is 130 grams per kilometre (g/km). A so-called limit value curve implies that heavier cars are allowed higher emissions than lighter cars while preserving the overall fleet average. Manufacturers will be given a target based on the sales-weighted average mass of their vehicles.
- Phasing-in of requirements: in 2012 65% of each manufacturer's newly registered cars must comply on average with the limit value curve set by the legislation. This will rise to 75% in 2013, 80% in 2014, and 100% from 2015 onwards.
- Manufacturers may receive emission credits contributing up to 7 g/km to the achievement of their specific CO2 target for the application of so-called eco-innovations;
- Credits for flex-fuel vehicles: Emissions of CO_2 of vehicles designed to be capable of running E85 shall be reduced by 5 % until 31 December 2015 for sales in Member States where at least 30 % of the filling stations provide this type of alternative fuel complying with the sustainability criteria for biofuels set out in relevant Community legislation;
- Long-term target: a target of 95 g/km is specified for the year 2020. The modalities for reaching this target and the aspects of its implementation will have to be defined in a review to be completed no later than the beginning of 2013.

A more detailed summary of the European CO_2 legislation for cars is presented in section 3.1.

Light commercial vehicles

A proposal[3] by the European Commission for a regulation of CO_2 emissions from light commercial vehicles has been published in October of 2009 and is currently under discussion. The proposed legislation is based on the same overall approach as designed for passenger cars. It uses a utility-based limit function for the mid-term target set at 175 g/km, which is to be phased in between 2014 and 2016. Furthermore the proposal contains a long-term target for 2020 set at 135 g/km.

[2] REGULATION (EC) No 443/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles, see: http://ec.europa.eu/environment/air/transport/co2/co2_home.htm
[3] COM(2009) 593, Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL setting emission performance standards for new light commercial vehicles as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles, see: http://ec.europa.eu/environment/air/transport/co2/co2_cars_regulation.htm

Heavy duty vehicles

Currently the European Commission is also gearing up preparatory work for the development of CO_2 policies for heavy duty vehicles, including the option of CO_2 regulation. In a recent call for tender by DG-ENV[4] the following policy options are mentioned as possible candidates:

- Emissions trading, either as part of the EU ETS or free-standing;
- Legislation to set performance requirements for whole vehicles, vehicle components and trailers;
- Enhanced vehicle market transparency, e.g. by means of fuel efficiency / CO_2 labelling of vehicles and of vehicle components;
- A monitoring system covering the performance of the vehicles sold as well as the amount of fuel sold to HDV;
- A strengthened programme for disseminating good practice to freight forwarders;
- A change in the legislation on weights and dimensions to allow certain equipment to reduce air resistance;
- A reduction of the existing speed limitation for heavy-duty vehicles.

Regulation of the energy efficiency or CO_2 emissions of complete vehicles or components is an important option in this list. A problem with this vehicle category, however, is that emission testing in type approval has so far been prescribed at the level of the engine (instead of at the vehicle level as is the case for passenger cars and vans). This engine test does not provide meaningful results with respect to the CO_2 emissions at the vehicle level. At the same time introducing a vehicle based type approval test is difficult due to the large share of so-called multistage vehicles, which receive a build-up from another manufacturer than the OEM. The large number of vehicle types in this sector is furthermore associated with a broad range of usage patterns. Ideas exist for solving this with a combination of testing and modelling, but the feasibility for this is to be assessed in the coming year. A more detailed discussion of issues relevant to the development of CO_2 regulation for HD vehicles is presented in section 3.4.

DG TREN has taken initiatives to review directive 96/53EEC on Vehicle size and Weights, which will include an evaluation of the impact of increase vehicle length to improve aerodynamic characteristics and an extended use of the “modular concept”.

Other related measures

As part of the Integrated Approach towards meeting the Community objective of 120 g/km the EU is also promoting the application of tyre pressure monitoring systems (TPMS) and gear shift indicators (GSI) and is setting regulatory targets for the maximum tyre rolling resistance. These issues are to be promoted by means of regulatory measures, i.e. by obliging application of certain technologies (TPMS[5] and GSI), or by labelling (in case of tyre rolling resistance[6]). Proposals for these are in preparation (see chapter 4). The contribution of biofuels to the strategy is ensured through the Fuel Quality Directive 2009/30.

2.1.2 Regulation for other transport modes

There are currently no regulations or standards for the CO_2 emissions of non-road modes of transport in force, but preparatory work that is needed for setting standards is being worked out by either the UN or the sectors themselves. For several modes (maritime ships, aircraft, trains) indexes are being developed that describe the efficiency in terms of CO_2 per seat-km or capacity-km. The development of these standards will need several years, as these developments are all recent. The indexes need to be tested, and before standards can be discussed, the baselines for different types of vehicles (e.g. RoRo and container ship) need to be defined.

Furthermore, overarching regulation is also under discussion, with setting emission targets for public transport or logistics as examples (CO_2 per ton-km of passenger-km, or caps on total emissions in the case of public transport). The advantage of overarching legislation is that it gives

[4] ENV.C.3/SER/2009/0038
[5] COM(2008)316
[6] COM(2009) 348

incentives to increase the efficiency of transport by a reduction of empty running and an increase in load factors.

CO_2 emissions of the rail sector are indirectly regulated by the fact that the production of the electricity for propulsion of trains is included in the European Emission Trading Scheme. Airlines will be covered by the ETS as of 2011-2012.

2.1.3 Fuel quality directive

The fuel quality directive 2009/30[7] (FQD, see [EU 2009b]) basically serves two purposes: to ensure (technical) compatibility of fuels with vehicles, and to reduce the negative (mainly environmental) impact of transport fuels. As part of the latter aim, the recent directive 2009/30 has introduced a GHG regulation, setting a CO_2 reduction target for road transport fuels for the period between 2010 and 2020, from well to wheel. This target can be met by blending biofuels with (proven) CO_2 reduction, or by reducing flaring and venting at fossil fuel production sites. The directive also enables an increase of the level of biofuels in diesel and gasoline sold in the EU.

In addition, several sustainability criteria are defined for biofuels, including a minimum GHG reduction requirement and a number of criteria to reduce direct land use change emissions and impact on biodiversity. These will need to be further developed in the coming years.

2.1.4 Renewable energy directive

The renewable energy directive 2009/28/EC [EC 2009a] recently set a 10% mandatory target for the share of renewable energy in road transport fuels for 2020. In order to promote biofuels produced from waste or woody biomass, these will be counted double towards the target. In addition, a methodology is provided to enable the inclusion of renewable electricity used for transport to also count towards the target. This directive makes use of the same sustainability criteria as the ones in the fuel quality directive, aiming to ensure that only sustainable biofuels count towards the target.

2.2 General issues for future regulation

2.2.1 Overview of options for future regulatory instruments

The present CO_2 legislation for passenger cars sets a target for the sales averaged CO_2 emissions per manufacturer using a mass-based CO_2 limit function (see sections 2.1 and 3.1). For the longer term a wider range of options should be discussed in the light of designing a follow-up for the present CO_2 legislation for passenger cars as well as new CO_2 legislation for other road vehicles and other transport modes. Some of the options discussed in this paper are:

- further tightening of the emission targets within the present approach for cars and light commercial vehicles;
- emission limits per vehicle:
  - setting an absolute emission maximum, either on its own (individual vehicle emission limits) or in combination with fleet averaging (as an upper limit);
- using utility-based limit curves that penalise high emitters (flattening out for high values of the utility parameter);
- using bin-based systems requiring increasing shares of vehicles over time to meet more stringent emission limits;
- regulation of the energy efficiency of components;
  - see chapter 4;

[7] DIRECTIVE 2009/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC, see: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0088:0113:EN:PDF

- regulation of well-to-tank emissions associated with production and distribution of fuels and other energy carriers
  - see chapter 5;
- regulation of CO_2 emissions per unit of transport function:
  - g/pass-km or g/tonkm, especially relevant for other modes than road transport;
  - see chapter 6;
- setting absolute restrictions on vehicle parameters (e.g. size, weight, power, power/mass ratio);
  - see section 4.4;
- limitation of maximum speed or other performance indicators;
  - This offers some room for creativity in combination with flanking measures such as steep tax differentiation between speed limited / unlimited vehicles;
  - see section 3.7;
- mandatory externally controlled limitation of speed and acceleration, dependent on location and condition of driving;
  - also possibly beneficial for reasons of air quality, noise and safety.

2.2.2 General criteria for design of regulation

General issues to be discussed and evaluated in the design and assessment of (options for) future regulation of GHG emissions from vehicles are:

- regulation should preferably not be technology specific;
  - Technology specific legislation has the risk of creating a lock-in into obsolete technology pathways, obstructing technological progress and limiting the room for the market for finding the most cost-effective solution for meeting the environmental goals while taking account of other goals and needs related to the specific product or application.
  - However, in cases where there are no or limited alternative technologies providing the same solution, technology specific legislation may be a suitable way to promote application and overcome possible market barriers (as e.g. with closed particle filters).
- definition of appropriate target level or limit value;
  - attainability with technologies deemed available in target year;
    - Targets may be challenging and should stimulate innovation. Therefore one should enable technology-forcing legislation and not only technology-following legislation;
  - taking account of cost-effectiveness from a user point of view as well as from a societal point of view (marginal abatement costs);
  - proportionality in relation to the overall GHG reduction objective;
  - proportionality with respect to reduction targets and associated marginal abatement costs in other sectors of economy or subsectors of the transport system;
    - Marginal abatement costs should be calculated taking into account fuel cost savings and other benefits, including reduction of other externalities besides GHG emissions.
- measurability
  - Measurability has a fundamental and a practical side.
    - Fundamental measurability means that something can be measured in principle in the lab at the vehicle level or on the road at the fleet level. This e.g. requires that the effect of a measure can be distinguished from effects of other measures and compared to a baseline. Measuring the impact of eco-driving for example is problematic from this perspective.
    - The practical side deals with availability of appropriate test procedures. For any regulatory requirement with target levels or limit values you must have a methodology against which one sets the requirement. This methodology should be representative with respect of normal vehicle use in traffic. Having appropriate test procedures available in time is a matter of planning ahead. But in some cases it may be difficult to establish practical test procedures, with practical related to technical feasibility, acceptable complexity and

acceptable costs. Besides test procedures one also needs a well identified party responsible for compliance with the legal requirement.

- proportionality between regulated reduction (e.g. sales averaged gCO_2/km measured on type approval test) and net real-world impact in Mton CO_2-equiv. per year (see also section 2.2.3);
- accountability: target stakeholders responsible for meeting target;
- fairness in distributing the required efforts and financial burden over various involved stakeholders;
- possible market distortion impacts:
  - Regulation always "distorts", i.e. impacts on, the market status quo, the relative competitiveness of manufacturers and their freedom to develop and market certain products. That in itself is not a problem and can nor should be avoided, especially for more stringent legislation required to meet ambitious long term goals. But it is useful to assess possible market distortion effects beforehand and to consciously decide which impacts are acceptable and proportional in relation to the desired effects of the regulatory legislation;
- possibilities for loopholes or perverse incentives;
- adverse incentives and trade-offs with other policy targets;
- possible rebound effects;
- appropriate level of penalties for non-compliance;
- relation with other GHG policy instruments applied to the same (sub)sector (see section 2.3).

More detailed criteria which have been applied to the design of CO_2 legislation for passenger cars and vans are discussed in section 3.3.1.

2.2.3 Technical issues

Regulatory activities in Europe with respect to transport for the moment focus on road vehicles. In the preparation of these policy instruments, however, fundamental questions arise that are also relevant to GHG emission regulation of other transport vehicles and modes. The main issues are:

- Definition of a (set of) test cycle(s) and accompanying test procedure that yield emission results which are representative for real-world use of the vehicles;
- Provisions for adequately dealing with alternative propulsion systems using conventional fuels;
- Provisions for adequately dealing with vehicle using alternative energy carriers:
  - biofuels;
  - electricity;
  - hydrogen;
  - more exotic options like compressed air, or metal-air batteries.

The latter point may require definition of a new metric for regulating GHG emissions from vehicles. It will require some form of well-to-wheel approach and will need to be able to deal with foreseen co-evolutions of the transport and energy system. This issue is discussed in section 2.4. Considerations related to test cycles and test procedures are discussed in the context of road vehicles in section 3.5.

For a mode like rail the non-operational activities such as construction, maintenance and operation of the infrastructure and all supporting functions are important sources of GHG emissions, which may need to be taken into account.

CO_2 emission standards or limits could also be related to the function of a vehicle and be expressed in e.g. g/passengerkm or g/tonkm. This is discussed in chapters 6 and 7. The “load” should always be the actual cargo being transported and should not include the weight of transport equipment. When a complete truck, a trailer or a container is placed on a boat or on a train the actual “load” is still only the load on the truck and the trailer or in the container.

2.2.4 Other greenhouse gases

Vehicle-related climate policies have so far focussed mainly on Tank-to-Wheel CO_2 emissions. In designing future regulatory instruments also other greenhouse gases may need to be taken into account. The main issues are:

- nitrous oxide (N_2O) and methane (CH_4);
- black carbon;
- radiative forcing resulting from water (H_2O) emissions from aircraft at high altitudes.

Nitrous oxide and methane

For assessing the GHG emissions in the Well-to-Tank energy chain of biofuels already the emissions of N_2O and CH_4 are taken into account. Emissions of N_2O are strongly related to fertiliser use in agriculture, while CH_4 emissions e.g. result from land-use change. In the production of biomethane from manure the avoidance of direct methane emissions may on the other hand even lead to net negative WTW emissions. Methane emissions are also relevant in the energy chains for conventional fuels (oil, natural gas and coal). Problems with emissions from N_2O and CH_4 in the energy chain is that they are first of all different for different specific production chains for each fuel, that they are distributed (i.e. not occurring in well-defined locations such as exhaust pipes) and difficult to measure directly. In the Fuel Quality Directive2009/30[8] the issue is tackled by means of default values for various energy chains based on state-of-the-art environmental assessments.

At the vehicle level emissions of CH_4 are especially relevant for vehicles running on natural gas. Due to the higher GWP a small amount of methane leaving the exhaust may significantly increase the overall GHG emissions of the vehicle. Methane emissions are in principle governed and controlled by exhaust gas regulation. In passenger cars methane emissions fall under the THC limit (total hydrocarbons). Assuming that all emitted hydrocarbons would be methane, the Euro 5 and 6 THC limit of 100 mg/km translates into 2.5 g/km gCO_2-equiv./km using the recent GWP of 25 for methane. For HD engines the Euro V and VI legislation contains an explicit CH_4 limit. The Euro VI limit value of 500 mg/kWh translates into 1.25 gCO_2-equiv./kWh. This is fairly insignificant compared to typical TTW CO_2 emissions of 650 g/kWh for a city bus engine on natural gas.

Engine out N_2O emissions from vehicles are generally small. Due to the high GWP of 298 a small amount of N_2O emissions, however, may still contribute significantly to total GHG emissions. According to IPCC TTW emissions are typically 2 - 5 g/GJ depending on fuel type for road vehicles and 0.08 g/kg fuel for ships. In [TNO 2003] a substantial measurement programme showed that especially in Euro 1 and 2 petrol vehicles the use of catalytic convertors under urban driving conditions could result in conversion of some of the NO_x emissions into N_2O, leading to elevated N_2O emission levels of between 5 and 40 mg/km (equivalent to 1.5 to 12 gCO_2-equiv.km). On rural roads and highways emissions were typically below 10 mg/km. In Euro 3 passenger cars on petrol emissions were much lower and for Euro 4 and beyond these were expected to be reduced even further. In Euro I to III HD vehicles N_2O emissions of below 10 mg/km were observed. For Euro IV and V these were expected to go up to around 40 mg/km. This amount is not insignificant but in CO_2-equivalents is a relatively smaller share of total TTW GHG emissions for HD vehicles.

N_2O emissions are not controlled by exhaust gas regulation. However, if levels remain at around 10 mg/km in case of passenger cars, regulation could become appropriate in view of the increasing marginal costs of CO_2 reduction when the CO_2 limit is further tightened.

Black carbon

Black carbon refers to various types of strongly light-absorbing combustion particles, the strongest of which is soot. The particles vary in size but generally they are much smaller than

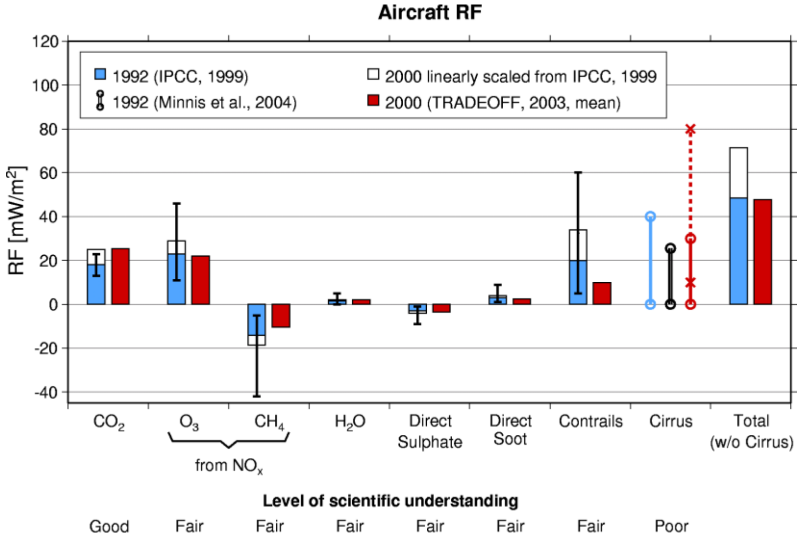
[8] DIRECTIVE 2009/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC, see: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0088:0113:EN:PDF

$PM_{2.5}$ and may not even get as large as $PM_{0.1}$. Black carbon is always a component of particular matter emitted from combustion sources, but the amount emitted will vary by the type of fuel used, the combustion process, and the performance of any emission control technologies or practices [ICCT 2009]. Black carbon absorbs visible light and converts it into infrared. It contributes to global warming through a positive radiative forcing when airborne, but especially when deposited on surfaces with a high albedo (snow and ice). IPCC ranks black carbon as the third most important positive climate-forcing agent after carbon dioxide and methane.

Indirect radiative forcing impacts

The climate impact of aviation not only results from GHG emissions, but also from indirect effects of non-GHG emissions and other effects such as contrails and increased formation of cirrus clouds. [IPCC, 1999]. According to [IPCC 1999] the total radiative forcing (a measure for the combined climate impact) in 1992 was 2.7 times higher than the direct radiative forcing of the CO_2 emissions of aviation, with a range between 1.9 and 4.0.

Figure 1 CO_2 and non-CO_2 related climate effects of aviation [Sausen, 2005]



Recent calculations show that [IPCC 1999] may have overestimated the radiative forcing of non GHG-effects. According to [Sausen 2005] in 2000 the total radiative forcing of aviation was about 2 times as high as radiative forcing from CO_2 emissions

To what extent these non-GHG impacts can be controlled with regulation is at present unclear, but they should in any case not be overlooked in the context of GHG policy for the aviation sector.

2.3 CO_2 regulation in relation to other policy options

2.3.1 Regulation versus economic instruments

Regulation and economic instruments can be seen as alternative policy instruments, but may also be seen as complementary measures, as will be explained in this section.

In general, economists tend to favour fiscal or other financial instruments over regulation on the grounds that the former would be more cost effective [OECD 2008]. Ideally this may be true as financial instruments (e.g. fuel tax or a cap & trade system) promote and award a wider range of technical as well as behavioural responses to meet the target, and allow affected entities to look for the most cost effective options for mitigating GHG emissions. Regulation tends to focus on specific products or even specific technologies, so that less options are available to meet the target. Regulation may thus lead to the application of technological options with high abatement costs relative to other options inside and outside the transport sector.

However, in many cases, including the case of EU policy to reduce GHG emissions from transport, there are also a number of reasons for favouring regulation over financial instruments or to opt for a combination of the two (see e.g. [OECD 2008]):

- Fiscal policy is difficult to establish in the European context. Member States cherish their independence with respect to fiscal policy and EU proposals for tax measures require unanimous decisions in the Council. Prevailing levels of fuel taxes currently fail to stimulate the desired level of reduction in fuel consumption, and the political acceptability of increased fuel tax is small in most Member States;
- Cap & trade systems for the transport sector are conceivable but more difficult to establish than in other sectors. A top-down approach, where fuel producers are the targeted entity, has the problem that fuel producers have limited influence on the efficiency of vehicles and can only influence consumer behaviour through price increases. Consumer response is very inelastic so that this approach may lead to very high and volatile costs of CO_2 credits. A bottom-up approach, where individual consumers / drivers are the targeted entities, has as main drawbacks the high number of entities, the difficulty of allocating permits and the high transaction costs. Overall, for the short and medium term the political feasibility of a cap & trade systems, or inclusion of transport in ETS, is considered limited;
- In Europe the EU is responsible for many standards and regulations as EU-wide harmonisation of such policies reduces trade barriers. CO_2 regulation for road vehicles and other transport modes can thus be established by the European Commission within the existing legislative and policy context;
- Regulation has proven to be an effective tool in other areas, especially in reducing noxious emissions from road vehicles;
- Regulation provides investment security to the industry. Targets are set well in advance so that the industry knows what it has to deliver;
- Regulation makes sure that efficient vehicles become available to consumers;
- Combining fuel / CO_2 taxes and fuel economy / CO_2 emission regulations may help to overcome imperfections in the market for vehicles that are not satisfactorily dealt with by fuel / CO_2 taxes, and may help to bring the technological mitigation options to the market that allow the various stakeholders to react effectively to increasing CO_2 prices under a cap & trade system.

The nature of these market imperfections is not well researched, but they seem to be related to the following issues (see e.g. [OECD 2008]):

- split incentives
    - These occur in energy conservation when different actors are involved in a process of applying more efficient technology. Often one actor (generally the producer or the owner, in the case of transport e.g. car manufacturer or lease company) has to bear the costs while another actor (generally the user) reaps the benefits of applying more energy efficient products. Especially in cases where the user is not fully aware of possible benefits or is not valuing these in a rational manner (and as a consequence is not expressing demand for the efficient product), it will be difficult for manufacturers to invest in energy efficient technology without government incentives guaranteeing a market;
- consumer "myopia" when it comes to valuing future fuel costs savings.
    - Consumers tend to underinvest in fuel economy, especially when improved fuel economy implies a loss with respect to other attributes of the vehicle (e.g. engine power);
- insufficient information at the point of purchase on the trade-off between more expensive technology and lower fuel costs;
- frictions in markets for used cars;
- inappropriate incentives in company car markets;
    - incl. existing company car taxation and the taxation of benefits in kind which makes it advantageous for firms to give company cars to their employees rather than paying them more;
- uncertainty for manufacturers about the reactions of car buyers and competing manufacturers to producing more efficient but more expensive vehicles.

These frictions can justify interventions such as providing better information and regulating fuel economy.

In relation to the above also the difference in behaviour between “commercial” costumers and “private” customers with respect to purchase cost and cost of operation should be noted.

The issue of split incentives may be alleviated but is not intrinsically solved by applying economic instruments. Regulation may help to promote the development and application of energy efficient technology and will as such make options available to actors that need to respond to the incentives given by economic instruments.

The other way around economic / fiscal instruments and other flanking policies (e.g. labelling) may help to create a market for fuel efficient vehicles which helps manufacturers to more easily meet the targets set for them by CO_2 regulation.

For long term EU GHG policy for the transport sector CO_2 emission regulation is therefore an important option whether in combination with other (financial) measures or not.

2.3.2 Relation with other instruments

Other important instruments for promoting the introduction of new, energy-efficient technologies are e.g. subsidies or temporary tax incentives, CO_2 differentiation of existing taxes, CO_2 taxation on fuels and communication and awareness measures such as labelling and information campaigns.

It could be argued that such additional stimulation measures are no longer necessary when manufacturers are legally obliged to meet a certain CO_2 target. However, especially in the case of CO_2 emission regulation, this need not be true.

If we compare it with the case of exhaust gas legislation (Euro standards) we see a difference as well as a similarity. The difference is that all new vehicles have to meet the same Euro limit values so that consumers have no choice that can be influenced by other measures. Nevertheless, before new limit values are in effect many Member States implement stimulation programmes (incl. subsidies) to promote early uptake of next Euro-generation vehicles. This is not only beneficial for the environment but may also assist manufacturers in creating an early market providing first returns on investment and in which economies of scale can help to bring costs down before new emission control technology is to be applied to all new vehicles.

In the case of CO_2 emissions manufacturers have to meet a sales averaged target. If a CO_2 value is regulated, either per car or on average, then parallel instruments such as labelling and fiscal measures will not lead to further CO_2 reductions beyond the target set by the regulation. They will instead influence how easy or difficult it is for manufacturers to meet their targets. Whether or how easily manufacturers meet their target in a given year is to a significant extent influenced by the consumers’ willingness to buy more fuel efficient or e.g. smaller or less powerful vehicles. Subsidies, labelling and other flanking measures can certainly help consumers make the choice for vehicles with lower CO_2 emissions and will thus help manufacturers to reach their targets. So they should be seen as (very useful) flanking measures but they do not lead to further CO_2 reductions on their own.

For labelling, CO_2 differentiation of taxes and for criteria defining eligibility for subsidies the existence of sufficiently accurate and reliable information on vehicle CO_2 emissions is necessary. This requires appropriate test procedures to deal with the different alternative technologies in a consistent manner. Also such test procedures should preferably relate to real-world driving as good as possible to make sure that subsidies and other incentives are spent on vehicles that bring the desired improvements in practice rather than on paper. The issue wrt alternative metrics for new energy carriers is also relevant to some of these other policy instruments.

2.4 Alternative metrics: from tailpipe to a WTW approach

Note: The text below is an adapted and updated version of chapter 5 of [CE/TNO/Öko/AEA 2008][9].

In the presently proposed regulation for passenger cars (Regulation No 443/2009) tank-to-wheel (TTW) CO_2 emissions as measured on the type approval test are used as a proxy for vehicle efficiency. For petrol and diesel the well-to-tank (WTT) CO_2 emissions are of the same order or magnitude, so that legislating TTW emissions is sufficient to achieve overall well-to-wheel (WTW) reductions of CO_2. Nevertheless already for these energy carriers the exclusion of WTT emissions will have some negative impacts if CO_2 legislation or market trends would lead to increased shares of diesel vehicles. Adjusting refinery outputs towards a higher diesel/petrol ratio has already led to increased WTT energy consumption and GHG emissions over the last decade.

This proxy of regulating TTW emissions only becomes fully inadequate as soon as other energy carriers come into play. If such alternative technologies are expected to have a significant share of the market by or beyond 2020 it will be necessary to define a suitable metric that can be applied to determine and regulate the CO_2 emission of cars that use other energy carriers than conventional petrol and diesel. The lack of appropriate metric and test procedures could on the one hand lead to overstimulation of vehicles on electricity or hydrogen, and may even present a loophole in the legislation if technologies that, because of their low type approval CO_2 emission figure, contribute to meeting the target under the CO_2 regulation would lead to increases in real-world emissions. Under the present regulation this may be the case for vehicles on electricity and hydrogen. On the other hand inconsistencies between the valuation of technologies under a CO_2 regulation and their real-world WTW GHG emission impacts may also become an obstacle for introduction of technologies that may effectively contribute to the target of CO_2 reduction in the transport section but that do not obtain a low CO_2 figure on the type approval test. This may be the case for dedicated vehicles running on biofuels. For a limited period of time such "flaws" of the regulation may be used without much harm to create a pull for new technologies. Once market shares become significant, however, a more generically balanced approach will be necessary to create a stable market and level playing field in which technologies compete on the basis of their real environmental performance.

In the extreme case of electric and fuel cell vehicles TTW CO_2 emissions as measured on the type approval test are zero, and the WTW CO_2 emissions are fully determined by the WTT production chains for electricity and hydrogen. For plug-in hybrids the same problem applies albeit to a less extreme extent. It needs to be assessed to what extent this problem may be resolved by the fact that CO_2 emissions from the production of electricity and hydrogen are covered by the ETS. For this reason the present metric is maintained as one of the alternatives in the discussion presented below. For dedicated vehicles on biofuels or other alternative carbon-based fuels the situation may be more complex as these are often produced outside the EU.

But even in case the market in 2020 is still expected to be dominated by petrol and diesel vehicles, one may need an adaptation of the metric to prevent the present metric to become an obstacle for introduction of promising new technologies. The new metric should preferably be technology neutral to create a level playing field for all possible alternative technologies. The new metric should allow a clear distinction between the responsibilities of stakeholders, where car manufacturers can in principle only be held responsible for developments in Tank-to-Wheel emissions. Changes in metrics and associated targets need to give planning certainty to the car manufacturers/industry.

Furthermore the new metric should be defined in such a way that a relative (i.e. n%) reduction of the new vehicle fleet average value of this metric leads to a net reduction in WTW greenhouse gases of the same order of magnitude.

[9] See: http://ec.europa.eu/environment/air/transport/co2/pdf/impacts_reg_options.pdf

Possible alternative metrics, including the existing one, are:
- tank-to-wheel (TTW) CO_2 emissions measured on the TA test in g/km;
- tank-to-wheel (TTW) energy consumption measured on the TA test in MJ/km;
- well-to-wheel (WTW) GHG emissions based on tank-to-wheel (TTW) energy consumption and CO_2 emissions measured on the TA test in MJ/km resp. g/km and separately defined well-to-tank (WTT) GHG emissions in gCO_2-eq./MJ.

2.4.1 TTW CO_2 emissions

The present proposed legislation for cars is based on the tank-to-wheel CO_2 emissions as measured on the type approval test. It ignores differences in well-to-tank emissions associated with the production of the different fuels / energy carriers used in road vehicles. The main alternatives to be considered are LPG, natural gas, biofuels, electricity and hydrogen.

For the case of electricity and hydrogen it can be argued that TTW CO_2 emissions are an appropriate metric. For electricity and hydrogen produced in sufficiently large plants the CO_2 emissions associated with the production process are covered by the European CO_2 emission trading system ETS. ETS sets a cap to the overall CO_2 emissions from covered sectors. These sectors include large scale electricity production and the fuels industry, so that also the production of hydrogen within the EU would be subject to the ETS cap. This means that any additional WTT CO_2 emissions resulting from the increased production of electricity and hydrogen for use in the transport sector need to be compensated by CO_2 reductions in other sectors falling under the ETS. In other words: the marginal CO_2 emissions from additional electricity of hydrogen production are zero for production plants covered by ETS. As such it can be argued that electric or hydrogen vehicles introduced into the transport sector can be considered as zero-emission vehicles: their TTW emissions are zero while their WTT emissions are compensated by reductions elsewhere. Assuming that electric and or hydrogen-powered vehicles are likely to obtain a significant share in the 2020 sales of passenger cars, the use of a TTW based CO_2 target thus allows the definition of much stricter target levels. A 10% market share of (zero-emission) electric or hydrogen vehicles allows a 10% lower 2020 target compared to what is feasible with petrol and diesel fuelled ICE vehicles alone.

It needs to be noted here, however, that the above reasoning is not entirely watertight. Electricity may also be produced in small plants (e.g. combined heat & power), which are not covered by the present ETS system. Similarly in the early years of market introduction hydrogen for fuel cell vehicles may be produced in small-scale reformers at fuel stations rather than in large centralised plants. The emissions of small hydrogen production facilities are also not covered by ETS. Furthermore the cap of the ETS system is not absolute itself. Even under a fixed cap there may be “carbon leakage”. The increased demand for electricity and hydrogen from the transport sector may drive up the CO_2 price under the ETS system, which may force energy-intensive industries to move their production plants to locations outside the EU. Furthermore a strong increase of the CO_2 price may at some point tempt governments to relax the ETS cap and to allocate additional credits.

In principle WTT emissions for hydrogen and electricity used in transport will be covered under Article 7a of the FQD (2009/30) which states that “Member States shall designate the supplier or suppliers responsible for monitoring and reporting life cycle greenhouse gas emissions per unit of energy from fuel and energy supplied. In the case of providers of electricity for use in road vehicles, Member States shall ensure that such providers may choose to become a contributor to the reduction obligation laid down in paragraph 2 if they can demonstrate that they can adequately measure and monitor electricity supplied for use in those vehicles.” with paragraph 2 stating that “Member States shall require suppliers to reduce as gradually as possible life cycle greenhouse gas emissions per unit of energy from fuel and energy supplied by up to 10 % by 31 December 2020, compared with the fuel baseline standard referred to in paragraph 5(b).” If this reduction target is applied per energy carrier (and per supplier) this provision in the FQD does not reduce the leverage resulting from the fact that TTW emissions of electric and fuel cell cars count as zero under the vehicle CO_2 regulation as described above. This would only be the case if trends in the average energy use per vehicle are properly matched with changes in the CO_2

emission per unit energy averaged over all energy carriers supplied to the transport sector. Furthermore the provision that electricity supplied to vehicles would need to be measured is something that can probably only be realised in the longer term with the aid of smart metering or smart grid systems.

In fact it can be shown that under a TTW based CO_2 regulation an increase in the share of EVs always leads to an increase in WTW emissions as long as the WTW emissions of EVs added to the fleet are not zero. As explained above treating EVs as zero-emission vehicles under the present regulation (based on type approval CO_2 emission values) creates a leverage which may promote the use of EVs as means for meeting the target. If this happens their (fictitious) zero emissions will be more than compensated by (real) higher emissions of conventional cars. Up to 2015 this is further amplified by the "supercredits" provision. For the short term such a leverage may be acceptable as a way of promoting the market introduction of zero-emission vehicles which may become a crucial part of long term sustainable transport system. In the long term, however, such implicit promotion should be replaced by legislation that stimulates technologies on the basis of their real contribution towards meeting the targets. The current system is an invitation to cross-subsidise internally in the manufacturer's business, and leads to the unwanted side effects as illustrated in Figure 2.

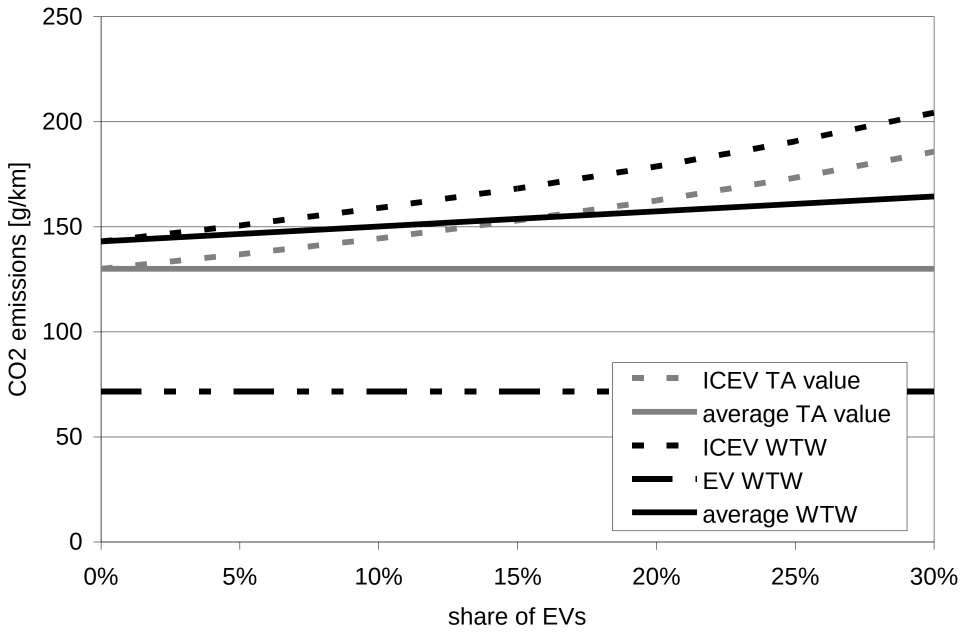


Figure 2 Effect of increasing the share of EVs in new vehicle sales on overall CO_2 emissions from passenger cars in case of a 130 gCO_2/km target

Figure 2 is a back-of-the-envelope example which shows the impact of an increasing share of EVs used to meet the 130 g/km target on average TA and WTW CO_2 emissions. Increasing the share of EVs leads to higher average TA CO_2 emissions for the remaining share of ICEVs. For this hypothetical example it is assumed that the WTW emissions of conventional vehicles are 110% of the TTW emissions and that the WTW emissions of EVs are 50% of those of a comparable 130 g/km ICEV (roughly equivalent to WTT emissions from electricity production equal to 500 g/kWh). In this example a 10% share of EVs leads to a 5% increase in average WTW emissions from passenger cars (assuming equal annual mileage for all vehicles). Even if the WTW emissions of EVs would be 90% lower than those of comparable ICEVs the average WTW emissions from passenger cars would increase by 1%. This effect can only be avoided if EVs use completely CO_2 neutral electricity.

The example of Figure 2 makes clear that one may need to consider separate vehicle-based targets for different technologies and that policy instruments may have to be designed that promote the application of these technologies independent of the CO_2 regulation applied to conventional cars. An alternative, discussed in section 2.4.2, would be the use of a TTW energy consumption or efficiency target.

For biofuels the issue is even somewhat more complex. A significant share of the future biofuels used in the EU, or the biomass from which they are produced, is likely to be produced outside the EU, so that WTT CO_2 emission are not covered by any cap & trade system. And even for the biofuels produced in the EU from feedstocks grown in the EU a large portion of the WTT CO_2 emissions is not subject to ETS (e.g. CO_2 and N_2O emissions from agriculture).

The same problem applies to natural gas and LPG imported from outside the EU, and to some extent even to future developments in the production of petrol and diesel fuels. GHG emissions associated with the use of natural gas tend to increase with longer transport distances. Focussing the CO_2 legislation on TTW emissions thus ignores that in the future the WTT emissions of natural gas will increase when it is imported from ever more distant locations. Similarly the possible increase in the production of petrol and diesel from unconventional oil (e.g. Canadian tar sands) will lead to an increase in the WTT emissions associated with the use of these conventional fuels, which is ignored in a TTW-based CO_2 legislation.

In principle WTT emissions for biofuels and fossil fuels used in transport will be covered by the Fuel Quality Directive 2009/30. To what extent the combined policies for vehicles and energy carriers lead to the desired level of net GHG emission reduction remains to be established.

Overall it can be concluded that although a TTW-based CO_2 legislation for cars will not accurately cover the trend in WTW GHG emissions associated with a change in the use of various fuels in transport, it might still be an appropriate proxy depending on the nature of these trends. This notion deserves some further elaboration.

2.4.2 TTW energy consumption

An obvious alternative would be to regulate vehicle efficiency in terms of MJ/km final energy consumption, based on the energy content of the energy carriers used. This approach however has a serious drawback. The end use energy consumption in terms of MJ/km of electric and fuel cell vehicles is less than half that of vehicles on petrol and diesel. Depending on the WTT energy chain the WTW GHG emissions associated with these technologies can be lower than those of petrol and diesel vehicles, but can also be much higher. Increasing the share of electric and fuel cell vehicles would thus create a large leverage for meeting a target defined in MJ/km, but would give no guarantee for net reductions in WTW GHG emissions. As argued above in the discussion of a TTW CO_2 based metric this might in the case of electricity and hydrogen not be as big a problem as it seems.

This issue is illustrated in Figure 3, in which the impact of an increasing share EVs on the average WTW emissions is shown for the case of a MJ/km target and two different assumptions for the WTT emissions of electricity generation. In this example a TTW efficiency target of 1.78 MJ/km is assumed, which is equivalent to a 130 gCO_2/km target for passenger cars on petrol and diesel (45% - 55%). For EVs a TTW energy consumption of 150 Wh/km (= 0.54 MJ/km) is assumed. The WTW emissions per kilometre for electric vehicles are calculated using a WTT emission factor of 500 resp. 50 g/kWh. The WTW emissions of conventional vehicles are again assumed to be 110% of the TTW emissions. In case of 500 g/kWh the average fleet emissions go up with increasing the share of EVs, while they go down when the WTT emissions of electricity are 50 g/kWh. In this calculation example the WTT emissions of electricity generation need to be below 290 g/kWh in order to achieve net WTW GHG emission reductions from increased use of electric vehicles. The current EU average CO_2 emission factor for electricity generation is around 440 g/kWh[10].

[10] See: http://ies.jrc.ec.europa.eu/uploads/media/WTT_Report_010307.pdf

This drawback can thus in principle be overcome by simultaneously implementing vehicle efficiency legislation in MJ/km and legislation aimed at reducing the GHG emissions in the energy chain, with a target expressed in gCO_2-eq./MJ. Achieving the desired overall WTW GHG reductions then requires coordination of strategies by the automotive and the fuels and energy industry. Imposing binding targets with respect to WTT emissions on the latter may however be difficult. In the longer term these would need to be related to the average WTT emissions, based on a sales-weighted averaging over all different energy carriers sold for application in transport. In this context developments with the Directive on fuel quality[11] should be monitored, notably the carbon reporting and reduction mechanism introduced in the proposed revision of this Directive[12]. Possible difficulties relate to the following issues:

- It is generally difficult to determine which share of the sold energy carriers is used by passenger cars;
- Future energy carriers for transport may be produced by a wide variety of companies, including companies that are traditionally not part of the fuels industry. This will certainly be the case for electricity but possibly also for biofuels and hydrogen.

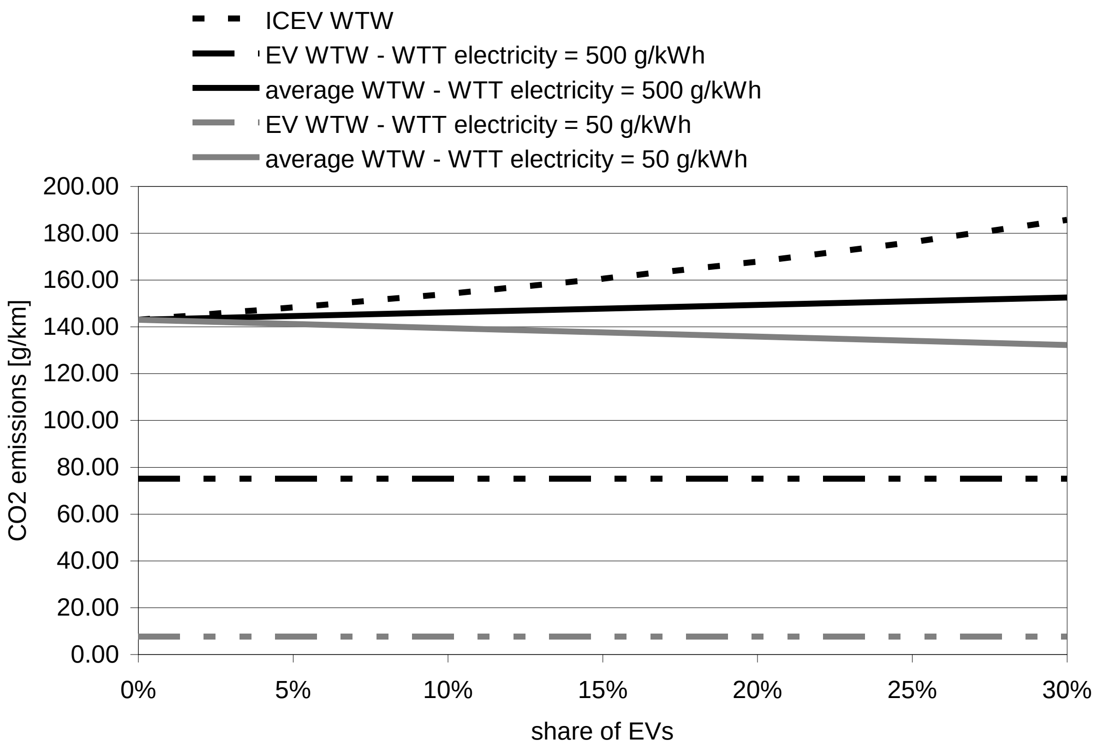


Figure 3 Effect of increasing the share of EVs in new vehicle sales on overall WTW CO_2 emissions from passenger cars in case of a 1.78 MJ/km TTW efficiency target (equivalent to 130 gCO_2/km for vehicles on petrol/diesel)

2.4.3 WTW greenhouse gas emissions

An alternative option is to regulate WTW CO_2 or GHG emissions. As car manufacturers have no influence over the WTT chains used to produce the energy carriers, the WTW GHG emissions per km per manufacturer would have to be determined on the basis of:

- TTW CO_2 emissions (g/km) and energy consumption (MJ/km) as determined on the type approval test;
- default / nominal values for the WTT GHG emissions (g/MJ) of the different energy carriers (petrol / diesel / NG / LPG / various biofuels / electricity / hydrogen).

[11] Directive 98/70/EC
[12] COM(2007)18

Default WTT values can be based on EU averages for the actual production of the energy carriers and could be periodically updated to reflect technical progress and changes in market shares for different production chains. A transparent and agreed methodology would be required for that. It is obvious that WTT emissions of different energy chains may differ from country to country, but as the policy aims at CO_2 reduction at the EU level, EU sales-averaged values can be used.

A first serious attempt at setting up the above sketched approach is included in the FQD and RED (Directives 2009/28 and 2009/30). See also the discussion in chapter 5. Default values are given for the WTT emissions of a large number of biofuel chains as of January 2008. Averages for the different fuels (e.g. bioethanol, biodiesel) can be calculated for a given year if the sales of fuels from different sources / chains are known. This could be part of a Monitoring Mechanism. Default WTT GHG emission figures should also be regularly updated to incorporate changes in production chains and new insights.

For natural gas, electricity and hydrogen default WTT GHG emission factors could be established along similar lines[13].

Figure 4 shows how various levels of future targets can be obtained with different combinations of TTW vehicle efficiency improvement and changes in the WTW GHG emission of the energy carrier used. The hyperbolas in the graph indicate lines of constant WTW GHG emission in g/km for different levels of the WTW emissions. These levels are expressed as equivalents of a TTW g/km target for ICEVs running on conventional petrol or diesel. The graph contains points that correspond to the average 2006 ICEV with a TA CO_2 emission of 160 g/km, the 130 g/km target for new ICEVs in 2015 and, as an example, a typical battery-electric vehicle (BEV) with am electricity consumption of 200 Wh/km and CO_2 emissions for electricity generation of 500 g/kWh (typical for the Netherlands). For conventional fuels a ratio between WTW and TTW GHG emission of 1.15 is assumed.

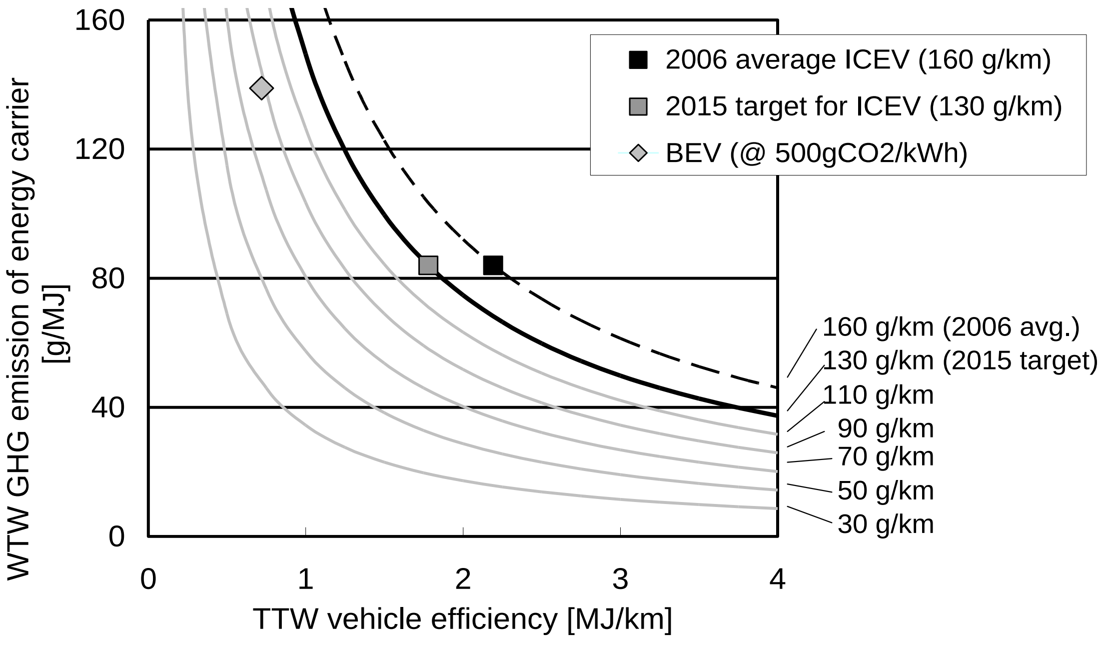


Figure 4 **Illustration of how various levels of future targets can be obtained with different combinations of TTW vehicle efficiency improvement and changes in the WTW GHG emission of the energy carrier used**

[13] The Commission is already consulting on how to establish the default values for fossil fuels. See: http://ec.europa.eu/environment/air/transport/pdf/art7a.pdf

Targets for the WTW GHG emissions in g/km on the basis of the TA test cycle can be set per manufacturer in a similar way as used now for the TA CO_2 emissions. Under such a system manufacturers are made responsible for achieving a reduction of the net WTW GHG emissions from newly sold vehicles. Measures contributing to meeting this target include making their cars more energy efficient and developing and selling cars powered by alternative, more sustainable energy carriers.

In the methodology for determining nominal or default WTT emission factors the following issues need to be taken into account:

- Do we use average or marginal emission factors, i.e. based on total emissions divided by total production or based on the additional emissions associated with the extra production of a given energy carrier?
- In case of electricity marginal emissions depend strongly on the time of charging. Assumptions or measured input data are needed regarding the share of peak and off-peak of day time and night time charging.

Possible problems with this approach are the following:

- The nominal values for the WTW GHG emissions of different energy carriers evolve over time as a result of developments in the technologies for producing these energy carriers and developments in the market (e.g. origin of biofuels). Car manufacturers have no control over these developments. While they need fixed targets to base their longer term research and vehicle development goals on, this metric provides them with targets that may move over time;
- For various vehicle types it is difficult to assess which (mix of) fuel(s) is actually used. This is especially the case for biofuels. Vehicles accepting a certain level of biofuel blended into fossil petrol or diesel may run on a wide range of blending percentages and may not even use biofuel at all. In this case it is difficult to decide which nominal WTW GHG value is to be attributed to these vehicles.

2.4.4 Conclusions with respect to metric

In order to enable early introduction of vehicles using alternative energy carriers the metric for the regulation of CO_2 emissions from vehicles may need to be adapted. Splitting the regulation in an efficiency target for vehicles (MJ/km) and a WTW GHG target (in gCO_2equiv./MJ) for energy carriers may look attractive from a theoretical point of view, but is complex in practice due to the large differences in vehicle efficiency of different propulsion technologies and the wide variation in WTW GHG emissions with which alternative energy carriers can be produced depending on primary source and production process. Despite such complicating factors this option does deserve further study as it clearly divides responsibilities between car manufacturers (vehicle efficiency) and producers of energy carriers (WTT efficiency, WTT GHG emissions, carbon content) and also because many stakeholders have expressed a preference for this option.

The problem with the leverage of vehicles with zero TTW emissions under the present CO_2 regulation schemes can in principle be solved by sufficiently tightening the target to reflect the potential of these new technologies. A consequence of that would be that the regulation would become less technology neutral as it would effectively force the use of zero TTW emission vehicles. Also setting targets in this way requires good insight in the feasible share of such vehicles in the target year. Such market shares are, however, difficult to “predict”.

A shift from petrol / diesel to electricity or hydrogen will in first instance result in higher average WTT emissions for the total amount of energy supplied to the transport sector, even in case the overall WTW emissions are reduced by this transition. In relation to the above mentioned tightening of TTW targets, such an increase of WTT emissions would have to be allowed. But this is difficult to communicate and should be carefully balanced to avoid possible increases in overall WTW emissions.

An option to be explored is to set separate limit / target values for vehicles with different types of power trains / energy carriers. These different regulatory requirements would need to be balanced in order to create a level playing field, but this could turn out to be more feasible than designing a generic and technology neutral overall regulation. This may also be combined with a bin-based regulation (ref. the Californian emission legislation and ZEV mandate), setting targets for the share of vehicles meeting different CO_2 emission limit or target values.

2.5 Life cycle aspects

In addition to including well-to-tank impacts of energy carriers, at some point it may also become relevant to include GHG emissions (and other environmental impacts) originating from the production and decommissioning / recycling of vehicles. Such impacts from the production chain are assessed in a Life Cycle Analysis (LCA).

Currently the GHG emissions associated with production and recycling of vehicles (incl. mining and production of materials) are of the order of 10% of the GHG emissions emitted in the use phase as a result of energy consumption for driving. This ratio may change in the future due to two major trends:

- As a result of existing legislation vehicles will become more energy efficient and will emit less CO_2 during driving. As a result the energy used and amount of greenhouse gases emitted in production and recycling will become a higher percentage of the energy consumed and GHG emission produced in the use phase;
- The shift towards sustainable vehicles will at some point involve drastic changes in propulsion technology, potentially leading significant changes in the life cycle GHG emissions. In the case of electric vehicles especially the use of batteries and the electric motors will have an impact. For fuel cell vehicles e.g. the use of platinum in the catalyst may significantly change the energy use and GHG emissions for manufacturing of the vehicle. The use of advanced lightweight materials, such as fibre reinforced composites, to reduce vehicle weight may also be expected to significantly affect the LCA picture.

It should be noted here that developments that may contribute to meeting long term EU targets for vehicle efficiency and GHG emissions associated with driving, may conflict with other EU policies, specifically the Directive 2000/53/EC on end-of-life vehicles[14]. This directive requires that "no later than 1 January 2015, for all end-of life vehicles, the reuse and recovery shall be increased to a minimum of 95 % by an average weight per vehicle and year. Within the same time limit, the re-use and recycling shall be increased to a minimum of 85 % by an average weight per vehicle and year." Composites are intrinsically difficult to recycle. They can be collected and incinerated with energy recovery, but according to the directive no more than 10% of the vehicle weight may be processed in this way. As an all-composite structure could amount up to 20% of a vehicle's weight, the use of such materials would thus be in direct violation with Directive 2000/53/EC.

2.6 Framework conditions

In view of the above one can include that it is of paramount importance to have appropriate test procedures in place in time when new technologies enter the market. Test procedures and regulations that do not explicitly or appropriately deal with these new technologies may form a barrier for introduction. On the other hand they may overstimulate new options, as could be the case with electric and fuel cell vehicles under the present CO_2 regulation for cars. Such overstimulation could be acceptable or even desired in the early stages of market introduction, but in the long term a level playing field needs to be created in which improved conventional technologies and new options compete on the basis of cost effectiveness towards meeting environmental target on the one hand and market attractiveness on the other hand.

[14] Directive 2000/53/EC on end-of-life vehicles, see: http://ec.europa.eu/environment/waste/elv_index.htm

2.7 Impacts of regulation

Table 1 indicates which reduction options are promoted by the different types of regulation discussed in this report. In this overview positive effects (GHG emission reduction, labelled green) and negative effects, labelled red) are distinguished. Regulation does not directly target transport volume, but depending on the impact of GHG reduction measures on total cost of ownership regulation may lead to an increase (if GHG reduction has a net user benefit) or decrease (in case of net user costs) of volume.

Table 1 Overview of which reduction options are stimulated by different types of regulation

	Reduced car-ownership	**More f fuel efficient vehicles**	**Shift to low-carbon energy carriers**	**Fuel efficient driving/sailing/flying**	**Reduced vehicle-kms due to higher vehicle utilisation**	**Modal shift to low-carbon modes**	**Limiting overall transport growth**
Regulatory instruments							
Vehicles							
Vehicle emissions		↓	↓				?
Component efficiency		↓					?
Energy carriers			↓				?
Transport performance / efficiency		↓	↓	?	↓	↓	?

↓	**Policy instrument leads to GHG reduction in the long term by inducing this reduction option**
↑	Rebound effect: Policy instrument leads to GHG increase by negative impact on this reduction option

3 Regulation at the vehicle level for road transport

This chapter starts with a somewhat detailed review of existing regulation in Europe and elsewhere and then moves towards discussions of more general issues relevant to the development of possible future regulatory instruments for road vehicles.

3.1 CO_2 regulation for passenger cars in Europe

In 2007 (see COM(2007) 19[15] and SEC(2007) 60[16]) the European Commission has outlined its plans for a new Community Strategy for reaching the EU objective of reducing CO_2 emissions from new passenger cars to 120 g/km in 2012. The Commission proposes an Integrated Approach. The main element of this approach is a regulatory framework for reducing the CO_2 emissions of the average new car fleet to 130 g/km by means of improvements in vehicle technology. To bridge the gap between this new car fleet average and the 120g/km goal the Integrated Approach comprises the following additional elements:

- setting minimum efficiency requirements for air-conditioning systems;
- compulsory fitting of accurate tyre pressure monitoring systems;
- setting maximum tyre rolling resistance limits in the EU for tyres fitted on passenger cars and light commercial vehicles;
- the use of gear shift indicators;
- fuel efficiency progress in light commercial vehicles with the objective of reaching 175 g/km CO_2 by 2012 and 160g/km CO_2 by 2015;
- increased use of biofuels maximizing environmental performance.

Together these elements are intended to achieve a net CO_2 emission reduction that is equivalent to the impact of reducing the new vehicle fleet average from 130 to 120 g/km. In December of 2007 the Commission has presented a detailed proposal[17] and accompanying Impact Assessment[18] for the regulatory framework to achieve a new car fleet average of 130 g/km.

In December 2008 the European Parliament and Council have reached agreement through a co-decision procedure on the details of the CO_2 legislation for passenger cars, laid down in Regulation No 443/2009[19]. Some important elements of the agreement are:

- Limit value curve: the fleet average to be achieved by all cars registered in the EU is 130 grams per kilometre (g/km). A so-called limit value curve implies that heavier cars are allowed higher emissions than lighter cars while preserving the overall fleet average. Manufacturers will be given a target based on the sales-weighted average mass of their vehicles.
- Phasing-in of requirements: in 2012 65% of each manufacturer's newly registered cars must comply on average with the limit value curve set by the legislation. This will rise to 75% in 2013, 80% in 2014, and 100% from 2015 onwards.
- Long-term target: a target of 95g/km is specified for the year 2020. The modalities for reaching this target and the aspects of its implementation will have to be defined in a review to be completed no later than the beginning of 2013.

In the CO_2 regulation for cars vehicle mass (reference mass) is used as utility parameter for differentiating the overall target to manufacturer specific targets. The utility-based limit function is a linear relation between the CO_2 target and the sales averaged reference mass:

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[15] COM(2007) 19: Results of the review of the Community Strategy to reduce CO_2 from passenger cars and light commercial vehicles, 7.2.2007
[16] SEC(2007) 60, Impact Assessment, accompanying document to COM(2007) 19, 7.2.2007
[17] COM(2007) 856, Proposal for a Regulation of the European Parliament and of the Council setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles, 19.12.2007
[18] SEC(2007) 1723, Proposal from the Commission to the European Parliament and Council for a Regulation to reduce CO_2 emissions from passenger cars, DRAFT Impact Assessment, 19.12.2007
[19] REGULATION (EC) No 443/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles, see: http://ec.europa.eu/environment/air/transport/co2/co2_home.htm

$$CO_2 = 130 + a \times (M - M_0)$$

with M the mass of the vehicle in kilograms (kg) and the slope a = 0,0457.Until 2015 M_0 is set equal to 1 372,0 kg, which is the average mass of passenger cars sold in Europe in 2006. After 2015 M_0 is to be determined on the basis of monitored developments in the average vehicle mass to avoid that autonomous mass increase trends would lead to a situation where individual manufacturers comply with their specific target but the overall target of 130 g/km is not met.

A number of implementing measures, detailing various provisions and procedures of the CO_2 legislation for cars, are still to be designed and adopted through a comitology procedure. These implementing measures cover issues relating to:
- the contribution of so-called "eco-innovations" to CO_2 reductions (see below);
- special derogations for niche and small volume manufacturers and for market entrants;
- monitoring CO_2 emissions and other features (e.g. footprint) from newly registered light duty vehicles.

The CO_2 and cars regulation, as defined in COM(2007)856 foresees that a review should be carried out by the European Commission no later than the beginning of 2013 in order to define the modalities of reaching the 95 g/km target for the new car fleet by 2020. The definition of suitable modalities for setting the 95 g/km target will include issues such as:
- the choice of a suitable utility parameter and shape of the limit function;
- a suitable metric for defining the target, taking proper account of the possible introduction of vehicles with alternative powertrains, including vehicles with low or zero “tank-to-wheel” CO_2 emissions on the type approval test but non-zero “well-to-tank” CO_2 emissions in the energy supply chain;
- options for increasing flexibility, including pooling and trading,
- provisions for small volume and niche manufacturers;
- possible credits for advanced technologies.

For the 2020 target a different utility parameter may be used. Footprint (track width x wheel base) will be reviewed as an important candidate. This parameter is included in the monitoring provisions detailed in Annex II of the passenger car CO_2 regulation.

COM(2007)19 and COM(2007)856 both call for a review to be carried out by the Commission in 2010 of the progress made to implement the Community’s Integrated Approach to reduce CO_2 emissions from cars. COM(2007)19 also calls for a review of the potential for further measures to move beyond the stated EU objective.

Eco-innovations

Article 12 of Regulation No 443/2009 states that manufacturers may receive emission credits contributing to the achievement of their specific CO_2 target for the application of so-called eco-innovations. These are innovative technical measures applied to vehicles which reduce the energy consumption and CO_2 emissions under real-world driving conditions but that do not affect the CO_2 emissions as measured on the type approval test. Examples are waste heat recovery, solar roofs and LED lighting. The total contribution of those technologies to reducing the specific emissions target of a manufacturer may be up to 7 gCO_2/km. A supplier or a manufacturer who applies for a measure to be approved as an innovative technology shall submit a report, including a verification report undertaken by an independent and certified body, to the Commission. The Regulation states that the Commission shall, by 2010, adopt detailed provisions for a procedure to approve such innovative technologies

Monitoring mechanism

Annex II of Regulation No 443/2009 describes provisions with respect to the monitoring and reporting of emissions from cars in the EU. It includes some amendments to the existing procedures for the Monitoring Mechanism (Decision 1753/2000/EC), specifically regarding the collection of data on the footprint (track width x wheel base) of cars. Currently the Commission is preparing further modifications of the Monitoring Mechanism, also in view of the monitoring requirements for the foreseen CO_2 regulation for light commercial vehicles.

Other relevant policy developments

An important development, especially with respect to the target for 2020, is the on-going work in UN-ECE (GRPE) work on defining a new light-duty vehicle test procedure (with the focus on developing a representative and world-harmonised driving cycle). This revised test procedure should better reflect real-world driving conditions and should take into account whenever possible the contribution of eco-innovations. Adoption of a new test cycle may require translation of the 95 g/km target, defined on the NEDC cycle, to an equivalent target for the new cycle. Other changes in the test procedure (test conditions, tolerances) may also require further work in the definition of the 2020 target.

3.2 Overview of regulation in other regions

3.2.1 Japanese top runner approach

Historically, Japan has almost no domestic energy resources and the country relies on overseas energy sources for the bulk of its needs. This, combined with Japan's stellar economic rise in the post-war years and the consequently enormous impact of the first and second oil crises in the 1970s, is why Japan has very early (1979) adopted legislation focused on the conservation of energy[20]. Initially, the machinery and equipment that was covered by the regulations was limited to *electric refrigerators*, *air conditioners*, and *passenger cars*. In 1999, the Energy Conservation Law was revised and the Top Runner program was introduced[21].

The importance of the reduction of in-use energy consumption was recognised but also that this in practice has limits that are determined by the equipment's efficiency. For this reason, the Top Runner program includes fuel efficiency norms for passenger cars, light commercial vehicles, HGVs and busses, categorized for the different vehicle classes. For each vehicle class, a limit is set for the maximum fuel consumption for vehicles sold as of a certain target year. These limits are set to some percentage of increased fuel efficiency with respect to the most efficient vehicle in each class in some reference year (see Table 2). The target values, as set in the Top Runner program, are thus derived from the best performing vehicles at the time that the standards are being developed (hence the name "Top Runner"). Alternative regulatory approaches, that have been considered but that are not adopted under the Top Runner program, are a minimum compliance target (such as the Minimum Energy Performance Standards) and a sales weighted average target (such as EC regulation No 443/2009). Anchoring the standard to the best performing vehicles helps to ensure a target that is economically fair on the one hand and sufficiently challenging on the other.

Table 2 Current efficiency targets for vehicles in the Top Runner program

Vehicle type	Reference year	Target year	Target efficiency improvement [%]
Petrol passenger	2004	2015	23.5
Diesel passenger	2004	2015	23.5
LPG passenger	2001	2010	11.4
Vans	2004	2015	7.2
Buses	2002	2015	12.1
Petrol HGV	2004	2015	12.6
Diesel HGV	2004	2015	12.6
Tucks and tractors	2002	2015	12.2

Because of technological progress, not only the target will slowly erode but it is to be expected that new technologies that are not targeted at the time that the regulation was established,

[20] "Law concerning the Rational Use of Energy", or "Energy conservation law"
[21] http://www.eccj.or.jp/top_runner/img/32.pdf, accessed September 2009

because of e.g. their limited prevalence, will grow to make a significant impact. It is therefore imperative that the targets are regularly updated as the market warrants.

In order to facilitate the adaptation of increasingly better performing vehicles by the public there are additional measures to be taken. An example is the need to provide information on the overall cost effectiveness of highly efficient products as compared to earlier products. Furthermore, rewarding retailers who actively promote sales of energy efficient products is deemed to be effective and important[21].

The fuel efficiency of a vehicle is determined on the basis of measurements and modelling. Using engine test data, an engine map is constructed. On the basis of this engine map and specific vehicle parameters the model calculates what the actual fuel consumption will be on distinct standardised types of journey. In Japan, this model has been accepted by both the type approval organisation and the industry. The results of the simulations are open to the public but the settings of the model parameters are determined in a closed discussion between the type approval organisation and the OEM. Some effect has already been achieved as part of the Japanese fleet already complies with the targets. These 2015 targets, however, do not seem to be overly strict for most classes [TNO 2008].

The Top Runner method is in principle also feasible within the EU. Models such as used in the Top Runner program are also available within Europe. Some further development, dependent on the desired level of representation and its concomitant complexity, however, is still required. Importantly, Europe differs from Japan in as much as that in Japan only one organisation is responsible for the type approval. In Europe there are several of such organisations in multiple countries. Furthermore the process of involving all parties, in order to secure sufficient trust, will be more complex in Europe than in Japan.

3.2.2 Californian / US

In the United States of America (U.S.) the regulations with respect to GHG emissions from road transport are not governed by a single authority. Under the Clean Air Act (CAA) the U.S. Environmental Protection Agency (EPA) is responsible for regulations that focus on GHG emissions. Under the Motor Vehicle and Cost Savings Act, however, the U.S. Department of Transportation (DOT) has delegated authority to the U.S. National Highway Traffic Safety Administration (NHTSA) for regulations that focus on fuel economy. To confuse matters even more, individual states can apply for exemption from federal regulations. The State of California has been recently granted such exemption (June 2009) to enact stricter air pollution limit values for motor vehicles than the federal government's[22].

CAFE

As a response to the 1973-1974 oil crises, the Energy Policy Conservation Act (EPCA) was enacted into law in 1975. In effect it added Title V: "Improving Automotive Efficiency" to the Motor and Vehicle cost Savings Act and established so-called Corporate Average Fuel Economy (CAFE) standards for passenger and light commercial vehicles. Fuel economy is expressed in miles per gallon (mpg), of a manufacturer's fleet of passenger cars or light trucks with a gross vehicle weight rating of 8500 lbs or less, manufactured for sale in the U.S., for any given model year. The fuel consumption is measured in accordance with the testing and evaluation protocol set forth by EPA.

The executive responsibility for CAFE lies with NHTSA. It is responsible for amending the standards; promulgating regulations concerning procedures, definitions and reports; considering petitions for exemption from standards for low volume manufacturers and establishing unique standards for them; enforcing fuel economy standards and regulations; responding to petitions concerning domestic production by foreign manufacturers and all other aspects of CAFE, including the classification of vehicle lines as either cars or trucks; collecting, recording and cataloguing reports; adjudicating credit plans; and providing program incentives such as credits for alternative fuelled vehicles. The responsibility for calculating the average fuel economy,

[22] http://edocket.access.gpo.gov/2009/pdf/E9-15943.pdf

however, lies with EPA. CAFE certification is done either one or two ways: 1) The manufacturer provides it own fuel economy test data, or 2) the EPA will obtain a vehicle and test it in its Office of Transportation & Air Quality facility. In practice, EPA performs actual tests on typically about 30% of the existing vehicle lines.

Initially CAFE was aimed at reducing the fuel consumption of new vehicles with 50% (to 27.5 mpg)[23] by 1985. This standard has not been significantly altered since, until in 2007, under the Energy Independence and Security Act (EISA), the new target was set at 35 mpg in 2020[24]. This is a minimum requirement, as NHTSA must set targets at the maximum feasible level in each model year. NHTSA will determine, based on all of the relevant circumstances, whether standards are required that reach the 35 mpg goal earlier than MY2020 [FR, 2009]. Feasibility is judged on the basis of:

- technological feasibility;
- economic practicability;
- effects of other standards on the fuel economy; and
- the need of the U.S. to conserve energy.

In order to reach the 2020 target, sub targets have to be set, starting from model year 2011. The process for determination of this roadmap is currently ongoing. In 2008, NHTSA proposed revised CAFE standards that substantially increase the minimum fuel economy requirements for passenger cars and light trucks for model year (MY) 2011 through MY 2015. These CAFE proposals used an attribute-based methodology to determine a vehicle's minimum fuel economy standard based on vehicle footprint, which is defined as the area enclosed by the point at which the vehicle's wheels touch the ground (i.e. wheelbase times track width). The footprint attribute is believed by both EPA and NHTSA to be the most appropriate attribute on which to base the standards, as vehicle footprint correlates reasonably well with CO_2 emissions, fuel economy and consumer choice.

The attribute-based CAFE standard uses a mathematical function that provides a unique fuel economy target for each vehicle footprint and is the same across manufacturers. Fuel economy targets were envisioned to be revised upward in subsequent model years to ensure improvement over time (Figure 5 and Figure 6). Separate continuous mathematical functions were established for passenger cars and light trucks, reflecting their different design capabilities. Individual manufacturers would be required to comply with unique fuel economy levels for their car and light truck fleets, based on the distribution of their vehicle production by footprint in each model year. Individual manufacturers would face different required CAFE levels only to the extent that their production distributions differ.

The above-described legislation and procedures have been proposed by NHTSA, but have not been adopted yet.

In the context of his calls for the development of new national policies to prompt sustained domestic and international actions to address the closely intertwined issues of energy independence, energy security and climate change, the current U.S. president requested the NHTSA to issue a final rule adopting CAFE standards for MY2011 only [FR, 2009]. The deferral of action to establish standards for MY2012 and later

> "[…] provides the NHTSA with an opportunity to review its approach to CAFE standard setting, including its methodologies, economic and technological inputs and decision making criteria, so as to ensure that it will produce standards that contribute, to the maximum extent possible within the limits of EPCA/EISA, to meeting the energy and environmental challenges and goals outlined by the U.S. president."[FR, 2009]

In the final ruling a CAFE standard of 27.3 mpg is adopted for all cars and light trucks in MY2011.

[23] 27.5 mpg petrol corresponds to 199 g CO_2/km and 27.5 mpg diesel corresponds to 228 g CO_2/km.
[24] http://www.eia.doe.gov/oiaf/aeo/otheranalysis/aeo_2009analysispapers/cafe.html

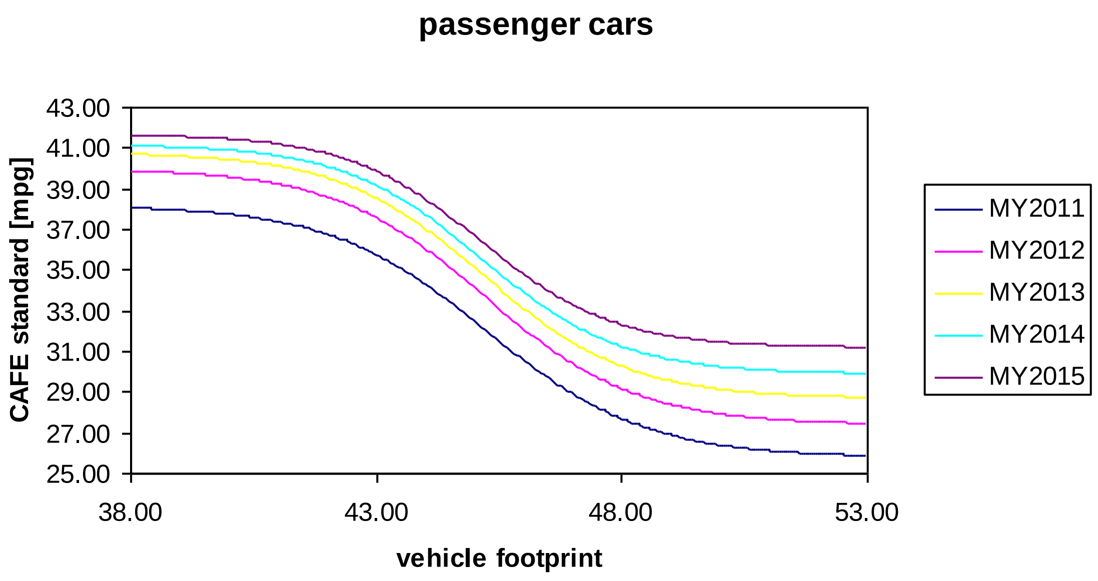


Figure 5 **Proposed CAFE standards for passenger cars for model years 2011 -2015 as a function of vehicle footprint (not yet adopted)**

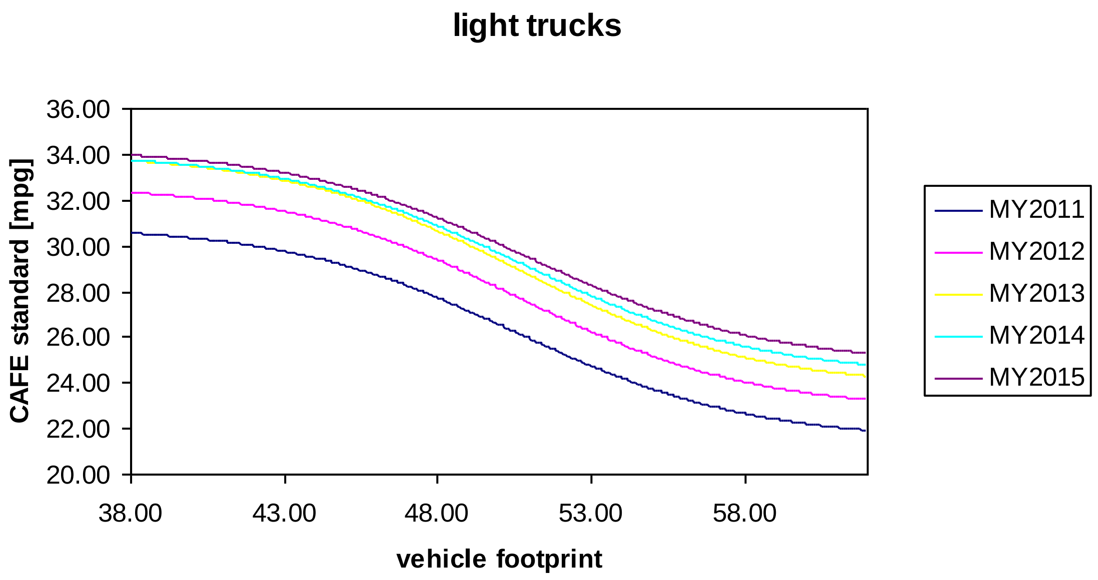


Figure 6 **Proposed CAFE standards for light trucks for model years 2011 -2015 as a function of vehicle footprint (not yet adopted)**

State of California

In California there is, since 2006, legislation with respect to GHG emission reduction from passenger vehicles and light commercial vehicles under Assembly Bill (AB) 32. This bill adds specific global warming legislation to the California Health and Safety Code. This new legislation is officially titled the “California Global Warming Solutions Act of 2006”. Until recently, however, California was not able to enforce this act because no exemption to depart from federal regulations had been granted. Recently, however, California has been granted such waiver under the CAA, because the act will allow California to enforce stricter regulations than required by federal legislation. The goal of the California Global Warming Solutions Act of 2006 is to reduce GHG emissions, state wide, to the level of 1990 by 2020. This limit will remain in effect after 2020 unless it is amended or repealed. The act requires the state board to adopt rules and regulations in an open public process to achieve the maximum technologically feasible and cost-effective greenhouse gas emission reductions, as specified. It allows the state, however, to include in the regulations the use of market-based compliance mechanisms such as an emissions trading system. To date, thirteen states and the District of Columbia, representing 40% of the U.S. light duty vehicle market, have adopted California's GHG emissions standards.

The standards adopted by the California Air Resources Board (CARB) phase in during the 2009 through 2016 model years. When fully phased in, the near term (2009-2012) standards will result in about a 22 percent reduction as compared to the 2002 fleet, and the mid-term (2013-2016) standards will result in about a 30 percent reduction. The specific standards, by vehicle type and model year, are as indicated in Table 3.

Table 3 Standards adopted by the California Air Resources Board (CARB) phasing in during the 2009 through 2016 model years

Tier	Year	CO2-equivalent emission standard (g/mi)	
		PC/LDT1 (Passenger cars and small trucks/SUVs)	LDT2 (Large trucks/SUVs)
Near-term	2009	323	439
	2010	301	420
	2011	267	390
	2012	233	361
Mid-term	2013	227	355
	2014	222	350
	2015	213	341
	2016	205	332

Eventually, a state-wide reduction of GHG emissions from transport is foreseen, such as depicted in the following Figure 7.

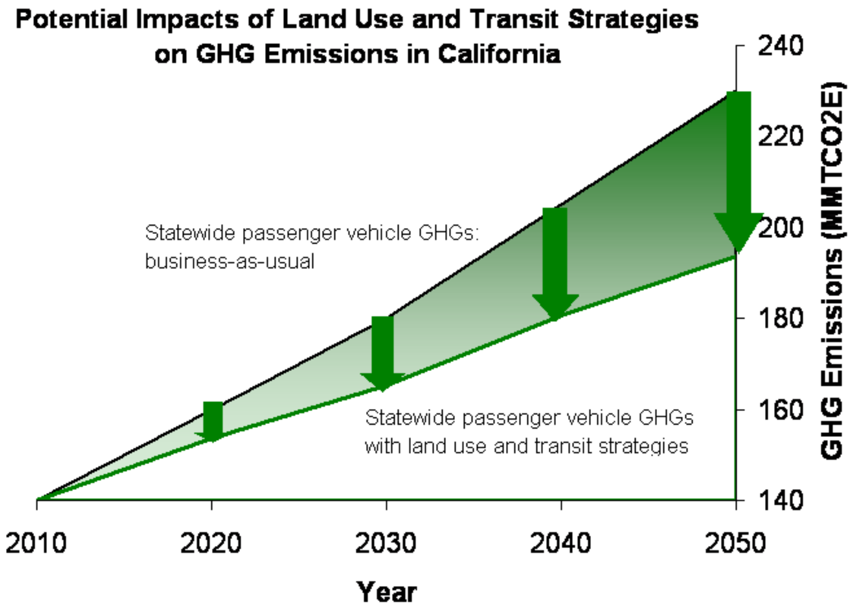


Figure 7 State-wide reduction of GHG emissions from transport in California relative to BAU baseline

Joint rulemaking to establish vehicle GHG emissions and CAFE standards

As will be clear from the above, currently in the United States of America one federal agency is responsible for a standard that focuses on GHG emissions, another federal agency is responsible for a standard that focuses on fuel economy and several state agencies are working on standards that address similar issues. Consistent, harmonized, and streamlined requirements hold out the promise of delivering environmental and energy benefits, cost savings, and administrative efficiencies that might not be available under a less coordinated approach.

Recently, U.S. president Obama has announced a national fuel efficiency policy, which is aimed to be stricter than ever. This policy represents an unprecedented collaboration between DOT, EPA, the world's largest auto manufacturers (the Association of International Automobile Manufacturers and BMW, Chrysler, Daimler, Ford, GM, Honda, Mazda, Toyota and Volkswagen)[25], labour unions, the environmental community, the State of California and other state governments[26]. EPA expects to propose a national CO_2 vehicle emissions standard under section 202(a) of the CAA, whereas NHTSA expects to propose appropriate related CAFE standards under EPCA as amended by EISA. It is intended that this joint rulemaking proposal will reflect a carefully coordinated and harmonised approach to implementing these two statutes.

EPA and NHTSA are currently considering proposing standards that would, if made final, achieve on average 250 g CO_2/mile (155 g CO_2/km) in model year 2016. These standards would be equivalent to a fleet average fuel economy of 35.5 mpg. The standards thus aim to surpass, already in 2016, the CAFE standard of 35 mpg for 2020 as set according to EISA in 2007. These new standards would apply to passenger cars, light-duty trucks, and medium-duty passenger vehicles. The standards would come into effect with the 2012 model year

Both EPA and NHTSA intended to propose attribute-based standards, based on vehicle footprint similar to the proposed CAFE standards of MY2011-2015 that were discussed above. Especially in the next few years, the proposed standards would provide compliance flexibility to manufacturers. This would *inter alia* allow manufacturers the time needed to incorporate technology to achieve GHG reductions and improve fuel economy during the vehicle currently scheduled redesign process. Proposed provisions to ensure such flexibility include:

- Credit carry-back, credit carry-forward, credit transfers and credit trading;
- Credits for reducing GHG emissions related to air conditioning system improvements;
- Flex-fuel and alternative fuel vehicle credits;
- Temporary lead-time allowance alternative standards for manufacturers with total U.S. vehicle sales below a specified cut-off (e.g. for manufacturers with U.S. sales below 400,000 vehicles a less stringent target corresponding to 125% of the vehicle's otherwise applicable foot-print target level could apply);
- Early credits for achieving emissions reduction in the 2009-2011 model years, based on a national level established by EPA equivalent to those of the California standards;
- Early credits for over-complying with CAFE in 2009-2011 model years for vehicles sold in states outside of California and its legislatively affiliated states (CAA section 177 states), without the use of FFV credits;
- Additional credits for electric vehicles and plug-in hybrids (e.g. in the form of multipliers such that these vehicles would count as more than one vehicle in the manufacturer's fleet average);
- Possible credits for employing technologies that achieve GHG reductions that are not reflected on current test procedures.

[25] http://www.epa.gov/otaq/climate/regulations.htm
[26] http://www.whitehouse.gov/the_press_office/President-Obama-Announces-National-Fuel-Efficiency-Policy/

3.3 Options for designing CO_2 regulation for vehicles

3.3.1 Methodology for designing and evaluating alternative options

A first evaluation of different options for the EU cars and CO_2 legislation was made in [IEEP/TNO/CAIR 2004]. A more systematic and detailed analysis of different options has been worked out in [IEEP/CE/TNO 2007]. The methodological framework developed in that study is also relevant for designing and assessing long-term options for CO_2 regulation of vehicles, and is therefore summarized below. Although the methodology was primarily set up as guidance for designing the CO_2 regulation for passenger cars and vans, most elements will be relevant also for defining a regulatory approach for HD road vehicles and even for vehicles in other modes.

In [IEEP/CE/TNO 2007] a wide range of options was generated on the basis of identifying feasible combinations of the following components of the regulation:

- Obligated or responsible legal entity:
    - options: trade associations; manufacturers or manufacturer groups; importers, distributors and dealers; and Member States
- Target focus
    - options for level of obligation: e.g. at Member State or EU level
    - options for nature of obligation: e.g. model/variant or group average target
- Target type:
    - options: single target (s), sloped line or other utility-based targets, other options
    - note: single target(s) also include systems where different fixed targets are assigned to different vehicle classes or categories as well as systems based on "bins" where different minimum shares of the fleet / sales have to meet different levels of fixed targets. The latter can be an intermediate option between a single target and a sloped line or utility-based target.
- Instrument/sanction:
    - options:
        - exclusion of non-compliant models / manufacturers from the market
        - fines or feebates (a system of fines with rebates to punish the worst performing cars and reward the best), possibly combined with various options of trading (e.g. among manufacturers, or with ETS credits)
- Choice of a utility function (in case of sloped line or other utility-based targets):
    - options for utility parameters: most considered options are vehicle mass, pan area (vehicle l x w), and footprint (track width x wheel base), but other options (incl. combined parameters) are conceivable;
    - options for type of utility-based limit function: e.g. linear, linear with flat shoulders for small and/or large cars, non-linear functions.

Alternative legislative options can be designed by combining different options for the above components. These legislative options can be evaluated and compared on the basis of a set of criteria possibly including the following:

- Cost-effectiveness;
- Average compliance cost per car: additional manufacturing or purchase costs or based on total cost of ownership (incl. fuel cost savings);
- Average compliance costs for small cars: For the analysis of options for the EU legislation for 2015 it was considered that cost impacts on small cars should remain limited;
- Certainty of meeting the overall target (e.g. set at level of EU sales average): whatever system is applied, there will be questions about the sanctions and the degree of compliance that results. However, even in the case of full compliance, some systems give much greater inherent certainty that the overall target will be met than others;
- Technology neutrality, incl. appropriately dealing with new propulsion technologies and alternative energy carriers;
- Possibilities for gaming;

- Perverse incentives, i.e. incentives for action by manufacturers that help them to meet their specific target more easily but that do not effectively contribute to meeting the overall target or to reducing real-world CO_2 emissions;
- Practicability: difficulty or complexity for implementation and operation of the system or of components of it;
- 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';
- Accommodation of new player/mergers: some systems, e.g. those that imply 'grandfathered' rights, are more difficult to apply to new entrants who have no history upon which to base their allocations;
- Distributional impacts: Even distribution of burden over manufacturers: compares distribution of compliance costs as well as distributional effects of fines and rebates between manufacturers/groups;
- Fairness to early movers: ability to reward early movers (who have already improved their fuel efficiency) relative to those (laggards) who have not;
    - This criterion was very relevant for the first regulation (130 g/km in 2015), but will be less of an issue for future targets as it may not be expected that manufacturers will significantly overachieve in meeting the 2015 target;
- Polluter pays principle: from a societal/moral point of view the system is 'fair' when owners or makers of large or high CO_2 emitting cars pay more for the efforts made by the obligated entity towards meeting the target;
- Market distortion (e.g. through exclusion of models);
- 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);
- Comprehensibility of the option: other things being equal, it is desirable that options be easy to comprehend and to communicate.

Which of the above criteria are considered relevant and applicable is to a large extent a political issue. Besides that obviously every methodology for defining targets should be evaluated with respect to technically feasibility and the availability of correct and sufficient data.

Whereas the focus for the 2012 legislation is on making conventional cars more fuel efficient, for the longer term regulatory options the way they deal with alternative technologies will also be a crucial additional criterion.

3.3.2 Considerations on utility-based CO_2 limits

[IEEP/CE/TNO 2007] and earlier analyses 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 legal instrument for regulating CO_2 emissions of passenger cars. A range of criteria can be used to compare and select suitable options, including in particular the following:

- Good measure of 'utility' (i.e. 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 (i.e. incentive to 'gaming') should be minimised;
- Adverse effects (e.g. 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.

For assessing the appropriateness of a utility parameter U for the purpose of setting CO_2 limit functions furthermore the following aspects are of importance:

- Arguments relating to a static situation (i.e. 'snapshot'):

- There should be some level of correlation between U and CO_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 (a U + b) determines to a large extent the distributional effects, i.e. 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_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_2 emissions at a given point against any particular measure of utility indicates that there is a spread of CO_2 intensity for the characteristic, and therefore significant potential for improvement simply by bringing the majority up to the level 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.
    - For any utility parameter the room for gaming can be reduced by appropriate selection of the slope of the limit function (see analyses in [IEEP/CE/TNO 2007] and [CE/TNO/Öko/AEA 2008];
  - 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.

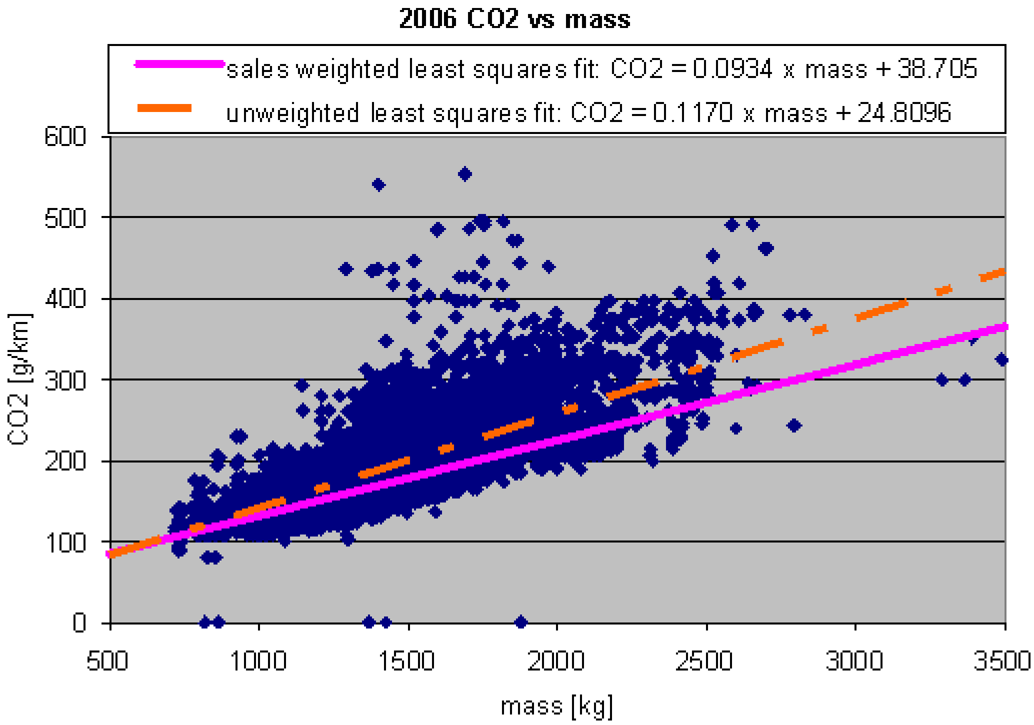
Although complex functions and composite parameters should not be excluded in principle on technical grounds, in defining the present EU cars and CO_2 legislation the general preference was to avoid these for two main reasons:

- 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.

At the same time the plot of vehicle CO_2 emissions against kerb weight, as shown in Figure 8, does not indicate a significant non-linearity in the general trend between CO_2 and mass.

As stated above, in order for a utility parameter U to be a suitable basis for differentiating CO_2 limits there needs to be a sufficient but not too perfect level of correlation between CO_2 and U. The regression line in Figure 8 illustrates that from this point of view mass is at first sight a suitable choice. That is, it shows a reasonably close correlation to CO_2 emissions, but also has a R^2 value significantly deviating from 1, i.e. there is a significant 'bandwidth' which suggests that there is room for improvement in relation to this parameter. The graph also exhibits a significant number of 'outlier' models (zero values are electric vehicles) towards the top or right-hand side of the cloud. These are not necessary very inefficient vehicles, but also indicate that each given value of mass may include a wide range of not necessarily comparable vehicle models (e.g. sedans and sports cars).

Figure 8 CO_2 emission of vehicles as function of vehicle mass (kerb weight)



Graph taken from [IEEP/CE/TNO 2007], based on the complete database of vehicles sold on the market in Europe in 2006 (AAA data for EU-14)

An alternative utility parameter for the medium term

For the assessments carried out in support of defining the EU cars and CO_2 legislation vehicle mass and pan area were included in the analysis. Footprint had to be excluded due to a lack of available data, although footprint was considered potentially superior to either mass and pan area. For the remaining two options results from the various analyses supported a slight preference for using mass. The final choice by the Commission for using mass as utility parameter was further motivated by the large stakeholder acceptance for these options.

An indicative analysis of the possible benefits of using footprint is presented in [IEEP/CE/TNO 2008][27]. This study comes to the following conclusions on the comparison of the three options:

Analysis in [IEEP/CE/TNO 2008], on the basis of combining different data sources to complement missing footprint data in the standard sales database, shows that there is a very close relationship between footprint and pan area for all cars. The unweighted least squares fit between the two parameters for all cars sold in 2006 gives an R^2 value of 0.91. Most of the values fall very close to the regression line. For reasons of simple geometry, however, some larger vehicles tend to have ratios that fall above the line, while small vehicles in particular tend to fall slightly below. That is, large vehicles have better possibilities to have a very long wheelbase relative to overall vehicle length, but for small vehicles such options are constrained by the wheel radius.

[27] Study carried out by IEEP, CE Delft and TNO for Transport & Environment

Table 4 Summary of the results of a qualitative assessment of utility parameters (from [IEEP/CE/TNO 2008])

Criterion	U=Weight-based	U=area-based	
		Pan area	Footprint
Good measure of utility	Proxy for other measures of utility, e.g. vehicle size, special features, but not generally seen as a virtue in itself[28]	Reasonable proxy for vehicle size	Good proxy for vehicle cabin size (excluding height, but an unnecessarily high cabin is undesirable anyway)
Continuously variable	Yes	Yes	Yes
Available	Yes – reported in Monitoring Mechanism	Yes – available but not reported	Not available up until now – required to be reported in Monitoring Mechanism under proposed Regulation
Understandable	Yes – very	Yes	Yes – fairly
Perverse effects/ gaming	Yes	Yes to an extent – e.g. deeper bumpers	Limited
Adverse effects	Yes – safety	No	No – safer
Not excluding options	Could exclude weight-reduction measures to reduce CO_2. Tends to favour heavier options eg diesels, hybrids and to penalize e.g. engine downsizing if this also leads to weight reduction.	Not greatly – it does reduce the incentive for reducing the width of the car, but it is generally difficult to do this without sacrificing utility in the form of cabin space and possibly road holding.	Not greatly – it does reduce the incentive for reducing the width of the car or its wheelbase, but it is generally difficult to do this without sacrificing utility in the form of cabin space, driveability or comfort.
Distributional impacts	Appears ‘fair’ and quite similar to pan area[29]	Appears ‘fair’ and quite similar to weight[30]	Not yet known – probably similar to pan area

Figure 9 illustrates the scatter of CO_2 emissions against footprint for all 2006 sales models and variants. As with mass and pan area, this illustrates a significant scatter of both footprint values and CO_2 emissions across the fleet. Not surprisingly given the close fit to pan area, the scatter pattern is quite similar for these two variables. As a consequence it may be expected that distribution impacts (burden for individual manufacturers) will also be similar for footprint and pan area.

[28] Indeed, in car reviews weight is often portrayed as a negative feature; but strictly speaking this is likely to refer to a perception of being ‘heavy’ caused by poor handling or acceleration characteristics. A heavy car can in fact be very driveable provided it has a commensurate level of power and suitable suspension and steering gear, and most luxury cars are relatively heavy.

[29] Note 9 of [IEEP/CE/TNO 2007] entitled “Quantitative analysis of various options with updated model” 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.

[30] Note 9 of [IEEP/CE/TNO 2007] entitled “Quantitative analysis of various options with updated model” 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.

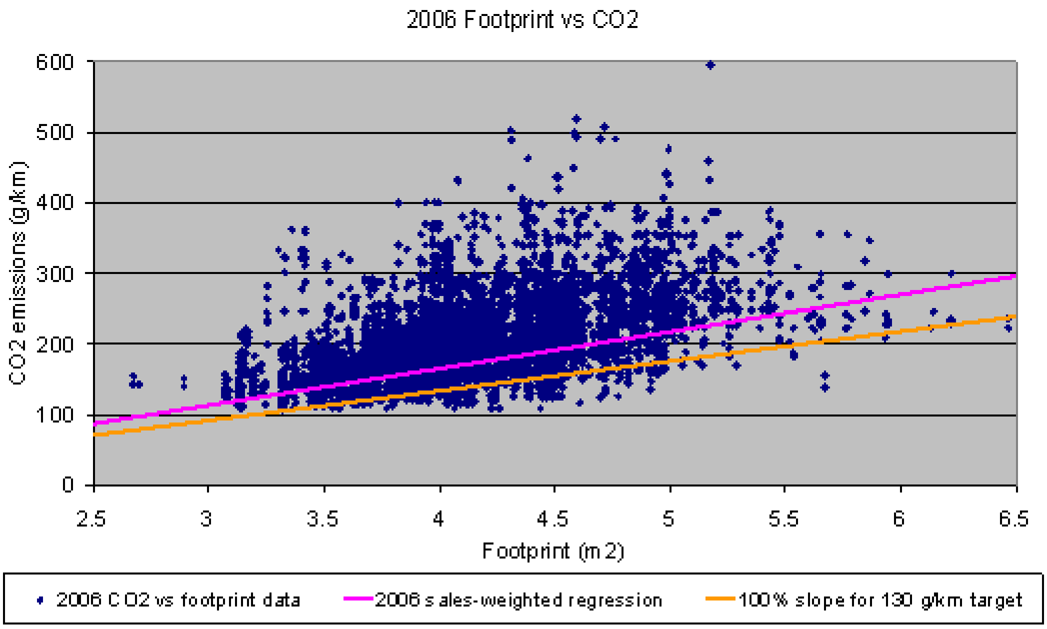


Figure 9 Footprint vs CO_2 emissions for all 2006 model variants (from [IEEP/CE/TNO 2008])

In summary, there appear to be a number of possible benefits of using footprint rather than weight as a utility parameter, as follows:

- Footprint is a good measure of the 'space' available in the vehicle cabin;
- It appears to limit the possibilities of manipulation or 'gaming' of vehicle characteristics to increase the CO_2 allowance for a particular vehicle;
- It fully rewards and does not penalise efforts towards weight reduction;
- Insofar as US evidence is applicable to Europe, this seemed to suggest that footprint was associated with improved safety, whereas weight *per se* was associated with an increase in fatalities.

In short [IEEP/CE/TNO 2008] concludes that there may be several clear benefits to using footprint as a utility parameter, and no obvious downsides once the data are available. ACEA has pointed out that footprint may also have certain disadvantages:

- A footprint based system would give the same CO_2 target to a car with or without safety features. Footprint thus punishes the installation of safety features;
- A footprint based system would restrict the vehicle design freedom and the high diversity of product portfolios;
- A footprint based system would punish front driven vehicles (particularly front driven vehicle designs tend to have a longer front end overhang compared to rear driven vehicles)

The EU Regulation No 443/2009 includes provisions for amending the Monitoring Mechanism to also include the collection of footprint data. This will resolve the data availability problem. The assessments to be carried in support of further detailing the modalities for the 95 g/km, set for 2020, are expected to include footprint as a candidate utility parameter.

Utility parameters for the long term

Continuous parameters like mass, pan area and footprint fulfil many of the criteria discussed above to a lesser or larger extent and were preferred over other options in the political context in which the present legislation was designed. They should however be considered as mere proxies for the utility of a vehicle, reflecting to a large extent the perceived usefulness of a vehicle (incl. aspects of comfort and luxury) rather than the true transport functionality (transport capacity). In view of the ambitious reduction levels that may need to be achieved in the long term more practical utility parameters such as number of seats and trunk space may need to be reconsidered and re-evaluated. What will be needed for applying these is a robust way of handling such parameters and means of combining them into an overall measure of utility.

3.4 Options for regulating CO_2 emissions from HD vehicles

3.4.1 Introduction

Due to the significant share of fuel costs in the vehicle operating costs, improving fuel efficiency of heavy-duty vehicles already has a high priority in customer demands and in the R&D efforts of manufacturers. Fuel efficiency of heavy-duty vehicles has improved on average about 1% per year between 1970 and 2005[31]. Nevertheless there appear to be effective technical CO_2 reduction measures that require promotion to be further developed and adopted (see also the paper on "Technical options for fossil fuel based road transport").

For the coming years establishing appropriate means for promoting energy efficiency improvement and CO_2 reduction in heavy duty vehicles (trucks and buses) is an important objective of the European Commission. In view of the projected large growth of freight transport up to 2050 and the overall GHG emissions reductions required for that time horizon, reducing CO_2 emissions from truck will have to become an important part of the long term EU policy on GHG emissions from transport.

From a technical point of view regulating GHG emissions from HD vehicles is a more difficult challenge than has been the case for LD vehicles for the following reasons:

- The type approval test for emissions in case of HD vehicles is an engine test carried out on an engine test bed. This test can be used to regulate the engine efficiency, but the potential for further improvements in engine efficiency is limited in case of HD vehicles. Furthermore the impact at the vehicle level depends on many other factors including the installed engine power in relation to vehicle mass and the entire vehicle configuration. Possible benefits from using advanced powertrains (e.g. hybrids), transmissions, etcetera can not be captured on the present TA test;
- Whole-vehicle type approval for HD vehicles is difficult first of all because it requires the use of HD chassis dynamometers, of which only a few are presently available in Europe. Also the maximum power and simulated mass of such facilities is generally too small for testing vehicles in the heavier segments of the market.
- Secondly the whole vehicle CO_2 emissions depend on the entire vehicle configuration. A large part of the market consists of so-called chassis-cab combinations or multi-stage vehicles. Multi-stage vehicles are vehicles that are sold and leave the factory as chassis-cabin combinations. These vehicles receive a dedicated build-up after the vehicles are sold by the OEM to customers, built to customer specifications by “final stage” manufacturers. Chassis with powertrain but without cabin are also sold by OEMs to bus manufacturers, who may sell the completed vehicles under their own brand names. A whole vehicle TA test carried out on a chassis-cab combination does not yield meaningful results for the completed vehicle. The huge number of different vehicle configurations based on multistage vehicles and the generally small size of the “final stage” manufacturers make it difficult to require complex and expensive CO_2 emission tests to be carried out on the complete vehicles.
- A further complication is the large variety in specific mission profiles that exist for this category of vehicles.

3.4.2 Technical possibilities for CO_2 reduction in heavy duty transport

Technical measures to reduce fuel or energy consumption of a vehicle can be split in two categories:

- Making the engine and drive-train more efficient by:
    - optimisation of the engine efficiency by, amongst others, down-scaling and exhaust energy recovery.
    - improvement of the transmission such as an optimised automatic gearbox.

[31] Source: ACEA

   - hybrid elements such as idle shut-down (avoiding idling of the engine), break energy recovery systems, and acceleration assistance.
- Reducing the need for mechanical (drive) energy by:
   - mass reduction
   - reduction of tractive resistance
   - reduction of rolling resistance
   - reduction of air resistance.

Regulation for HD vehicles should preferably promote innovations on all these aspects. This not only involves truck manufacturers but also manufacturers of trailers and vehicle build-ups. In addition a wide range or operational and logistical measures may reduce CO_2 emissions from transport, but these are generally not influenced directly by regulatory instruments, which are the subject of this paper.

At the moment the heavy duty fleet largely consists of Euro III, IV and V vehicles. In the year 2020 the fleet will predominantly consist of newer Euro V vehicles and Euro VI conform vehicles (expected to be introduced in 2014). Especially in long distance transportation, Euro VI compliant vehicles will probably dominate the fleet 2020. With the introduction of Euro VI another significant step in engine efficiency is not to be expected. Quite likely, EGR and SCR will have to be combined in order to comply with the NO_x emission limit in Euro VI. On top of that a closed soot filter will have to be mounted in order to comply with the particulate emission demands. The weight of the vehicles is likely to come down in the coming years, particularly by replacement of the existing trailer fleet. On top of that there will be advancements in the field of rolling resistance and tyres, where the use of super singles can reduce rolling resistance. This type of tyre has only a very modest market share up to now for several reasons. Also due to the increased awareness and the development of regulation for tyres and rolling resistance, a substantial increase in the coming years can be expected. Developments beyond 2020 are difficult to predict, although it is clear that improving fuel efficiency is a key driver in the HD market and this may be expected to be further strengthened in the longer term future by increasing oil prices or increased price volatility.

3.4.3 Test methods for regulation of CO_2 emissions from HD vehicles

An important aspect of regulating CO_2 emissions from HD vehicles is that for each type of heavy goods vehicle the CO_2 emissions must be determined in such a way that they are representative of real world practise. For that reason it is desirable to include the following aspects in the test method:
- Efficiency of the engine;
- Efficiency of the drive train;
- Air resistance;
- Vehicle mass;
- Dynamic behaviour, described by a (set of) test cycle(s) representative for the (range in) mission profile(s).

Apart from this, also rolling resistance will be an important parameter influencing CO_2 emissions. The rolling resistance is largely determined by the type of tyres, and these will be changed several times in the lifetime of the truck. Thus, the rolling resistance of the truck can substantially vary over the course of its lifetime. It would be better to regulate rolling resistance of tyres separately.

Defining a suitable test procedure is also relevant for labelling (either in g/km or in g/tonkm), which is alternative policy instrument for promoting fuel efficiency suggested by ACEA.

Dependent on ambition level and the number of parameters that should be incorporated, the following options can be chosen:
1. Engine test
2. Vehicle simulation model in combination with engine tests:
   - in a comparable manner as used in the Japanese Top Runner system.
   - simulating engine loads representative for use in specific vehicles / applications, e.g. in a hardware in the loop simulation environment.

3. Measurements on transient chassis dynamometer or a power train test stand.
4. Measurements on a test track.
5. Measurements in the field (on or off a fixed trajectory).

In Table 5 an overview of the most important advantages and disadvantages of the various options. In the following paragraphs a more detailed explanation will be given. All options may use a single standardized test cycle, but preferably a set of test cycles should be used to cover the range in mission profiles for different classes of HD vehicles. Different vehicle types could then be tested / assessed on different drive cycles representative for their typical usage profile.

Table 5 ***Overview of possible test methods for standardizing CO_2 emissions of heavy goods vehicles with advantages and disadvantages***

#	Option	Advantage	Disadvantage
1	Engine test bench	– Matches with present emission tests – Moderate costs	– Not representative for all aspects that determine the CO_2 emission
2	Vehicle simulation model + engine test bench	– Low costs if the model can be kept simple – Possibility to use different standardised test cycles for different vehicle types – Fairly representative if the model is OK	– Usefulness depends on availability of correct parameters – Complex in the case of a vehicle with hybrid powertrain – Transient behaviour of engine are tested to some extent only – Confidentiality of data
3	Transient chassis dynamometer/ power train test bench	– Possibility to use different standardised test cycles for different vehicle types – Representative	– High costs – Limited capacity in Europe – Air drag must be determined separately
4	Measurements on test track	– Representative – Matches the present research with PHEMS	– High costs
5	Measurements in practise	– Representative	– Reproducibility is a problem – Need for a fixed trajectory

Measurements on the engine test bench (option 1)

The development and also type approval tests of heavy goods vehicle engines are done on an engine test bed. The engine is thus tested and formally approved (according to some Euro class) separate from the vehicle in which it will be mounted.

The type approval tests comprise formally the assessment of HC, CO, NO_x, and particulate matter (PM_{10}), although in practise also CO_2 is being measured. The fuel consumption is monitored gravimetrically, but could as well be determined based on CO_2 emissions. This calculation is then done based on the atomic mass of carbon, the amount of carbon in the fuel and the density of the fuel.

The measurements are being done in two test cycles: the European Steady State Cycle (ESC) and the European Transient cycle (ETC):

- During the European Steady State Cycle (ESC) 13 revolution-power load combinations are measured and are thus not based on a real driving cycle. The cycle is not truly representative for CO_2 emissions in practise, because the area where the points are located does not cover the complete practical use. Apart from that, also transient behaviour (how the engine reacts during changes of power load) of the engine is not incorporated.
- The European Transient Cycle is based on recorded real-world driving profiles cycles, whereby a more or less representative test cycle is composed of load patterns for urban (1/3 of the total), rural (1/3 of the total) and motorway driving (the remaining 1/3).

In connection with the introduction of Euro VI for heavy-duty vehicles the UN/ECE WHDC procedure will be the basis for engine certification. In this context ACEA has pointed out that it may be far easier to find acceptable standardized test procedures for components such as tyres and for engine systems than for complete heavy-duty vehicles.

Unfortunately tests like these are not suited for direct determination of representative fuel consumption in practise. This is caused by the fuel consumption solely being determined by engine efficiency and further because the loading of the engine is relatively high in these cycles. The efficiency of the rest of the drive train, but also of the rolling resistance as well as air drag are not included.

Vehicle simulation model in combination with engine test bench (option 2)

Using a vehicle simulation model (including a model of the engine + drive train, based on a measured engine map) the fuel consumption and the CO_2 emission over one or several (dynamic) test cycles can be calculated. Prerequisite is that the engine characteristics of the CO_2 emission and or fuel consumption are available. The model calculates how much time the motor spends in which part of the load-emission space en determines the corresponding CO_2 emission. An example of this approach is the Japanese Toprunner system for HD vehicles.

The simulation model typically incorporates the following parameters:

- Vehicle weight
- Air drag of the vehicle
- Rolling resistance of the tyres
- Gearing ratios of the gear box
- Possible friction losses and inertia in the drive train
- Possible losses in auxiliary aggregates such as the dynamo, compressor and steering pump
- CO_2 emission and fuel consumption maps in the revolution-torque characteristic field of the engine.

In a practical approach of the test method, a number of fixed default or standardised parameters could be defined, e.g. for air drag or rolling resistance. This limits the amount of work to be put into the evaluation. If a manufacturer can show that his product scores better than the standard values, then the real values can still be put into the model.

The simulation model will become (much) more complex in case also complex drive trains, such as automatic gear boxes or hybrid drive trains have to be taken into account. In that case the specific characteristics of the components and control strategies of the whole have to be programmed, which can be a lot of additional work. For example to simulate a complete hybrid drive train correctly, the physical control computer of the hybrid drive train can be coupled to the model by a “hardware in the loop” set-up (HIL). Also this requires considerable effort, and makes it necessary to define the HIL set-up including connectors, signals and so on.

An important requisite for successful implementation of a regulation based on vehicle simulation models is that the manufacturers accept the model including the additional modules that are required for automatic gear boxes and hybrid drive trains. This approach is most likely to be successful if it gets a European status that has been defined in legislation.

An advantage of this test method is the relatively low costs per vehicle in case a conventional vehicle is being considered. With a hybrid vehicle the costs of the test will initially be high per manufacturer, but will are likely to come down once more types are being ‘standardized’. With regard to representation of the method it can be said that the dynamic behaviour of the engine and the drive train probably can’t be simulated completely correct, even if a dynamic driving cycle is taken as starting point. The degree to which a certain vehicle type is advanced will influence this.

In the US an evaluation is currently ongoing regarding different options to improve fuel efficiency of heavy-duty vehicles. This study is performed by NAS (National Academy of Science) and included in the study is an evaluation of the feasibility of using computer simulation of complete heavy-duty vehicles. The party involved in this study is Argonne National Laboratory[32].

Measurements on a dynamometer or on a test track (option 3 and 4)

The measurements on a dynamometer (chassis dynamometer or powertrain test bed) and on a test track have been taken together in this description because they are in principle not very different. For both it applies that a test is being performed with a complete vehicle over the same (dynamic) test cycle (or cycles).

For dynamometer as well as test track it is probably best to measure CO_2 emission directly, given that measurement of fuel consumption based on volume or mass is generally less reliable for a short test cycle (say 30 to 60 minutes). For measurements on the road or on a test track, so-called Portable Emission Measuring Systems (PEMS) are available. Such systems can accurately measure CO_2 emissions.

Some points of attention for dynamometer measurements:
- The vehicle mass that has to be set, is usually limited to 20 tons.
- The air drag and rolling resistance of the vehicle must be programmed. These have to be separately determined (coast down test) and accepted. A good option in case of rolling resistance is the use of a standard default values.
- Availability of dynamometers on which these tests can be performed is limited (4 facilities in Europe)

A point of attention for measurement on a test track is that the environmental circumstances such as wind speed, pressure, temperature and humidity, which will influence the measurement. A manufacturer might intentionally pick favourable test conditions to obtain desirable test results. It may be considered whether correction factor for such favourable conditions could be developed.

The major advantage of tests with complete vehicles is that for each type of truck (conventional, automatic, hybrid, electric) the same test method can be used. The disadvantage may be that reproducibility of the test method may be worse than the measurement of the engine on a test bed (option 1) or a vehicle model (option 2), especially with a measurement on a test track where the environmental circumstances are very variable.

It should be noted that for hybrid vehicles the methods to determine the fuel consumption correctly are still in development. Determining the true fuel consumption of a hybrid vehicle is complex because part of the work is done by the electric engine, and the charging status of the batteries at the beginning and end of the test run must be taken into account. This way the measured CO_2 emissions are not only strongly dependent on the driving cycle, but also on the condition of the battery pack at the beginning of the test. These issues, however, have been dealt with in the existing test procedures for hybrid LD vehicles, so developments for HD vehicles can build on that.

It is noted that under the SmartWay test protocol of the American Environmental Protection Agency also measurements on dynamometer as well as on a test track are allowed.

Measurements in practical use (option 5)

With measurements in practical use, the determination of fuel consumption and or CO_2 is being considered, where the vehicle to be tested takes part in normal road traffic. It would be best to opt for a standardised route with a combination of city, rural and motorway use. In order to obtain a reasonable accuracy, the route should be long (e.g. 500 km) so that incidental traffic differences are smoothed evenly. It is also possible to drive a smaller route a couple of times.

The major advantage of this method is the representation because the vehicles take part in real traffic. A disadvantage is the reduced reproducibility and comparability of several test locations (in case an approach with several test locations is opted for).

[32] Source: ACEA

Comparison of test methods for CO_2 emissions of HD vehicles

In Table 6 an overview of several test approaches to determine fuel consumption and the CO_2 emissions is given. In it the various options are judged on the following aspects:

- Reproducibility
- Representation of reality
- Availability
- Expected costs

Table 6 Overview of various test methods (++ = good; + = fair; 0 = mediocre; - = bad)

	reproducibility	representation	availability	costs
Engine test bench	++	-	+	++[1]
Vehicle model + engine test bench	++	+ / 0	+	+ / 0
Dynamometer / power train test bench	+	++ / +	-[2]	+ / 0
Test track	0	++	+	+
Practise test	-	++	+	+ / 0

[1] In case engine test can be done directly following the present emission measurements
[2] Capacity in Europe is limited at this time

For all options another key prerequisite is the existence of a well defined party responsible for compliance. This is at present not well arranged in the EU.

Based on above options the following test methods are considered viable and useful for regulating the CO_2 emissions of HD road vehicles:

- Engine test bench in combination with modelling to determine a representative fuel consumption (option 2);
- Dynamometer and/or test bench measurements on a complete vehicle. Here, identically to the EPA protocol, both options may be approved, but opting for one of the two is also possible (options 3 and 4).

It should be noted that the combination of engine tests and modelling matches the present legislation best (the legislation being based on bench tests completely). However, the application of models for the same means is relatively new.

In a general sense, it is possible within a certain regulatory structure that several options can be allowed in parallel. For conventional vehicles it could be possible for example, to opt for modelling or for a dynamometer or test track measurement, whereas for more advanced vehicles having hybrid or electric propulsion a dynamometer or test track measurement would be compulsory. That way the costs can possibly be limited. For each option procedures and references must be developed, so that the use of various options leads to comparable results.

Upon the introduction of the method it must also be determined who can make the calculations and or the tests. These might be done by:

- An independent institute
- The manufacturer in cooperation with the type approval bodies.

Confidentiality of the relevant data can be problem in some of the possible measurement / modelling methods.

The issue of test methods requires more research before regulation of CO_2 emissions from HD vehicles can be developed.

3.4.4 Options for regulation of CO_2 emissions from HD vehicles

Available options for regulating CO_2 emissions from HD vehicles strongly depend on the type of test procedure that can be used and vice versa. Furthermore the options are determined, as explained above in section 3.3, by the viable combinations of obligated or responsible legal entity, target focus, target type, instrument/sanction, and possible choice of a utility function.

The following are some possible alternatives:
- an engine efficiency target or limit value, applied per engine or on the sales average per manufacturer;
- a powertrain efficiency target or limit value, based on measurements on a powertrain test bed with simulated load for one or more vehicle configurations, applied per powertrain or on the sales average per manufacturer;
- a whole vehicle CO_2 emission target or limit value based on simulating engines / power trains in default vehicle configurations, applied per engine / powertrain or on the sales average per manufacturer;
- a whole vehicle CO_2 emission target or limit value based on whole vehicle testing on a dynamometer or test track for a limited number of standardised vehicle configurations, applied per vehicle model / type or on the sales average per manufacturer;
- regulation for vehicle components (e.g. tyres or trailers) or for specific aspects (e.g. aerodynamics).

Targets or limit values applied per engine, powertrain or vehicle may be differentiated according to class of application.

For regulation applied at the level of the sales average per manufacturer it will be necessary to adequately deal with the different model spectrums and sales distributions of different manufacturers. This may be done by means of a utility-based limit functions (e.g. payload in case of HD vehicles) or e.g. by normalising all CO_2 measurement results in gCO_2/tonkm on the basis of assumed default payload values per vehicle, differentiated according to vehicle category.

All of the above options only capture and promote improvements in engine and powertrain efficiency. To capture improvements with respect to the complete vehicles (e.g. weight reduction or aerodynamics of cab or trailer) one may need to consider separate regulations for vehicle build-ups, trailers or components. These could also include mandatory application of certain devices and technologies (e.g. wind deflectors to improve vehicle aerodynamics). To what extent such options can be promoted by means of quantitative performance targets and standards (and associated test procedures) will need to be studied in the coming years. For tyre rolling resistance standards and associated test procedures and limit values are already being prepared. The following options may also be potential candidates for some kind of performance regulation:
- air drag of trailers
- air drag of cabins
- energy consumption of auxiliaries
- payload to weight ratio of vehicle build-up and trailers
- payload to weight ratio of whole vehicle

Especially for reduction options related to vehicle mass and aerodynamics the EU and national regulation on weight and dimensions of HD vehicles may need to be reviewed and revised to allow promising options that under the present regulation may go at the expense of allowed payload (weight or volume).

3.4.5 Long term issues with respect to regulating CO_2 emissions from HD vehicles

In the long run also in HD vehicles a transition towards the use of renewable energy carriers will have to be made. In view of that the same issues with respect to suitable metric and targets at the level of vehicle (TTW) and energy carrier (WTT) become relevant.

3.5 Issues for future regulation of CO_2 emissions from road vehicles

3.5.1 Relation between type approval and real-world

A proper relation between (trends in) emissions measured on the type approval test and (trends in) real world emissions requires among other things appropriate test procedures (including the driving cycle and test conditions). This is relevant for CO_2 legislation but also for e.g. labelling schemes and CO_2 differentiation of taxes, as these build on type approval CO_2 data.

Representative driving cycle

An important point to be solved for future CO_2 legislation for cars is the issue of the increasingly poor correlation between emission and fuel consumption values measured on the Type Approval test and values realised under real-world driving conditions. This discrepancy has already been identified for exhaust gas emissions, but may be expected to start playing a role also – or even more – for the case of CO_2 emissions and fuel consumption. In this case not only the issue of meeting policy targets is at stake, but also whether vehicles deliver to consumers the fuel cost savings promised by favourable type approval test figures used in advertising.

The present test cycle is not representative of average driving in the EU. It insufficiently covers the various driving modes encountered (urban / rural / highway and various levels of dynamics in driving on these road types), and tends to favour technologies that improve part load efficiency under urban driving conditions. In order to promote application of technologies that deliver the best CO_2 reduction in real-world driving a more representative test procedure is needed. The test cycles for HD vehicles and motorcycles have already been modernised and are based on speed-time patterns recorded in real-world driving. The test procedure for LD vehicles is clearly lagging behind in this respect.

Already in the MATADOR project, it was shown that different propulsion technologies perform differently on different driving cycles and that generally fuel consumptions and emissions under real-world driving conditions deviate significantly from values measures on the type approval test. Also in a comparison of energy efficiency of different technologies (or different configurations of the same technology) the relative performance may be different under different driving conditions. In the case of hybrids, e.g. fuel consumption benefits are large in urban driving and stop-and-go driving occurring under heavy congestion, but are limited to none under free-flow highway driving conditions.

Type approval test procedures as they are now, especially with the not very representative NEDC cycle, could lead to the development of vehicles that have low CO_2 emissions on the TA test but that do not deliver the same reductions in real-world driving. If this happens, the average reductions of sales average TA CO_2 emissions as measured in the Monitoring Mechanism will not be reflected to the same extent in measurements of real-world fuel consumption (on the rollerbench using a real-world driving cycle, or for the fleet as a whole based on total fuel sales and total mileage).

Recently, in UN-ECE (GRPE) work has started to develop a new light-duty vehicle test procedure (WLTP, with the focus on developing a representative and world-harmonised driving cycle). This development will have impacts on the type approval and real-world emissions of air pollutants as envisaged by the Euro 5/6 legislation[33]. As the progress of this development under UN-ECE may be insufficient for the new cycle to be used in relation to defining the 95 gCO_2/km target for 2020, the European Commission is considering initiating a separate project to develop a new test cycle and amendments to other aspects of the type approval test procedure in the coming years. This new procedure should contain provisions for off-cycle emissions and should preferably also include mobile air conditioners as well as various foreseen eco-innovations that currently do not contribute to the CO_2 emissions as measured on the type approval test.

[33] Regulation (EC) 715/2007, Article 14(3)

Representative mileage weighting

Another aspect playing a role is the fact that for the CO_2 legislation sales averaged CO_2 emissions are established by averaging emissions in g/km of all models weighted by their sales volumes. When progress in reduction of this average value is seen as a measure for effects in the real-world, this implicitly assumes that all vehicles drive the same mileage. This clearly is not the case. In most countries large vehicles and diesel vehicles have higher annual mileages as well as higher lifetime mileages than small resp. petrol cars. Especially diesels have a longer lifetime in total kilometres that can be driven with the vehicle. Different vehicle segments thus contribute differently to the average CO_2 emission realised on the road. Furthermore changes in the sales average TA CO_2 emission are not only related to improved efficiency but also to market shifts between segments and fuels. This means that vehicle down-sizing (trend towards smaller cars) contributes to meeting the target. The size of the average car, however, can also decrease as a result of more households buying a small second or third car. In this case the total distance driven by cars may increase so that it is not evident that total real-world CO_2 emissions decrease as a result of an average decrease in size of the new vehicle fleet.

3.5.2 Factoring in alternative energy carriers in a vehicle based regulation

The present regulation for passenger cars creates a framework for setting CO_2 emission targets for the sales averaged CO_2 emission per manufacturer in 2015. The main instrument targets vehicles running on petrol and diesel as well as niche vehicles running on natural gas and LPG for which CO_2 emissions are measured during Type Approval. In the regulation the measured CO_2 emission is mainly used as a proxy for vehicle efficiency. As such the lower specific CO_2 emissions of natural gas and LPG (due to a lower C/H ratio) are implicitly given credit.

For future regulation special provisions will have to be made to deal with new vehicle technologies that may enter the market in the future. These new technologies include dedicated or high-blend biofuel vehicles, such as flex-fuel vehicles running on E85, as well as vehicles consuming electricity (battery-electric vehicles or plug-in hybrids) or running on hydrogen.

A discussion of possible generic ways of dealing with alternative technologies is included in the analysis of possible metrics for future targets presented in section 2.4 of this report. Below some specific aspects for road vehicles are discussed. Section 3.5.3 addresses the issue of test procedures required to deal with these alternatives.

One of the upcoming issues already for the short term concerns the impact of EVs on emission levels from conventional vehicles. As explained in section 2.4 of this report, treating EVs as zero-emission vehicles under the present regulation (based on type approval CO_2 emission values) creates a leverage which may promote the use of EVs as means for meeting the target but which may also lead to a net increase of WTW GHG emissions compared to the situation in which the target is met by CO_2 emission reduction in conventional vehicles only. Up to 2015 this is further amplified by the "supercredits" provision. For the short term such a leverage may be acceptable as a way of promoting the market introduction of zero-emission, but in the long term such implicit promotion should be replaced by legislation that stimulates technologies on the basis of their real contribution towards meeting the targets. The current system is an invitation to cross-subsidise internally in the manufacturer's business, and leads to the unwanted side effects as described in section 2.4. It is also clear that the present regulation does not award manufacturers that only produce vehicles with zero emissions on the TA test. For adequately dealing with such new technologies one therefore may need to consider separate vehicle-based targets for different technologies and policy instruments may have to be designed that promote the application of these technologies independent of the CO_2 regulation applied to conventional cars.

3.5.3 Test procedures for alternative energy carriers

Biofuels

The present Type Approval test procedures do not cater for the use of biofuels. Specifications for the TA reference fuel are being changed to include a 5% share of biofuel. Regulation 692/2008[34] specifies the revised fuel quality of reference fuels. In Annex IX the reference petrol fuel for type approval testing is specified to have a volumetric ethanol content of 5% (E5), while the diesel reference fuel needs to contain 5% FAME (B5). For flexible fuel vehicles also other reference fuels are specified (E85 and –provisionally– E75, NG/Bio-methane G20 and G25). For FFVs the Euro 6 legislation will almost certainly also involve type approval testing with E85 on the NEDC cycle with cold start. Furthermore a -7° C test is foreseen, probably using E75, with separate limits for HC and CO. A proposal for amending the test procedure is to be approved by the CATP (Committee for Adaptation and Technical Progress). In UN-ECE / GRPE (Geneva) and MVEG (Brussels) at present no concrete developments, other than the ones mentioned above, are taking place with respect to including various biofuels and blends in the emission test procedures.

The above means that the impacts of blending 5% biofuel into petrol and diesel are to some extent included in the measurement of regulated components. However, as biofuel burnt in the engine also produces CO_2 this change in reference fuel does not significantly affect the measured CO_2 emission in the Type Approval test. Vehicles capable of using high-percentage blends or pure biofuels are usually also able to run on conventional fuel and are being type approved using the conventional reference fuel. As such the present Type Approval system and the Monitoring Mechanism based on this TA system do not give implicit credits to vehicles designed to drive on biofuels.

The amendment of the Fuel Quality Directive (2009/30) addresses the carbon content of commercial fuels, and covers Well-to-Tank GHG emissions from biofuels (Annex IV of the Directive).

It needs to be decided whether and how manufacturers are given credit under future CO_2 legislation for cars for the sales of vehicles capable of running on especially high percentage biofuels. One complicating issue in this respect is that the CO_2 allowance should ideally reflect the extent to which they are actually likely to be run on biofuel rather than conventional fuel.

Alternative propulsion systems

Type approval test procedures are in place for electric and hybrid vehicles (including hybrid vehicles charging electricity from the grid)[35]. With the present procedures, electricity consumption is measured (next to the CO_2 emissions from fuel use in case of hybrids), but no emissions are attributed to this electricity consumption. For hybrid charging from the grid it will lead to a relatively low TA CO_2 emission value. Depending on the origin of the electricity or hydrogen, however, the well-to-tank energy chain for these energy carriers does involve emissions of CO_2 and other greenhouse gases, but this can vary very substantially in different areas and according to the time of recharging, etcetera. For the 2012 target vehicles running on electricity or hydrogen could be treated by exemption, but for post 2020 targets such exemptions could lead to significant options for gaming.

Hybrid vehicles
The procedure for hybrids caters for different types of hybrid powertrains (with or without charging from the grid) and adequately deals with the impact of different initial states of battery charge on the amount of emissions, fuel consumption and electricity consumption measures on the TA test. For hybrids the main issue is how to deal with the electricity consumption of so-called plug-in hybrids (charge depleting hybrids charging electricity from the grid).

[34] COMMISSION REGULATION (EC) No 692/2008, of 18 July 2008, implementing and amending Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information
See: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:199:0001:0001:EN:PDF
[35] In GRPE context a further refining of the procedure for dealing with recent plug-in hybrid concepts has recently been developed.

Electric vehicles
Battery-electric vehicles are in principle covered at the national level by the present TA test procedures with reference to UN-ECE regulation 101. EU type approval of battery-electric vehicles has comes into effect with the Framework Directive 2007/46/EC in April 2009. Details of the procedure may need to undergo changes in the future if more experience with TA testing of battery-electric vehicles would e.g. point out that the present procedure does not adequately represent the performance of electric vehicles relative to other technologies.

Hydrogen
Procedures for type approving hydrogen powered vehicles have been agreed at the EU level in co-decision, following a proposal from the Commission[36]. These procedures, however, do not yet deal with energy consumption or emission requirements but only refer to the make-up and installation of “hydrogen components” and “hydrogen systems” in vehicles. In UN ECE the Sub-Working Group Environment (SGE) of the Informal GRPE Working Group Hydrogen Fuel Cell Vehicles - GRPE-H_2FCV[37] is analysing needs for dedicated type approval testing methods with respect to energy consumption and environmental impacts of fuel cell vehicles running on hydrogen. No concrete proposals have been developed yet.

Eco innovations
A future new test procedure would have to take eco-innovations into account, either by default through its better design, or by adding optional tests that can be undertaken in case a car carries certain technologies. In case these options turn out not to be feasible, it may be considered to continue the use of the concept of eco-innovations for technical measures that reduce CO_2 emissions but are not covered by the new test cycle.

3.5.4 Monitoring

In important element of any regulation based on targets applied to the sales averaged performance of a product will be monitoring of changes in sales and of the resulting average performance. With individual manufacturers as obliged entities, as is the case for the CO_2 legislation of cars, the results of the applied monitoring mechanism have to provide proof for the level of compliance of individual manufacturers.

There are significant inconsistencies in monitoring in the EU Member States. Such existing inconsistencies need to be corrected/solved as soon as possible in order to enable a robust and accurate monitoring of registrations, CO_2 emissions and other car parameters starting from January 2010 as required by the Regulation regarding CO_2 emissions from passenger cars.

Preferably the data collected under the monitoring not only allow proper calculation of the specified average values, but also some level of analysis of the underlying changes in sales / market that contribute to meeting or not meeting the targets. Such information will provide valuable insights for improving the provisions and modalities of the regulation as well as for setting future targets.

As follow up to the Technical Focus Group meeting in which this paper was discussed with stakeholders ACEA has proposed the following recommendations with respect to improving the Monitoring Mechanism:
- "Short-term: ACEA recommends a monthly update of the type approval data databases used by Member States;
- Long-term: ACEA asks for the rapid implementation of the common vehicle database at EU level and used by all Member States as mentioned in Recital 26 of the Regulation;
- ACEA requests the establishment of a clear and transparent procedure for the assessment of possible data inconsistencies with full access to data at Member States level for affected manufacturers. Such procedure should include a list of contact points (at Commission and Member States level) in case of identified inconsistencies;

[36] COM(2007)593, see http://ec.europa.eu/enterprise/automotive/pagesbackground/pedestrianprotection/index.htm#hydrogen
[37] http://www.unece.org/trans/doc/2008/wp29grpe/H2SGE-03-IP-01e.doc#_Toc185055244

- ACEA requests that manufacturers should get access to the manufacturer specific data monitored by Member States already during the monitoring year (e.g. via secured Internet website). That means, Member States need to update the data on a monthly basis.
- According to the passenger car regulation, the European Commission shall notify each manufacturer of its provisional calculation for that manufacturer. In case of an inconsistency notification by a manufacturer towards EU Services, the process of data publication (annual CO_2 emissions average of manufacturer's EU fleet) and the payment of the reputed Excess Emissions Premiums should be discontinued as long as the inconsistency is clarified. If the inconsistency cannot be settled within 6 months, an arbitration process can be initiated by both parties."

3.6 Penalties

Regulation No 443/2009[38] contains penalties to be applied to manufacturers for not complying with the targets set in the passenger car CO_2 regulation. Important issues with setting the height of penalties are:

- For regulations based on targets applied to sales averages it is reasonable to limit the penalty for small levels of non-compliance. Market developments can not be steered exactly and small deviations from the target can only be determined ex post.
- For larger deviations penalties should at least be proportional to the level of deviation, but may also be chosen to increase supra-linearly with the level of non-compliance.
- Penalties should be higher than the costs for meeting the target. Ideally the penalty level is set somewhat above the marginal costs for meeting the last g/km reduction. Given uncertainties about future costs, and differences in the cost curves for different manufacturers depending on their product portfolio and technology status, this is in practice quite difficult to establish.

Collected penalties can flow into the general Commission budget but can also be allocated to specific purposes, e.g. the stimulation of R&D into energy efficient technologies.

Besides levying penalties for non-compliance one stimulate manufacturer to exceed the target by paying them a rebate for the extent by which their average CO_2 emission is below the target. In such a feebate system the rebate can be (partly) paid from the collected penalties, so that the measure is largely of fully cost neutral.

3.7 Regulation of power, maximum speed, or maximum performance

CO_2 emissions of vehicles on the type approval test and in real world driving can not only be improved by improving power train efficiency and reducing vehicle mass, air drag and rolling resistance. Especially in the passenger car market a large share of the fleet's inefficiency results from the use of high performance engines. Under low load conditions, generally occurring in normal traffic, these have poor efficiency, while they may also promote a more aggressive and therefore more energy-consuming driving style when traffic allows this.

Regulating the maximum installed power or power-to-weight ratio may therefore be considered an option to reduce energy consumption of vehicles under normal average driving conditions. It needs to be considered whether power or torque needs to be limited.

Alternatively limits could be set for top speed or maximum acceleration. Capping top speed only has significant environmental benefits when it discourages marketing of high-performance cars. If engine power is not reduced, but instead top-speed is only electronically limited, then the issue of part load operation under normal traffic conditions remains. Capping the maximum acceleration

[38] REGULATION (EC) No 443/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles, see: http://ec.europa.eu/environment/air/transport/co2/co2_home.htm

could discourage the use of very powerful engines, and can thus be expected to have effect under normal driving conditions.

Besides limiting top speed as described above speed limiters, enforcing that vehicles do not exceed the maximum speed allowed on the road, can help to reduce CO_2 emissions. A requirement to equip vehicles with speed limiters is a regulatory instrument. In the longer term such speed limiters could even be externally controlled.

In any case, vehicle "down-rating" options as described above are also one of the responses that manufacturers have at their disposal for meeting stringent CO_2 emission limits. They will also be stimulated by other e.g. economic instruments. It should be noted that such down-rating in principle involves a welfare loss. But it can be debated whether vehicle performance and other luxury features that go at the expense of fuel economy represent true added value or are mainly desired for "keeping up with the Joneses".

3.8 Mandatory application of technologies

Regulation that requires mandatory application of energy saving / CO_2 emission reducing technologies may be part of an overall package of policy instruments regulating CO_2 emissions from road transport.

From a theoretical point of view more generic regulation is preferred over such technology-specific regulation as it allows the market rather than the legislator to determine the most cost-effective means of meeting the target. However, given market imperfections and resulting chicken-and-egg problems with introducing new technologies, mandatory application may in some cases be a suitable instrument of bringing innovations to the market.

In the following cases mandatory application of technologies may make sense:

- retrofitting existing vehicles, e.g. with low rolling resistance tyres
- promoting application of technologies that do not yield (large) benefits on the type approval test but that do significantly improve real world CO_2 emissions:
    - examples under the Integrated Approach are tyre pressure monitoring systems, gear shift indicators and low rolling resistance tyres;
    - examples under the present CO_2 legislation for passenger cars are the so-called eco-innovations, e.g. solar roofs and efficient LED lights.

The mandatory application may have to be combined with regulation setting minimum performance requirements at the component level (e.g. in case of low rolling resistance tyres and efficient LED lights).

The regulation may also take the form of an obligated share of certain technologies in the total sales. In this way the application of e.g. electric or fuel cell vehicles could be promoted. Over time the required share of these technologies may be increased. In the end, however, a more generic regulation that creates a level playing field for competing technologies is preferred over technology-specific measures.

3.9 Summary of future issues regarding regulation of CO_2 emissions from road vehicles

In summary of the above or in addition to what has already been discussed the following issues are of importance in the context of designing long term strategies for regulating CO_2 emissions from road vehicles:

- Development of appropriate test methods for assessing CO_2 emissions, energy efficiency or other energy efficiency related performance characteristics at the level of the vehicle or of components;
    - The test methods for LD vehicle will require improvements. These relate to dealing with new technologies and especially to improving the correlation between effects measured on the TA test and real-world impacts in terms of average g/km emissions;

  - Test methods for measuring energy efficiency and CO_2 emissions for HD vehicles still need to be developed;
- Inclusion of appropriate mileage weighting to improve the correlation between monitored developments towards meeting the target and impacts on net total GHG emissions (in Mton p.a.);
- Designing an appropriate metric for dealing with new energy carriers and the resulting shifts in well-to-tank and tank-to-wheel energy efficiency and GHG emissions.
- Defining appropriate target levels and associated target years, taking account of the required reduction levels on the one hand and the foreseen availability and costs of technical measures to meet the targets on the other hand;
- Once a regulatory system has been set up targets need to be tightened periodically, taking into account observed market effects and cost developments, new innovative technologies becoming available, etcetera.

4 Regulation of components for road transport vehicles

4.1 Relation with definition of eco-innovations

Article 12(1) of EC regulation No 443/2009, dealing with "…emission performance standards for new passenger cars…" states that savings achieved through the use of innovative technologies shall be considered in contributing to the specific emissions target of a manufacturer. In order to be considered an eco-innovation its effect should not be covered by the standard test cycle CO_2 measurement or by other mandatory provisions [Article 12 (2c)].

Current examples of such eco-innovations are:

- solar roofs that provide power for auxiliary electrical systems;
- efficient lighting (e.g. LEDs);
- exhaust heat recovery.

The manufacturer applying for consideration of CO_2 savings resulting from the application of an eco-innovation shall submit evidence of the CO_2 reduction for each type, variant, version of a car on which this application will be used. This information is to be reviewed by the European Commission. Upon decision by the European Commission manufacturers may receive up to 7 g/km as credits for eco-innovations contributing to meeting their 2015 target.

Article 13(3) of Regulation No 443/2009 states that by 2014 the Commission shall make appropriate proposals to adapt the type approval test procedures to reflect adequately the real CO_2 emissions behaviour of cars and to include the approved innovative technologies as defined in Article 12 that could be reflected in the test cycle. From the date of application of the revised procedure for the measuring of CO_2 emissions, innovative technologies shall no longer be approved under the procedure set out in Article 12 of Regulation No 443/2009.

The eco-innovation shall thus be considered a temporary measure (short term fix) to be replaced by a more structural promotion of such technologies by including them into the type approval test procedures. It is yet to be seen whether this can be done in such a way that their CO_2 reduction potential counts towards achieving an overall CO_2 target set at the level of vehicles or the manufacturer sales average, or that separate regulations are required to set targets for the efficiency or reduction potential of these eco-innovation-type technologies. In principle the concept of "eco-innovations" can also be continued as a means to promote application of innovative CO_2 reduction technologies, provided that the concept proves workable over the coming years. Issues are e.g. agreement on evaluation methods to be applied and the way these deal with regional variations in conditions that may affect the impact of eco-innovations.

Other development on components that reduce GHG emissions, which are not covered by the standard test cycle but which are dealt with in other existing or proposed legislation are discussed below.

4.2 Current developments

4.2.1 Tyre Rolling Resistance

It has been recognized that by improving tyre resistance properties, significant fuel consumption benefits can be achieved. Tyres and tyre pressure can improve vehicle fuel efficiency by more than 5%, according to estimations[39]. For this reason, legislation is under development to promote

[39] EC COM(2006)545/final

so-called low rolling resistance tyres (LRRTs)[40]. The regulation is aimed at providing information so that market forces may promote improvements of tyre properties above the minimal requirements set for type approval[41] and in doing so improve energy efficiency of road transport.

Tyres are characterised by a number of parameters which are interrelated. Improving one parameter such as rolling resistance may have an adverse impact on other parameters. Improving rolling resistance is likely to affect wet grip and acoustic performance. Tyre manufacturers should be encouraged to optimise all parameters and the aim of the proposed legislation is to promote this though the operation o f market forces and by doing so improve the energy efficiency of road transport.

In order to foster spreading of low rolling resistance tyres the European Commission has recently released two pieces of legislation:

- Regulation 661/2009 concerning type-approval requirements for the general safety of motor vehicles defines maximum levels of rolling resistance so that the worst performing tyres are not allowed to be sold on the European market anymore. This regulation has been adopted on 13th July 2009.
- Regulation 2008/348 provides for an energy efficiency labelling of tyres. As of 2012 tyres will be accompanied by an A to G rolling resistance label, an A to G wet grip label as well as an indication of the level of noise of the tyre. The European Commission has agreed on 1st October on this legislation that should be formally adopted by the Parliament and published in the official journal during first half of 2010

The tyre label ranks the tyres from “A to G” in descending order of energy efficiency. Table 7 lists the proposed classes for C1, C2 and C3 tyre types.

Table 7: Proposed grading of fuel efficiency classes[42]

C1 tyres		C2 tyres		C3 tyres	
RRC in kg/t	Energy efficiency class	*RRC* in kg/t	Energy efficiency class	*RRC* in kg/t	Energy efficiency class
$RRC \leq 6.5$	A	$RRC \leq 5.5$	A	$RRC \leq 4.0$	A
$6.6 \leq RRC \leq 7.7$	B	$5.6 \leq RRC \leq 6.7$	B	$4.1 \leq RRC \leq 5.0$	B
$7.8 \leq RRC \leq 9.0$	C	$6.8 \leq RRC \leq 8.0$	C	$5.1 \leq RRC \leq 6.0$	C
Empty	D	Empty	D	$6.1 \leq RRC \leq 7.0$	D
$9.1 \leq RRC \leq 10.5$	E	$8.1 \leq RRC \leq 9.2$	E	$7.1 \leq RRC \leq 8.0$	E
$10.6 \leq RRC \leq 12.0$	F	$9.3 \leq RRC \leq 10.5$	F	$RRC \geq 8.1$	F
$RRC \geq 12.1$	G	$RRC \geq 10.6$	G	Empty	G

Information that is contained in the labelling should be in accordance with harmonised testing methods that should be reliable, accurate and reproducible. For this reason, the parameters should be measured in accordance with UNECE Regulation No 117[43] and its subsequent amendments.

[40] **Amended proposal for a regulation of the European Parliament and of the Council on labelling of tyres with respect to fuel efficiency and other essential parameters,** COM(2009) 348 final/2
[41] EC COM(2008)316 under adoption
[42] RRC denotes “Rolling Resistance Coefficient”
[43] OJ L 231, 29.08.2008, p. 19

4.2.2 Tyre Pressure Monitoring Systems

Rolling resistance, and hence fuel consumption, are strongly correlated with tyre pressure. Under-inflation causes a marked increase in rolling resistance. For this reason an obligation for tyre pressure monitoring systems (TPMS) is currently being included in a proposal for new type-approval requirements for the general safety of motor vehicles.

The proposed regulation stipulates that vehicles in the M1 category shall be equipped with a Tyre Pressure Monitoring System, capable of warning the driver when any tyre is operating at a dangerously low pressure level, and advising the driver when any tyre is operating at a pressure level significantly below the optimum pressure for good fuel consumption (EC COM(2008)316 Article 9(2)). In the context of this regulation, a TPMS is a system fitted on a vehicle, able to evaluate the pressure of the tyres or the variation of the pressure over time and to transmit corresponding information to the user while the vehicle is running.

The effect of being equipped with a TPMS on the vehicle's fuel consumption, however, is nil as long as the driver decides not to act on the information provided by the TPMS. Dependent on the makeup of the TPMS, therefore, there may be a poor relationship with real world GHG emissions.

4.2.3 Air conditioners

The use of mobile air conditioners (MACs) significantly increases real-world fuel consumption of vehicles. Various technologies are being developed that may reduce this impacts.

Measuring energy use of MACs is not included in the type approval test. The main issue with mobile air conditioners is the definition of a suitable test procedure to measure the impact of airco use on the fuel consumption and CO_2 emissions of a vehicle. Previous studies for the Commission [TNO 2002 and 2005] have shown there is no simple way of including air conditioners in the type approval test procedures. A test procedure that yields meaningful results is complex and needs to be carried out in a climatic test cell with simulated solar irradiation.

Development of dedicated test procedures is expected to take place in 2010 under auspice of DG ENTR.

4.3 Other candidates for regulation at component level

Other types of components could also be eligible for regulation aiming to promote increased energy efficiency. Examples are systems for power steering and power-assisted brakes, servo motors, and in-car systems (navigation and entertainment). For cooled freight transport the energy efficiency of cooling equipment and of superstructures can be regulated.

4.4 Regulations for other vehicle attributes that impact on CO_2

In the long run other aspects of the vehicle, which impact on CO_2 emissions or energy consumption, could be subject to regulation. This may include e.g. weights, dimensions, and aerodynamics.

5 Regulation of energy carriers

5.1 Introduction

Energy carriers, in other words the fuels used in transport, have been regulated in the EU for some time now. Compatibility with vehicle engines, reduction of air pollutant emissions and toxicity of the fuel were the main drivers behind these regulations. Quality standards and specifications have been tightened at regular intervals, to adapt to changing engine and technology requirements, and to reduce polluting and toxic emissions.

Since 2003, and again more recently in the Renewable Energy Directive (RED) [EU, 2009a], targets have also been set for the share of biofuels and (in case of the RED) for the share of renewable energy sold within Member States. This type of policy might be viewed as different from the quality standard type regulation of the energy carriers as it does not prescribe exactly what fuel will be sold, but leaves more freedom on how to meet the target.

The recent Fuel Quality Directive (FQD) [EU, 2009b] also introduced a new regulatory policy measure, namely a target for the reduction of the well-to-wheel greenhouse gas emissions (GHG) of the fuels used in the sector. In addition, sustainability requirements for biofuels were introduced in the RED and FQD.

In the following, we briefly describe the various regulatory policies that can impact the energy carriers in the sector, and look at the potential effect and pros and cons of these policies in the context of transport climate policy. The policy options will also be related to the technical options for GHG reduction that were identified in earlier papers.

Note that many of the options described in this chapter will also have to be seen in conjunction with appropriate vehicle policies (regulation or financial), as fuels and vehicles need to be developed together.

5.2 Regulation of energy carrier or energy source

This option implies that the EU sets (mandatory) targets of energy carriers or energy source, in order to reduce CO_2 emissions of the sector. The 5.75% indicative biofuel target for 2010 is an example of this type of regulatory policy [EU, 2003], as is the 10% share target of renewable fuels, defined for 2020 in the RED [EU, 2009a]. The regulation might be designed to either specify exactly what type of fuel or energy source should be used (e.g., ethanol), or leave some freedom to the market on what to offer (e.g., biofuels, or renewable energy. Companies will then aim to meet the regulation with the energy carrier or source of least cost, with additional considerations such as technical or logistical issues and availability (security of supply).

A number of pros and cons of this policy measure can be identified.

Pros:
- It can accelerate market introduction of alternative fuels that would otherwise not be achieved (to that extent) due to higher cost or other (real or perceived) disadvantages of the alternative.
- It can offer relatively high investment security to industry, if the risk of intermediate modifications are (perceived to be) low.
- Costs to governments are low, unless they choose to support the regulation by tax reductions or subsidies (which is the case in various EU Member States).
- The policy is already in place in the EU, and experience is being gained. Increasing the target in the future and further improving the details of the regulation will thus be relatively easy.

Cons:

- Costs to the energy providers (such as petroleum companies) and thus to consumers may be higher than expected, for example due to changes in market conditions.
- The policy needs to be adapted regularly to changing circumstances, e.g., due to changes in environmental performance (as was the case in the recent biofuel policy debates), or technological and cost developments.
- Depending on how detailed the regulation is, this policy requires governments to have (or obtain) ample independent knowledge of the energy carriers and energy sources available, and of the expected future developments.

This policy could be applied in any mode, but as an EU policy it seems best suited for surface transport. If applied to a global transport mode such as shipping, it might increase the cost of EU bunker fuels relative to non-EU fuels, which may create a shift in the global bunkering market (depending on how ambitious the target is). A global approach, via the IMO and ICAO, seems preferable for these modes.

5.3 Regulation of CO_2 emissions from well to wheel

An alternative policy option is regulation of the CO_2 emissions of the fuel from well to wheel, leaving it up to the market to decide how these emission are reduced: with different types of energy source or energy carrier, by efficiency improvements of current production routes, etc. The recent FQD introduced this policy measure in the EU, as it sets a target for CO_2 emission reduction of road transport fuels for the period 2010 to 2020.

This options differs from the previous one because it does not prescribe the type of fuel which could be considered a means to reduce CO_2 emission, but directly focuses on the CO_2 reduction. Again, the market (i.e. the petroleum and other energy companies) will aim to meet these targets in the cheapest way, with additional considerations such as, for example, reliability from a technical and security of supply perspective.

Pros:

- This policy can accelerate market introduction of alternative fuels or other CO_2 reduction options that would otherwise not be achieved (to that extent) due to higher cost or other disadvantages of the alternative.
- It can offer investment security to industry, if the risk of intermediate modifications are (perceived to be) low.
- Costs to governments are low.
- Allows governments to control CO_2 emissions of the fuels, but only relative (per litre or GJ), not the absolute emissions.
- Compared to the previous policy option, governments do not need to prescribe the technological means to reduce CO_2, but rather leave that to the market. This should increase cost efficiency, i.e., result in lower cost per tonne CO_2 reduction, as one can expect the market to react to the policy in the most cost effective way. The market can also adapt their reaction to changing circumstances, e.g., in technology or cost, without the need for changing policies.
- The policy is already in place, and experience will be gained in the coming years. Increasing the target in the future and further improving the details of the regulation will thus be relatively easy.
- The polluter pays principle is directly adhered to.

Cons:

- Governments have no direct control on the type of energy carrier or source that is promoted, as the target can be met by various means (e.g., biofuels, CO_2 reductions in the fossil fuel chain, renewable electricity in electric vehicles, etc.). If there is a need to promote specific types of energy carriers, additional, perhaps temporary incentives for specific technologies (subsidies, for example) would be needed.

- Costs to the energy providers (such as petroleum companies) and thus to consumers may be higher than expected, for example due to changes in market conditions.
- The policy may need to be adapted regularly, e.g. due to changes in environmental performance or technological and cost developments. However, we expect that would be less often or urgent than in the previous option, as the regulation can be met in a more flexible and diverse way.
- Depending on how detailed the regulation is, this policy requires governments to have (or obtain) ample independent knowledge of the energy carriers and energy sources available, and of the expected future developments. Again, this seems to be more of an issue in the previous option.

As concluded for the previous policy option, this policy could be applied in any mode, but as an EU policy it seems best suited for surface transport. If applied to a global transport mode such as shipping, it might increase the cost of EU bunker fuels relative to non-EU fuels, which may create a shift in the global bunkering market. A more global approach might then be preferable.

Note that monitoring and verification procedures are an essential part of these regulations and not always straightforward, because of the large scale international trade of transport fuels and the life cycle approach of this type of regulation – emissions of biomass cultivation or biofuel or energy production can not be measured at the end product. It is expected that monitoring and verification will be set up and further developed in the coming years for the FQD directive, and useful experience will be gained there.

5.4 Electric transport: interaction with regulation for the electricity sector

In the case of electric transport, the energy is generated in the power production sector, where EU regulation is already in place. The main policies regulating the CO2 emissions of that sector are currently the following:

- The CO_2 emissions of the sector are included in the EU ETS, that effectively puts a cap on these emissions, with the possibility of trading with other participants (industry and, in a few years, aviation) and CDM.
- The RED sets a 20% target for the renewable energy share in 2020 in the EU. The transport sector will contribute partly to that target (probably with a 10% share as regulated in the RED), the rest will have to be met by the electricity sector. However, no specific targets have been set for this sector yet, apart from a number of countries such as the UK.

The electricity consumed by the electric trains in the EU are already subject to these policies.

However, as one of the main technological options for CO_2 reduction in the future is electrification of the road transport sector, the share of transport energy falling under the power production policies might well grow significantly in the future. Taking the perspective that transport is responsible for all emissions that the sector causes, i.e. ‘from well to wheel’ (as has also been the case with biofuels), it can be argued that the sector is also accountable for the emissions of the transport electricity production. Various choices can be made regarding wither and how this responsibility is implemented in transport policy, for example in the Fuel Quality Directive and in the CO_2 regulations for vehicles (see e.g. section 2.4 for a detailed assessment of options to move these regulations towards a well to wheel approach) In any case, transport and power sector policy will then become more strongly related.

Looking at the EU ETS, an increase of electricity use in transport will increase demand for emission allowances, increasing the price of the allowances. This will make more emission reduction measures cost effective, both in industry and in the power generation sector, leading to CO_2 reductions somewhere in the ETS. Therefore, if the EU ETS cap is not widened in response to this development, electric transport can be considered to be climate neutral.

As long as the share of electric vehicles is small, the impact on the ETS can be expected to be negligible. However, there are a number of potential risks that may create undesired side effects in the longer term, if shares of electric and plug-in hybrid vehicles increase. As the EU ETS also includes industry that is exposed to global competition, the EU and its Member States have been very careful in the past not to increase the energy cost for these companies too much. Too high costs may lead to relocation of production to outside the EU, which has negative economical consequences but also leads to emission leakage. Therefore, the EU might decide to increase the cap of the ETS in the longer term, to compensate for the additional demand of the transport sector, in order to reduce the price of emission allowances. This would obviously reduce the CO_2 emission reduction effect of electrification. It would, nevertheless, still result in a cap of the CO_2 emissions of this part of the transport sector, as is currently the case for electric rail transport and, from 2012 onwards, aviation (see also paper 7 on economic instruments and emission trading in transport for further information).

The impact of the (current) RED would be that if electricity gradually replaces gasoline and diesel in the future, this would lead to less liquid (or gaseous) renewable transport fuels, i.e. biofuels, and more renewable electricity - at constant renewable energy targets.

In the future, the transport sector could then benefit of any further greening of the power sector, for example of further increases of the renewable energy target, or the future reduction of the CO_2 emission cap.

5.5 Sustainability criteria for fuels

In recent years, the sustainability of biofuels has received a lot of attention, and partly severe criticism. Especially the carbon emissions due to land use change were found to be very significant in some cases, rendering the environmental benefits of current biofuels policies questionable at best (see, for example, [JRC, 2008][Gallagher, 2008][SCOPE, 2009]). In the past few years, a growing number of EU Member States wanted to specifically promote only biofuels with good environmental and socio-economical performance, and sustainability criteria for biofuels were developed - first in a number of Member States (UK, NL and Germany), and then also in the EU. The RED and FQD [EU, 2009a][EU, 2009b] therefore include a number of sustainability criteria for biofuels, including a minimum GHG reduction requirement (excluding ILUC emissions for the time being) and exclusion of areas of high biodiversity value or high carbon content for biomass cultivation. It is expected that these criteria will be further developed in the coming years, by including indirect land use change (ILUC) emissions and by further developing and improving the definitions and methodologies used.

The ILUC debate has made clear that a full and integral analysis of these fuels is required to determine the environmental impact, and that policies are essential to ensure that the fuels that are used are truly sustainable. We expect that the research regarding the sustainability and actual impact of biofuels will continue in the coming years, and that the sustainability criteria of these fuels will be further developed as a response.

The CO_2 emission regulation of the FQD mentioned earlier can be seen as a first step in regulating the sustainability of other types of transport fuel as well. Assuming that a realistic methodology will be developed to calculate the life cycle CO_2 emissions of fossil fuels[44], it will promote use of fossil fuels with low GHG emissions from well to wheel, and discourage use of fossil fuels that require significant amounts of energy to produce, such as oil shales, or significant flaring.

Further tightening of the CO_2 reduction target in the future may help the sustainable development of energy carriers further.

In addition, one can image that other sustainability issues and fuels can also be included in the regulations if required, for example other environmental or socio-economic criteria of fuel or

[44] to be derived in the coming years

energy production, not only for biofuels but also for other energy carriers and sources such as fossil fuels, hydrogen, electricity, etcetera.

The EU can apply this type of regulation for all fuels sold in the EU. Note that again, monitoring and verification procedures are an essential part of these regulations and not always straightforward, because of the large scale international trade of transport fuels and the life cycle approach of this type of regulation – sustainability of biomass cultivation or energy carrier production can not be measured at the end product.

5.6 Regulation to stimulate market introduction of alternative fuels

New energy carriers can encounter various barriers to their introduction, some of which are related to their availability. First of all, there might be problems commonly known as ‘chicken and egg’ problems. For example, people will not buy electric cars, CNG or flex fuel vehicles unless there are sufficient charging points, CNG and E85 pumps available and people are confident that they will not run out of fuel due to lack of filling stations.

Governments may thus accelerate the introduction of both new energy carriers and new engine technologies by ensuring the availability of the energy carriers. Regulation can be one means to ensure sufficient availability of energy carriers. Petroleum companies can be obliged to supply certain types of fuel at certain filling stations, e.g., at filling stations with more than x pumps.

The advantage of this type of regulation is that is removes the chicken-and-egg barrier, which may greatly enhance the uptake of a new technology and the market share of the energy carrier.

A disadvantage is, however, that costs may be high. The regulation may require companies that sell transport fuel to invest in separate fuel distribution, pumps, in case of electricity in power infrastructure and charging points or battery swap stations, etc.. As long as the number of customers is limited, these costs will not be compensated by sufficiently high additional income. Therefore, this type of policy seems to be attractive only to support and accelerate development in energy carriers that have a very high chance of success in the future.

5.7 Fuel quality standards and compatibility

If fuels are incompatible with engines, there is a risk that engines do not function optimally, that emissions increase or that engines get damaged (irreparably). Fuel standards are also necessary to facilitate inter-EU trade and transport of the fuels.

Adequate standards are thus required for all energy carriers on the market, and introducing new energy carriers means that new standards need to be developed timely, in cooperation with the vehicle and engine manufacturers and, in case of electric transport, with electricity production and infrastructure companies. Clarity in the introduction planning of new fuels, particularly when dealing with increased content of biofuel blends in conventional gasoline or diesel fuel, is required to allow manufacturers to make their vehicles compatible with commercial fuels available not only at the time of market introduction but also with fuels as they might be introduced 3, 5 or 10 years after.

Regulation is already in place for fuel quality standards of petrol and diesel. Parameters such as octane and cetane numbers, oxygen and sulphur content, vapour pressure and density are regulated, to reduce pollutant emissions and to ensure compatibility with vehicle engines.

These standards are updated regularly. The recent FQD, for example, provides updated standards for petrol, diesel and gas oils that are allowed on the market. Part of the recent update was to increase the maximum allowed shares of biodiesel (FAME) and ethanol in petrol and diesel, to 7 and 10 v/v% respectively. Standardisation for higher blends of biofuels and newer types of biofuels (such as HVO, BTL, etc.) will have to receive sufficient attention in the coming decades, as these fuels will gain increasing market shares.

The European Committee for Standardisation (CEN) is the EU body that designs new standards for transport fuels. They are currently, among other things, working on standards for higher biofuels blends and various types of biofuel. Regarding electric road transport, CEN is currently working on the development of performances measuring methods, of vehicle interactions with infrastructure and environment during charging and on safety and other aspects[45]. Their global counterpart is ISO (International Organization for Standardization).

5.8 Safety standards and regulations for energy carriers

Particular attention should be given to potential safety issues related to new energy carriers. Regulations should address and reduce fire and explosion hazards, for example, during fuel transport and distribution, battery charging, etc. Each energy carrier will have specific issues that need to be addressed in this respect.

Again, CEN and ISO are the institutes working on these types of standards and regulations.

5.9 Conclusions for future GHG policy

A number of regulatory policies have been implemented in recent years to reduce the GHG impact of transport energy carriers: the renewable energy directive ensures a share of renewable energy in the sector and the FQD aims to reduce the well-to-wheel GHG emissions of the fuels. In the coming years, these policies will be further developed, details will be elaborated and experience will be gained. Further tightening these regulations after 2020 can be an essential part of energy policy in the transport sector.

These two regulations impact on the fuel developments until 2020, with a review in 2014. As both the type of energy carriers and their GHG emissions are important to the future transport system and its GHG emissions, further development of the regulations (until 2020) and increasing of the targets (after 2020) seems advisable. They may also be extended to energy carriers in other (non-road) modes, if suitable renewable fuels or other CO_2 reduction measures exist [46]. Aviation, for example, might benefit from a renewable energy target, as renewable fuels (biofuels) are one of the few CO_2 mitigation options. However, it can only be implemented once renewable energy options exist that a) are technically suitable, b) can be produced in sufficient quantities and c) meet the sustainability criteria.

Extension of the CO_2 regulation to other countries can also be a useful way forward, as this can prevent that the policy mainly leads to, for example, a shift in global crude oil flows, with the low CO_2-crude being sold in the EU, rather that in ensure improvements in crude oil production.

In terms of GHG emission reduction, CO_2 regulation of the fuels seems to be the best way forward. It leaves the choice of CO_2 reduction measure and energy carrier up to the market, where the most cost effective measures (in terms of cost per tonne CO_2 reduction) are likely to be taken. Further reducing the CO_2 emission target in future regulation could thus provide an effective means to promote low-carbon fuels in the future.

A renewable energy target impacts on GHG emission much more indirectly, as the GHG impact depends on the renewable energy used. However, it may provide a strong stimulus for renewable energy use in transport, which may reduce cost and promote investments in R&D. If the target is

[45] http://www.cen.eu/CENORM/Sectors/TechnicalCommitteesWorkshops/CENTechnicalCommittees/CENTechnicalCommittees.asp?param=6282&title=CEN/TC%20301, consulted on 25 August 2009.
[46] With perhaps maritime shipping as an exception as increased bunker fuel cost in the EU may lead to bunkering elsewhere, reducing the impact of the policy However, as not all maritime shipping would relocate their bunkering to outside the EU, this potential impact should be further assessed.

designed flexibly, allowing many different types of renewable energy to count towards the target (as is the case in the current RED directive), the market will be stimulated to find the most cost effective renewable energy solution for transport. Together with the CO_2 regulation of the fuels, this can be expected to result in a drive for low carbon renewable energy.

In any case, the recent biofuels debate has shown that comprehensive sustainability criteria are essential to ensure that these policies do not lead to undesired and, in some cases, very significant negative effects on emissions, biodiversity, etc.. In view of the global impact on commodity and energy source markets, indirect effects should also be included in these criteria, as soon as possible. As part of these efforts, GHG monitoring and reporting needs to be developed further in the future, improving its accuracy and reliability. In the future, sustainability criteria may also be extended to other types of transport energy such as fossil fuels, hydrogen and electricity to ensure sustainability of fuels used.

A global approach to these issues is preferable to a EU approach, in view of the global fuels, biofuels and biofuel feedstock (commodity) market. This would have benefits from a trade point of view, it would make verification and enforcement easier and it would prevent that the EU policy only leads to a shift in biofuels trade flows (with the sustainably produced biofuels being sold in the EU), rather that in ensure that the global biofuel production develops sustainably. The EU should thus endeavour to define global sustainability criteria, in addition to EU criteria. The development of global criteria does, however, not seem to be a prerequisite, as the EU can be seen to have its own responsibility regarding the impact of its policies, and EU measures can demonstrate the feasibility of this type of policy and thus further the global development of criteria.

If electric transport increases in the future, the policies of the power sector come into play: the ETS sets a cap on CO_2 emissions, and various member states have implemented renewable energy policies. Further greening of the power sector, no doubt an important part of climate policy in the next decades, will then also reduce GHG emissions of the transport sector. It should be realized, though, that this development will impact on the power sector and the ETS, and increase the efforts needed by the power sector to reduce CO_2 emissions.

6 Options for regulation of modes

6.1 Introduction

Unlike for passenger cars (and trucks in e.g. Japan), there are no regulations in place for reducing GHG emission of other modes in the EU or the rest of the world. However, there are some interesting developments that can be linked with vehicle regulations in the future.

Regulation of the fuel efficiency of the vehicle can be divided in different levels. Engine based efficiency standards may have a positive effect on fuel consumption. In the past decades passenger car engines have become significantly more efficient, although net effects at the vehicle level have been largely counteracted by increases in vehicle weight and on board energy consumption from air conditioners and other auxiliaries. Research is needed to investigate whether the engine efficiency of diesel engines for non-road applications could be improved significantly with regulation of the fuel efficiency of the engine. If so, regulation could be relatively easily implemented along with the current emission testing for air pollutant emissions. The emissions limits for air pollutants (g/kWh) could be complemented with a regulation for the consumption of fuel over the standardised cycle.

Setting a target for the energy consumption of the whole vehicle is, however, more effective and cost efficient, as there are much more options than for vehicle efficiency improvement than just the engine [Hazaldine, 2009]. It has been substantiated by the different branches that the difficulty for this is that setting a vehicle-based standard or regulation for busses, trains and ships is difficult, because of the big amount of variants since mass production is not standard for non-road modes. However, the International Maritime Organisation (IMO) has already made great progress with a design index for new sips. Therefore, we will investigate the option for setting standards for the whole vehicle rather than setting just standards for the engine.

Technology specific regulation is a last option to reduce the energy consumption of vehicles. An advantage of technology specific regulations is that it is usually easier to implement, since it does not require standardized test cycle procedures. However, this kind of technology push is not always the most efficient one, because companies always have a clearer view on costs and options than governments do. Therefore, governments should be reserved with requiring specific technologies. Objective environmental standards and regulations in place will incentivise the industry to come with the most cost effective options. In the case of a demonstrated chicken and egg situation, governments (e.g. with CNG and hydrogen infrastructure) may need to ease transitions by sharing risks or providing subsidies. However, the environmental benefits should be rather undisputable in such cases.

For operators of trucks, buses, trams, metro’s and trains it is currently not possible to have a clear view on the fuel / energy consumption of new vehicles, because there are no accepted test cycle for assessing the fuel consumption. Only for rail diesel application the test cycles for locomotives and for railcars, as defined in the directive 2004/26 on emissions from non-road mobile machinery could be used for this purpose. Up to now, computer simulations by manufacturers are the only source that can be used. The development of objective cycles/indexes is a first step to make the introduction of regulatory standards possible.

Co-benefits of regulation at the vehicle level are reduced fuel consumption and costs. Over the lifetime of the vehicle, investment cost can be recovered to certain extent, depending on the level of investment costs, the efficiency improvement and the oil price.

6.2 Regulation for maritime shipping

It is difficult for the EU to develop regulation for maritime shipping. The sector is international, with ships operated by European companies sailing under foreign flags and competition with ports in other regions in the world. It is preferred to develop policies in an international setting through IMO and ICAO.

Since the agreement of the Kyoto protocol, discussions on the CO_2 reduction of maritime shipping have been held, since this sector is not under the Kyoto Protocol. For maritime ships the IMO has developed 2 types of indexes (Resolution A.963(23)) that give information on the fuel efficiency of ships (IMO, 2009):

- Indexes expressing the GHG efficiency of the design of the ship (EEDI); and
- Indexes expressing the GHG efficiency of the operation of the ship (EEOI).

Emission indexes are designed to benchmark design or performance of ships. This information can be used by ship owners and ship operators for self-improvement. Potentially, emission indexing could be used mandatory schemes. However, in such cases a baseline is needed. In addition to regulation, EEDI and EEOI can either be used in voluntary agreements or economic incentive systems. These latter are discussed in Paper 7.

The EEDI expresses the emission of CO_2 from a ship under specified conditions (e.g. engine load, draught, wind, waves, etc.) in relation to a nominal transport work rate. The unit for EEDI is grams of CO_2 per capacity-mile, where “capacity” is an expression of the cargo-carrying capacity relevant to the cargo that the ship is designed to carry. For most ships, capacity will be expressed as deadweight tonnage.

Presently, the EEDI is not finalized and baseline data have been approximated by using data from existing ship databases rather than being obtained through the process of establishing the EEDI for individual ships. Also, the introduction of Common Structure Rules (CSR) has increased the steel weight of new ships, which may need to be taken into account. Presently, some work remains within MEPC to finalize the development of EEDI baselines.

The EEOI expresses actual CO_2 efficiency in terms of emissions of CO_2 per unit of transport work, using the following formula (MEPC/Circ.471):

$$EEOI = \frac{\sum_i FC_i \times C_{Carbon}}{\sum_i m_{cargo,i} \times D_i}$$

Where:

- FC_i denotes fuel consumption on voyage i.
- C_{carbon} is the carbon content of the fuel used.
- $m_{cargo,i}$ is the mass of cargo transported on voyage i. And
- D_i is the distance of voyage i.

The unit for EEOI is grams of CO_2 per capacity-mile, where “capacity” is an expression of the actual amount of cargo that the ship is carrying. For most ships, capacity will be expressed as tonnes of cargo moved; however, other units (such as passengers, TEU, cars and more) may also be used. Unlike the EEDI, the EEOI changes with operational conditions. The EEOI may thus be calculated for each leg of a voyage and reported as a rolling average or periodically.

From the trials conducted to date, it appears that the value of the EEOI will, amongst others, depend on the average utilization of the cargo-carrying capacity that can be achieved in actual operation. The latter is affected by the cyclical “business climate” for the various trades. Hence the average indicator for a ship category may vary from one year to the next, given changes to demand and competition, and among trade routes. Some transport tasks appear to offer the possibility for high average utilization (e.g., return cargo, or trade triangles), while other trade patterns (e.g., distribution of smaller cargo parcels) may result in inherent low efficiency that is related to the nature and geography of the transport demand, not to the operation or choice of ship. All of these issues may make it hard to establish a baseline for the EEOI.

The discussion about technical policy options in IMO focuses on options that are based on what is now known as the Energy Efficiency Design Index (EEDI). MEPC 58 approved the use of the interim method of calculation for trial purposes, with a view to further refinement and improvement; hence the EEDI is still being developed. The second IMO GHG study [IMO, 2009] discusses a mandatory limit on the value of EEDI for new ships, a mandatory reporting of the EEDI for new ships, and a voluntary reporting of the EEDI for new ships.

In the longer term, between 2015 and 2020 the further developed EEDI (baseline information and quality improvement) can be used to regulate de fuel efficiency of new ships, which has a significant potential. By setting a stringent baseline, the technical options [Hazeldine, 2009] available will be needed to meet the baseline. After 2020 a further tightening / strengthening with long enough lead times is optional, as the sector is able then to prepare. However, such an approach only tackles the CO_2 emissions of new ships, while the lifetime of ships is often 25 years or longer. The effect of a fuel efficiency standard or regulation for new ships may have significant effect since the size, power and fuel consumption of recent build ships is much higher than of older ships. Ships build since 2000 represent 50% of the worldwide available propulsion power [GL, 2008]. Barriers of the introduction of mandatory fuel efficiency standards are rather from a political point of view than from a technical point. The EU is not the obvious regulating body, since the ship building industry is concentrated in Asia nowadays and the EU has no influence on the ships build there. The only option for enforcing any such scheme would be to make compliance with the design efficiency limit value a condition of entry to all EU ports with the port state having responsibility for monitoring.

The barriers for the introduction of fuel efficiency regulation for existing ships are higher, since the EEOI is strongly dependent on operational characteristics and the business climate. Furthermore, investments for retrofitting techniques for existing ships are also higher. The EU can however use the EEOI as an instrument to incentivise the efficiency of maritime shipping by e.g. the differentiation of port dues (see paper 7).

6.3 Regulation for inland shipping

In the area of inland shipping there are currently no developments like for maritime shipping. However, the approach that is used for maritime shipping could also be used to develop a similar approach for inland shipping. However, vehicle regulation is only possible when there is an index available.

6.4 Regulation for trains

The consumption of electric energy by trains is covered by the EU-ETS. Regulation of the energy efficiency of trains can be considered as an additional measure to further promote reduction of energy consumption by the rail sector. For diesel trains no policy instruments exist as yet. For this type of trains some form of regulation could be considered as the main instrument.

In the EU project Railenergy[47] the rail sector is developing its own standard outlining how to simulate and verify the energy performance of tractive rail vehicles. The new standard has been presented in September 2009 in Tours during the UIC Energy efficiency days 2009, and includes a global methodology (“Global Model”) for the overall modelling and measuring of the energy flow in the complete railway system (from infrastructure to rolling stock). The standard will be issued as an UIC/UNIFE standard entitled "standard service profiles" outlining how to predict (calculate/simulate) and verify (by testing) the energy performance of tractive rail vehicles. The standard will also be proposed to European standardization bodies (CEN/CENELEC). In contrast to maritime shipping, setting regulatory standards is not discussed.

[47] www.railenergy.org

To proposed standard calculates the energy consumption for given service profiles: suburban, regional, intercity, high speed - and freight (mainline and shunting), using a set of defined parameters as:

- Average commercial speed
- Average load factor
- Average specific mass
- Network characteristics (supply)
- System, topography, no of stops)
- Operation (time table, driving style)

The proposed standard will calculate the energy consumption per seat kilometre (kWh/seat-km).

It is worthwhile to note here that CER[48] believes that regulating the energy consumption of trains by using the "Railenergy standard" will lead to sub-optimisation and will not lead to substantial GHG emission reductions. CER states that rail vehicles are usually designed and optimised for special use cases (operation in flat areas, mountainous, speed profile, weather conditions etc.). Regulation of energy consumption according to different (very rough) service types like high speed, intercity and regional, would therefore be too imprecise. An energy consumption standard for manufacturing would therefore be complicated and might lead to no further improvement. CER considers a regulation per transport function (g/passengerkm or g/tonnekm) as unnecessary.

CER further states that the energy efficiency of railway operation is highly dependent on how the train is operated and not only on the vehicle itself. Railways are currently implementing Eco-Driving systems in connection with energy metering as well as traffic flow management systems, which will make the traffic of trains more fluid (avoiding unnecessary stops) and thus more energy efficient.

By the lack of energy efficiency indexes, the mass per seat has been used in the past. A Dutch study [CE Delft, 2005] shows that for the Dutch Railways that mass reduction of the new fleet has a potential of 15% electricity consumption reduction compared to the existing fleet. The mass of trains have thus significant impact on their energy consumption, but the mass of trains significantly differ. The impact of mass depends very much on the application (e.g. urban, regional, intercity, high speed). The weight of the Japanese Shinkansen high speed train has a weight of 537 kg/seat, while the new Dutch Thalys has a mass per seat of 1,021 kg [CE Delft, 2005]. It should be noted here that in the Shinkansen the space per seat is much smaller than in European high speed rail vehicles. Furthermore the Shinkansen is only operated on dedicated tracks while European high speed trains generally have additional systems on board to allow operation on regular tracks also.

The Danish railways (DSB) have used setting a maximum to the weight of the train in the specifications for the Copenhagen suburban train by purchase. The result was 360 kg per seat, which can be seen as a benchmark for that time (1996).

With energy consumption per seat-km being the best indicator, a regulatory standard should be ideally based on that. The mass indicator might however also be useful in the future, possibly as an additional requirement, because there is a close link between mass and energy consumption. When data becomes available on the energy efficiency of trains due to reporting, targets might be set for the different train types identified. The EU is the obvious body for such standards, as all other environmental standards for trains are defined in EU Directives. Were a standard being developed it would be possible to enter it into force before 2020, after a trial period, with a further tightening of limit / target values in the longer term.

6.5 Regulation for aircraft

During the last 15 years the developments in fuel efficiency of aircraft has been relatively limited. This development can be supported by the introduction of regulatory standards for fuel efficiency.

[48] Community of European Railway and Infrastructure Companies. Input provided in writing.

There is considerable interest within ICAO and member states regarding options to set fuel efficiency or GHG standards for commercial airplanes. Currently, several working groups (a.o. ICAO) are developing metrics to compare CO_2 intensity of different aircraft models [ICAO, 2009].

An aircraft index might take into account the following design parameters into account:

Design parameter	**Illustration**
Design speed	Engine efficiency is strongly influenced by design speed and
Design range	Aircraft become less efficient on mission lengths over 5000 km due to the need for heavier frames
Degree of optimization of aircraft to mission	Aircraft are not well-optimized to a specific mission profile today.

Options for an index can include: g/available tonkm, g/available seat-km.

For in-use indexes, the index g/MTOW tonkm might be an option. In-use indexes could be used within the EU to incentivize the use of more efficient planes and higher occupancy rates.

Setting an airframe CO_2 standard for planes should be less technically challenging than ongoing discussions to set standards for other modes as heavy duty vehicles and maritime ships that have a greater diversity of duty cycle and vocation. From a technical point of view, the introduction of an index and a standard for air planes seems achievable. However, the political process may need several years following on the development of an index. A regulatory standard might be in use well before 2020 to be tightened after that date. Appropriate lead times may increase acceptance, give time for anticipation, and reduce the costs for the industry.

Also for aircrafts it might be a UN body that is the most appropriate body for setting a world wide standard. Depending on the reduction target against the baseline set, the potential effect on CO_2 emissions might be significant.

7 Overarching regulation

In addition to regulation at the vehicle level, overarching legislation may be considered as an instrument to improve the efficiency of transport. In this chapter we illustrate several opportunities in the field of public transport, logistics and at the city level. We end up with personal carbon budgets.

An increase in transport efficiency is often associated with overarching regulation rather than regulation on the vehicle mode, because improvement on the network level also gives benefits. Furthermore other pollutants, traffic safety and congestion levels may benefit of such optimization.

Overarching regulation requires a metric that allows comparison of different modes. This could e.g. be emissions in gram per passenger kilometre or per tonne kilometre. Such metric can not only be used for regulation but also for labelling or for voluntary agreements with (sub)sectors and stakeholders.

7.1 Public transport

Instead of setting targets for new vehicles, it is also possible to set standards or targets for the public transport fleet as a whole. Below we illustrate some examples and explore the options for this kind of regulation.

Directive 2009/33, on public procurement of clean and energy efficient vehicles, prescribes to take the lifetime energy and emission impacts into account. By this Directive, the EU promotes clean and energy-efficient road transport vehicles by increasing the market for these vehicles, and R&D. The Directive ensures that the additional purchase costs of more sustainable vehicles will be offset against the in-use benefits. Such a kind of outweighing costs and benefits could also be required from the market, and could be broader applied than public service vehicles alone.

Directive 2009/33 can be combined with a cap on total emissions, to have a clear objective. The Dutch province of Gelderland is attempting to include a climate emissions reduction target for the next public transport service agreement from 2010. With this development Gelderland is one of the first public transport authorities that includes a target in the contract. This implies that the new operator will need to reduce its fuel consumption related to the performance due to investments in fuel efficiency measures like hybrid buses, reduced air resistance, fuel efficient tyres, etc. The CO_2 cap is defined by the public transport authority, but national or EU legislation could also demand for a certain fuel efficiency improvement per year. The CO_2 cap could be linked to the number of loaded vehicle kilometres driven.

Another option is to define a target or limit value for the emissions per passenger-kilometre. However, this needs significantly more monitoring efforts by the operator.

Several Dutch cities (Amsterdam, Rotterdam) have defined a climate reduction programme, but refrain from setting explicit targets for the transport operator.

In 1999, the Dutch Railways (NS) signed a Long Term Agreement on energy efficiency (LTA) with the Dutch Ministry of Economic Affairs. According to the agreement NS must improve the energy efficiency by 11% from 1997 to 2010. Characteristic of this kind of non-binding targets is that parties agree that measures with a pay back time of less than 5 years will be taken. Parties can not be legally bound to the agreed goals. Such non-binding agreements could be transformed into binding targets in the future. However, formal legislation needs better underpinning and description of the demands and need to be legally tenable.

7.2 Logistics

At the moment carbon footprints of logistics are being studied in many EU member states and many companies and working groups are developing guidelines for the calculation of the footprint of the distribution of goods. The European Normalisation Institute (CEN) is developing a standard for the measurement of the CO_2 emissions of transport services, including logistics. . There is also ongoing work to develop Environment Product Declaration (EPD) rules for transport and emissions and they should be ready in 2010. In France, a proposal for a Directive has been issued that enforces to print the CO_2 emissions associated with a delivery on the delivery note. Due to this development, France has initiated the development of an EU wide standard for measuring CO_2 due to logistics. Also the UK has announced that they will install a working group to discuss the development of a standard.

A regulatory standard for the transportation of goods could be expressed in terms of g/tonkm. However, setting a baseline is very difficult because several design parameters need to be taken into account:

Design parameter	**Illustration**
The nature of goods	Low density goods limit the mass that can be loaded
The nature of the transport	Load factors differ for the different modes Detour factors between line haul and distribution significantly differ

The guidelines that are followed for carbon foot printing over the EU are very different at the moment. Questions as how to deal with transhipment, detouring and empty running first need to be aligned. To be able to regulate CO_2 emissions of logistics, a lot of work needs to be done to develop a common framework.

The guidelines first need to be finished before regulatory standards can be designed and baselines set. Once the guidelines and baselines have been set, GHG indexes can be used in contracts between market parties and also the government can set a certain baseline for individual companies. Another option is to differentiate taxes (e.g. road taxes) on the basis of the GHG index performance. Such options need the developments of baseliner per subsector, and are therefore only possible on the longer term, after 2020.

An option to start with in the nearer future is obligatory carbon footprinting for transport companies on the basis of a CEN standard. Under section 6.2 we already indicated some of the practical hurdles of introduction of operational indexes.

7.3 Urban areas

It is also possible to set targets for urban areas. The urban areas are then responsible for the reduction of the emissions in their area. Setting this kind of targets does not include the setting of standards for vehicles, operations or companies as is the case in with the regulation of public transport and logistics. Setting a target for urban areas means that a cap is set on the emissions that may be generated in an area. Urban areas can not regulate vehicle emissions. However, they can have major influence on:

- Transport efficiency (load factors)
- Transport movements
- The use of public transport
- The use of bikes
- Technology development

Establishing environmental zones is a powerful regulatory instrument at the local level. Some cities already have zones that are only accessible to electric cars.

The regional nature of such regulation can be very beneficial for tailor-made solutions, that fit within the local circumstances. Also the local context contributes to the communication between local authorities and stakeholders.

Also for the method of setting this kind of targets or standards, first it needs to be determined how the emissions are measured. For example the emissions of energy use are not in the region. Also a strong monitoring system is needed.

Setting a cap for urban areas might also include emissions of other sectors and is not limited to transport alone.

In the EU, more than 600 cities go beyond the objectives of EU energy policy in terms of reduction in CO_2 emissions. The Covenant of Mayors is a commitment by more than 600 signatory towns and cities to through enhanced energy efficiency and cleaner energy production and use. The covenant of Mayors is a non-binding initiative that contains elements that could be used for a binding system. However, a solid legal basis is needed for such an approach.

7.4 Personal carbon budgets

A last option is to work with personal carbon budgets, tradable or non-tradable. In the case of a non-tradable system, people are only allowed to drive a limited amount of kilometres in their car. Under the cap, carbon permits might be distributed on the basis of people characteristics like: school going/job/retiring, household size and welfare work.

The system of transit rights known as Ecopoints shows some similarities with a personal carbon budget. This system applied to heavy goods vehicles (HGV) with a gross weight of more than 7.5 tons passing through Austria, whether loaded or empty. Ecopoints quotas were distributed annually by the European Commission among Member States.

A personal carbon budget will trigger citizens' attention for fuel efficiency and developments in this area. Also the cost and benefits of trips will be outweighed better than is the case at the moment. The effect of such a system depends on the cap set by the government.

Tradable system are being discussed more intensively at the moment (a.o. [Raux, 2004]), carbon permits can be traded from the one to another. Several studies indicate, however, that fuel suppliers are a more appropriate party for trading, since the transaction costs are high in a system where end users (car owners) will be the trading party [CE Delft, 2008]. Paper 7 elaborates on this subject.

8 Conclusions

Regulation of vehicle emissions

- In Europe regulation of CO_2 emissions has recently been agreed for passenger cars and will be proposed for light commercial vehicles soon. Activities in support of defining appropriate means for regulating CO_2 emissions from HD vehicles (trucks and buses) are being started. For other modes there is no EU policy yet, but some initiatives in international context are being taken;
- It is likely that there will be a need to continue to regulate and to further tighten regulatory targets for GHG emissions from road vehicles over the whole period until 2050. Regulation is expected to remain useful also as an accompanying measure after the introduction of economic instruments such as a cap & trade system or CO_2 taxation;
- It seems likely that these types of regulations will need to be extended to other modes of transport (in particular if their share of transport GHG emissions increases as foreseen for ships and aviation) as discussed in section 6 and as already proposed by ICAO for aircraft. To what extent this is the domain of the European Commission remains to be discussed;
- However, due to changes that can be expected in vehicles and energy use, the nature of GHG emission regulation for transport may need to change to take better account of WTW energy emissions and embedded energy in vehicles. An alternative to a WTW-based regulation for vehicles would be a coordinated development of TTW regulation for vehicles and WTT regulation for fuels and other energy carriers, to ensure that a transition to powertrains using other energy carriers brings the desired net WTW GHG emission reductions. In the longer run a regulation of the life cycle impacts of vehicle production and decommissioning could also be considered;
- An important prerequisite for setting emission standards or regulatory targets / limit values is the availability of appropriate test procedures. These are also relevant for other, flanking measures such as labelling and CO_2 differentiation of taxes. An important issue for further development of these test procedures is to improve the correlation between reduction measured on the type approval test and effects on emission under real-world driving conditions;
- In addition to regulating emission at the vehicle level it may be useful to introduce efficiency regulations for a number of relevant vehicle components. Such regulatory standards could replace the provisions for "eco-innovation" in the current legislation for passenger cars, especially for options that are difficult to incorporate in a future revision of the type approval test procedure for vehicle emissions and fuel consumption.
- In general a regulatory framework for reducing CO_2 emissions from road vehicles should as much as possible:
    - o be technology neutral;
    - o allow flexibility for manufacturers to comply with the targets in the most cost effective way;
    - o avoid undesired market distortions;
    - o maintain of even promote the industry’s global competitiveness;
    - o support the required transition towards sustainable vehicles and energy carriers.
- Depending on e.g. future GHG reduction targets or market trends, for the longer term it may need to be considered to replace the present regulatory approach based on setting targets for the sales-averaged CO_2 emissions per manufacturer using a utility-based limit function by a less flexible approach. Possible options for this include e.g.:
    - o emission limits per vehicle, setting an absolute emission maximum, either on its own (individual vehicle emission limits) or in combination with fleet averaging (as an upper limit);
    - o using utility-based limit curves that penalise high emitters (flattening out for high values of the utility parameter);

  - using utility parameters that more directly relate to the true transport functionality (transport capacity), such as number of seats and trunk space;
  - using bin-based systems requiring increasing shares of vehicles over time to meet more stringent emission limits;
  - setting absolute restrictions on vehicle parameters (e.g. size, weight, power, power/mass ratio) or limitation of maximum speed or other performance indicators;
- Especially for other modes than road transport regulation of GHG emissions per unit of transport function (e.g. g/pass-km or g/tonkm) may become relevant.

Regulation of emissions from the energy chain

- The fuel quality directive 2009/30 and renewable energy directive 2009/28/EC contain provisions aimed at reducing the well-to-tank GHG emissions of energy carriers used in transport;
- In terms of GHG emission reduction from the energy chain, CO_2 regulation of the fuels seems a suitable way forward. It leaves the choice of CO_2 reduction measure and energy carrier up to the market, where the most cost effective measures (in terms of cost per tonne CO_2 reduction) are likely to be taken. Further reducing the CO_2 emission target in future regulation could thus provide an effective means to promote low-carbon fuels in the future. It would also help to counteract the trend towards higher WTT emissions in the production chain for conventional fuels.
- A renewable energy target impacts on GHG emission much more indirectly, as the GHG impact depends on the renewable energy used. However, it may provide a strong stimulus for renewable energy use in transport, which may reduce cost and promote investments in R&D. If the target is designed flexibly, allowing many different types of renewable energy to count towards the target (as is the case in the current RED directive), the market will be stimulated to find the most cost effective renewable energy solution for transport. Together with the CO_2 regulation of the fuels, this can be expected to result in a drive for low carbon renewable energy.
- In any case, the recent biofuels debate has shown that comprehensive sustainability criteria are essential to ensure that these policies do not lead to undesired and, in some cases, very significant negative effects on emissions, biodiversity, etc.. In view of the global impact on commodity and energy source markets, indirect effects should also be included in these criteria, as soon as possible. In the future, sustainability criteria may also be extended to other types of transport energy such as fossil fuels, hydrogen and electricity to ensure sustainability of fuels used.
- If electric transport increases in the future, the policies of the power sector come into play: the ETS sets a cap on CO_2 emissions, and various member states have implemented renewable energy policies. Further greening of the power sector, no doubt an important part of climate policy in the next decades, will then also reduce GHG emissions of the transport sector.
- The start that has been made on regulating WTW emissions from transport energy is likely to need to continue to ensure that appropriate signals are given to suppliers and users of transport energy in view of the fact that different actors only face and are able to impact on part of the emissions;

Regulation of other life cycle GHG emissions

- In addition to including well-to-tank impacts of energy carriers, at some point it may at some point become relevant to include GHG emissions (and other environmental impacts) originating from the production and decommissioning / recycling of vehicles in the regulation of GHG emissions from cars and other transport modes.
- It should be noted that some developments that contribute to meeting long term EU targets for vehicle efficiency and GHG emissions associated with driving, may conflict with the Directive 2000/53/EC on end-of-life vehicles[49]. The very targets for recycling and reuse

[49] Directive 2000/53/EC on end-of-life vehicles, see: http://ec.europa.eu/environment/waste/elv_index.htm

included in this directive may be difficult to reach for vehicles in which a large amount of composite is used to reduce vehicle weight.

General conclusions

- An integral set of policy instruments is necessary to regulate WTT and TTW emissions in such a way that the introduction of clean technologies, relevant for realising ambitious long term emission reduction levels, are stimulated without creating loopholes or even adverse impacts on WTW GHG emissions in the intermediate timeframe. In the long term a level playing field needs to be created in which improved conventional technologies and new options compete on the basis of cost effectiveness towards meeting environmental targets on the one hand and market attractiveness on the other hand. Combining an energy efficiency target at the vehicle level (rather than a CO_2 emission target) with a WTW GHG emission target at the level of energy carriers appears an option, but requires more research to investigate whether it provides better safeguards for realising net WTW emission reductions and against loopholes;
- In the longer term other emissions which cause radiative forcing may need to be taken into account. These include black carbon and N_2O emissions from combustion engines in general as well as impacts of emissions of water vapour and other substances by aircraft at high altitudes.
- It seems quite likely that some overarching measures as outlined in section 7 will increasingly need to be deployed to reinforce the effects of other policy instruments. A combination of vehicle regulation and measures targeting in-use parameters incentivises application of fuel efficient vehicles and optimal use of the vehicles. Therefore not only efforts in setting regulatory vehicle standards, but also in in-use standards for logistics, public transport, etcetera may be useful.

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