Reducing fuel consumption and CO2 emissions from motor transport

Petrovic Velimir[a], Knezevic Dragan[b], Sirotanovic Ivan[c] and Petrovic Stojan[b,c]

[a] IMR Institute, Belgrade, RS, vecapetrovic0@gmail.com
[b] University of Belgrade, Belgradey,RS, dknezevic@mas.bg.ac.rs
[c] TehnoLab CMV, Belgrade, RS, Ivans.ser@gmail.com

Abstract: Transport is responsible for around a quarter of World greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after industry. Road transport alone contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2). While emissions from other sectors are generally falling, those from transport have continued to increase until 2008 when transport emissions started to decrease on the back of oil prices, increased efficiency of passenger cars and slower growth in mobility. The paper presents the information on EU measures to reduce fuel consumption, as well as CO2 emissions from road transport introducing limits for CO2 emission from passenger cars, vans and heavy duty trucks. These limits follow ACEA voluntary agreement on fuel consumption reduction and define the targets for CO2 emission in the year 2015 and 2020**.**

Key words: CO2 emission, Fuel consumption, Motor vehicles, Transport

1. Introduction

Transport is the sector with the highest final energy consumption (accounting for 19% of global final energy consumption in 2007 in the World) and, without any significant policy changes, is forecast to remain so. Also, transport sector is the second biggest greenhouse gas emitter and more than two thirds of transport-related greenhouse gas emissions are from road transport. However, there are also significant emissions from the aviation and maritime sectors and these sectors are experiencing the fastest growth in emissions, meaning that policies to reduce greenhouse gas emissions are required for a range of transport modes. Additional problem is that transport will account for 97% of the increase in World primary oil use between 2007 and 2030. The consequent energy security and greenhouse gas emission implications of oil-dominated road transportation mean that reducing the fuel used in this sector is one of the highest priorities for all countries.

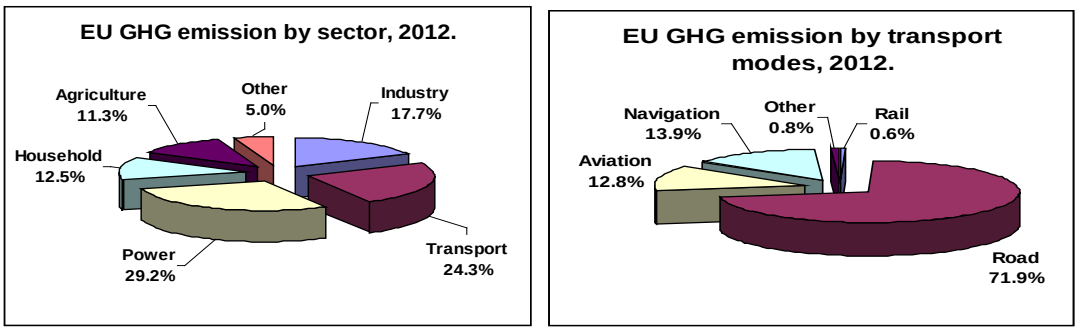

Figure 1. EU-28 greenhouse gas emissions by sector and mode of transport, 2012

Figure 1 shows EU28 greenhouse gas emissions by sector and mode of transport. In 2012 transport participates with almost 25% in total greenhouse gas emissions in EU. Also, road transport accounts more than 70% of total transport greenhouse gas emissions [1].

Figure 2 shows relative changes of greenhouse gas emissions in EU from different energy sectors relating to the greenhouse gas emissions in 1990 [1]. Greenhouse gas emissions in other sectors decreased 15% between 1990 and 2007 but emissions from transport increased 36% during the same period. This increase has happened despite improved vehicle efficiency because the amount of personal and freight transport has increased. Following economic crisis, since 2008 greenhouse gas emissions from transport have started to decrease. Despite this trend transport emissions were in 2012 still 20.5 % above 1990 levels and would need to fall by 67 % by 2050 to meet the 2011 Transport White Paper target reduction of 60% compared to 1990.

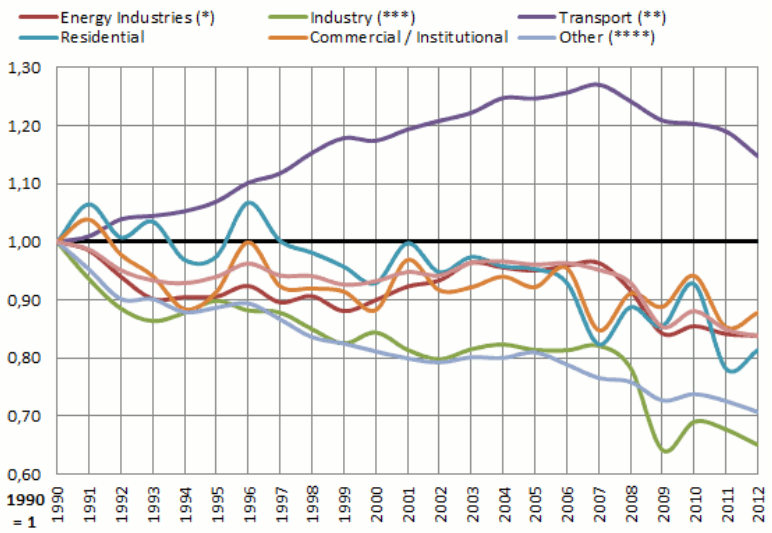

Figure 2. EU greenhouse gas emissions from transport and other sectors, 1990-2012

Road transport contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas. While these emissions fell by 3.3% in 2012, they are still 20.5% higher than in 1990. Transport is the only major sector in the EU where greenhouse gas emissions are still rising [2].

The objective of this paper is to present the measures undertaken in European Union for the reduction of fuel consumption and CO2 emissions. These maesures can be classified in two groop:

1. In first groop are mandatory measures that need technological improvments of engines for passenger cars, light commertial vehicles and heavy duty vehicles. The effects these measures can be checked during certification testing (subsections 2 to 4).
2. In second groop are measures for fuel consumptio reduction of vehicle in use. Their effects can not be cheched on test bed during certification, but they can additionally decrease fuel consumption (subsections 5 to 9).

2. Reducing CO2 emissions from passenger cars

Cars are responsible for around 12% of total EU emissions of carbon dioxide (CO_2).

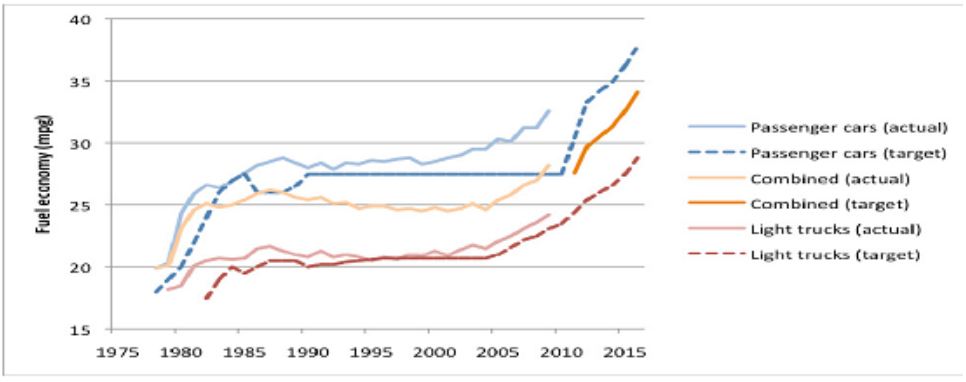

Figure 3. Fuel economy regulation in US [3]

Situation in the United States will be shortly mentioned as additional information. In US vehicle fuel economy has been regulated since 1975, when the Corporate Average Fuel Economy (CAFE) program started. Under CAFE, cars and light trucks up to 8 000 pounds (about 3 600 kg) are required to meet a minimum fuel economy target based on miles per gallon (MPG). Separate standards exist for cars and light trucks. The standards were initially set through the mid-1980s, and have been in force ever since at approximately the same levels, though in recent years the standard for light trucks has been raised. For cars, the standard can only be changed via Congressional legislation but for light trucks, the Department of Transportation (DOT) has the authority to set higher or lower standards. Actual fleet fuel economy to Model Year (MY) 2009 and CAFE standards up to MY 2016 are shown in Figure 3 [3].

In March 2009, the NHTSA (via the DOT) published the final rule of reformed CAFE program for passenger cars and light trucks (the Reformed CAFE), as well as standards for model year 2011. Under the Reformed CAFE system, each passenger car and light truck manufacturer is required to achieve the level of CAFE, which is based on each vehicle's target level and set according to vehicle size. The targets are assigned according to the vehicle's "footprint" (the product of the average track width multiplied by the wheelbase). Each vehicle is assigned to a target specific to the footprint value (Figure 4) [3]. Passenger vehicles and light trucks are still regulated separately but adhere to the same compliance methodology.

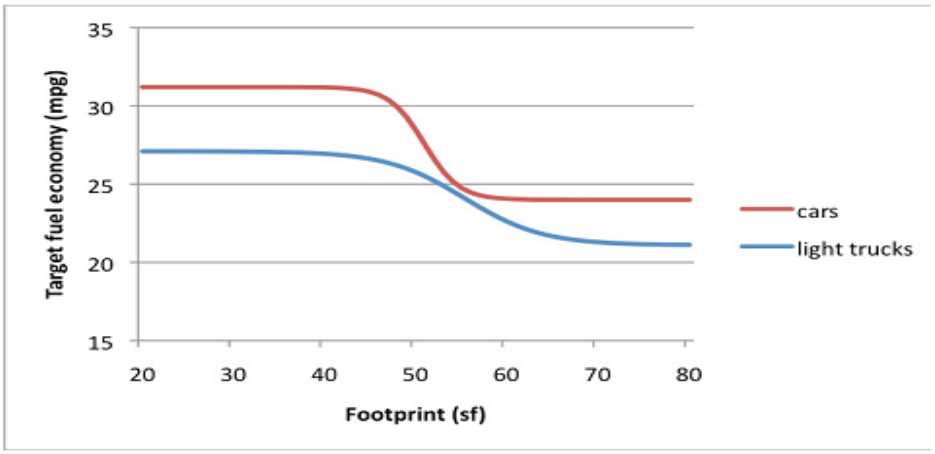

Figure 4. The Reformed CAFE targets for MY 2011 [3].

In April 2010, DOT and the Environmental Protection Agency (EPA) further revised the CAFE standards, which will improve the United States' fuel economy to 35.5mpg by 2016. This is equivalent to 6.6 L/100km and represents a 30% reduction in fuel use compared to the new light-duty vehicles in the United States in 2005. Although this represents a significant reduction in fuel economy over the period, it should also be stated that fleet fuel economy is much higher than in most other developed countries and will remain so even with a substantial reduction such as that planned.

In the late 1990s, the European Commission agreed with the European Automobile Manufacturers' Association (ACEA), the Japan Automobile Manufacturers' Association (JAMA) and the Korean Automobile Manufacturers' Association (KAMA) that each association would commit to the same quantified CO2 emission objective for the average new passenger car sold in the European Union. The content of the commitments was that the members of each of these associations should collectively achieve a CO2 emission target of 140 g CO2/km by 2008 (ACEA) or by 2009 (JAMA and KAMA). The problem of sharing the burden of the objective between the different manufacturers was left to each association itself to decide. While significant CO_2 emission reductions were achieved in the initial years, since around 2004 the manufacturers could no longer meet their voluntary targets. Although vehicle CO2 emissions reduced from 172 g/km to 153 g/km over the period 2000 to 2008 [4], in 2007 the Commission announced that "the strategy had brought only limited progress towards achieving the target of 120 g CO2/km by 2012" and that "the review of the strategy has concluded that the voluntary commitments has not succeeded and that the 120 g target will not be met on time without further measures" [5].

As a result, EU legislation sets mandatory emission reduction targets for new cars. This legislation is the cornerstone of the EU's strategy to improve the fuel economy of cars sold on the European market. In April 2009 the European Union adopted the Regulation (EC) No 443/2009 to reduce CO2 emission from passenger vehicles [6].This Regulation establishes CO2 emissions performance requirements for new passenger cars in order to ensure the proper functioning of the internal market and to achieve the overall objective of the European Community of 120 g CO2/km by 2015 as average emissions for the new car fleet. This Regulation sets the average CO2 emissions for new passenger cars at 130 g CO2/km, by means of improvement in vehicle engine technology, while complementary measures will contribute a further emissions cut of up to 10 g CO2/km, thus reducing overall emissions to 120 g CO2/km. These complementary measures include efficiency improvements for car components with the highest impact on fuel consumption, such as tyres and air conditioning systems, and a gradual reduction in the carbon content of road fuels, notably through greater

use of biofuels. An average of 130 g CO2/km means a fuel consumption of around 5.6 litres per 100 km (l/100 km) of petrol or 4.9 l/100 km of diesel. The average emissions level of a new car sold in EU in 2014 was 123.4 g CO_2/km well below the 2015 target. Since monitoring started under current legislation in 2010, emission has decreased by 17 g CO_2/km (12 %).

This regulation was amended in March 2014 by the Regulation (EU) No 333/2014 which sets a target of 95 g CO2/km for the average emissions of the new car fleet. This means a fuel consumption of around 4.1 l/100 km of petrol or 3.6 l/100 km of diesel. The 2015 and 2021 targets represent reductions of 18% and 40% respectively compared with the 2007 fleet average of 158.7g/km.

Each manufacturer must meet their fleet average specific emissions of CO2 (g/km). Specific emission for each car is defined by a limit value curve of permitted CO2 emissions for new cars according to the mass of the vehicle (Figure 5). This curve is set in such a way that a fleet average for all new cars of 130 g CO2/km is achieved. Actually, the cars with heavier mass have higher limits and the cars with lighter mass have lower limits. Only the fleet average is regulated, so manufacturers are still able to make vehicles with emissions above the curve provided these are balanced by vehicles below the curve.

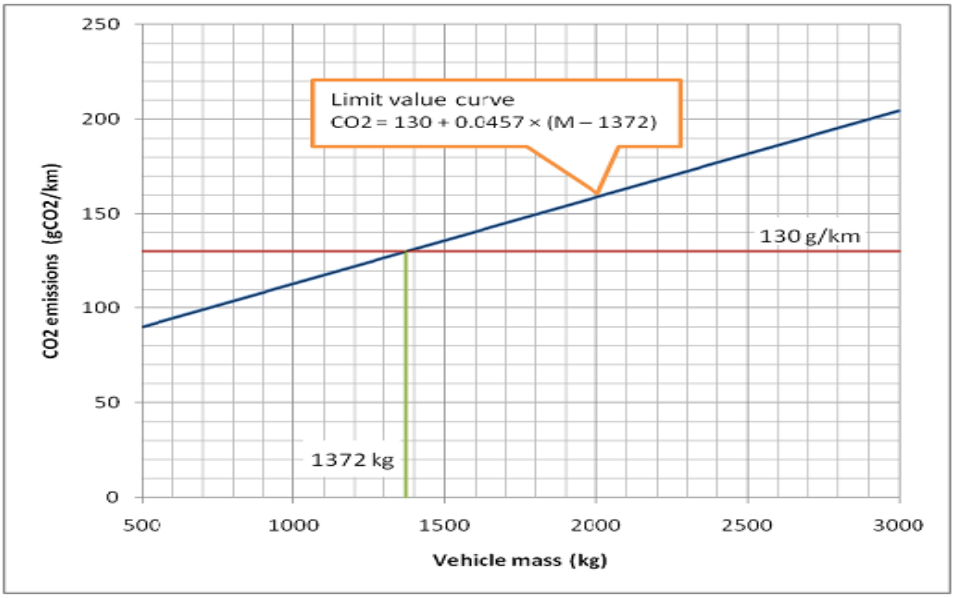

Figure 5. Value curve of permitted CO2 emissions for new cars [3]

Specific Emissions of CO_2 (g/km) of each new passenger car registered in that calendar year is calculated by formula [6]:

$$Specific\ Emissions\ of\ CO_2 = T + a \times (M - M_0) \quad (1)$$

where:

T is CO_2 emission target: $T = 130\ g/km$ from 2012 through 2019; and $T = 95\ g/km$ from 2020.
A is a coefficient: $a = 0.0457$ from 2012 through 2019; and $a = 0.0333$ from 2020.
M is mass of the vehicle (kg)
M_0 is average vehicle mass: $M_0 = 1372\ kg$ for calendar years 2012-2015. $M_0 = 1392.4\ kg$ for 2016. From 2016, the value of M_0 is adjusted annually to reflect the average mass of passenger cars in the previous three calendar years.

The specific emissions target for a manufacturer in a calendar year shall be calculated as the average of the specific emissions of CO2 of each new passenger car registered in that calendar year of which it is the manufacturer. A manufacturer will be required to ensure that the average emissions of all new vehicles are below the average of the permitted emissions for specific cars given by the curve. In 2012 65% of each manufacturer's newly registered vehicles 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. A shorter phase-in period will apply to the target of 95g/km. 95% of each manufacturer's new cars will have to comply with the limit value curve in 2020, increasing to 100% in 2021.

In the initial period, certain types of vehicles receive additional incentives:

- Vehicles of CO_2 emissions below 50 g/km receive *super-credits*. Under the 2015 regulation, each such vehicle is counted as 3.5 cars in 2012 and 2013, as 2.5 cars in 2014, 1.5 cars in 2015, and as 1 car from 2016 through 2019.
- The 2020 regulation also allows super-credits, capped at 7.5 g/km, to apply from 2020 to 2022. Each car emitting < 50 g/km will count as 2 cars in 2020, 1.67 cars in 2021, 1.33 cars in 2022, and as 1 car from 2023.
- CO_2 emissions of vehicles capable of running on a mixture of gasoline with 85% ethanol (E85) are reduced by 5% until the end of 2015. This reduction applies only where at least 30% of the filling stations in a Member State provide E85.

Certain flexibilities are available for manufacturers, as follows:

- Pooling—Several manufacturers may form a pool to jointly meet their CO_2 emission targets.
- Low volume manufacturers—Manufacturers with fewer than 10,000 new cars registered per annum may apply to the European Commission for a derogation from the specific emission targets. Several conditions apply.
- Eco-innovation— Innovative technologies can help cut emissions, but in some cases it is not possible to demonstrate the CO_2-reducing effects of a new technology during the test procedure used for vehicle type approval. Manufacturers may apply for credits for innovative CO_2 reducing technologies which are not accounted for in the current test cycle—for example, energy efficient lights. The total contribution of eco-innovation credits is limited to 7 g CO_2/km in each manufacturer's average specific target.

Manufacturers who miss their average CO_2 targets are subject to penalties:

- From 2012 to 2018, the penalties are €5 per vehicle for the first g/km of CO_2; €15 for the second gram; €25 for the third gram; €95 from the fourth gram onwards.
- From 2019, manufacturers will pay €95 for each g/km exceeding the target.

3. Reducing CO2 emissions light commercial vehicles

In May 2011 European Parliament adopted the Regulation (EU) No 510/2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO2 emissions from light-duty vehicles. The regulation is applicable to vehicles category N_1 with a reference mass not exceeding 2610 kg [8].

This Regulation sets the fleet average CO2 emissions for new light commercial vehicles at 175 g CO2/km, by means of improvements in vehicle technology. From 2020, this Regulation sets a target of 147 g CO2/km for the average emissions of new light commercial vehicles registered in the Union subject to confirmation of its feasibility.

Regulation No 510/2011 is very similar to EU Regulation No 443/209 and also it defines specific emission of CO2 according the similar formula (1). However the value T is 175 from 2014 to 2019 and 147 since 2020, coefficient a is 0.093 from 2014 to 2019 and 0.96and M_0 is 1706 kg from year 2014 to 2017, but from 2018 the value of M_0 is adjusted annually to reflect the average mass of passenger cars in the previous three calendar years. EU regulation No 253/2014 from February 2014 amended the Regulation No 510/2011, confirmed the target 147 g CO2/km from 2020 onwards and defined the value $T = 147$ *g/km* and $a=0.096$ from 2020 onwards.

Also, all other details are similar [8]:

- Manufacturers must meet their average emission targets in 70% of their LCV vehicle fleet in 2014, 75% in 2015, 80% in 2016, and 100% from 2017 onwards.
- Vehicles with extremely low emissions, below 50 g/km, are given additional incentives in the initial period—one low emitting vehicle will be counted as 3.5 vehicles in 2014 and 2015, as 2.5 vehicles in 2016, 1.5 vehicles in 2017, and 1 vehicle from 2018. There are no super-credits under the 2020 regulation.
- The penalties for manufacturers who fail to meet their average targets are: until 2018 the penalty is €5 per vehicle for the first g/km of exceedance, €15 for the second g/km, €25 for the third g/km, and €120 for each subsequent g/km and From 2019, the penalty is €120 for each g/km exceeding the target.

Other provisions on biofuels application, eco-innovation, pooling and low volume production are similar as for passenger cars.

4. Reducing CO2 emissions from Heavy-Duty Vehicles

Trucks, buses and coaches produce about a quarter of CO_2 emissions from road transport in the EU and some 5% of the EU's total greenhouse gas emissions – a greater share than international aviation or shipping. Despite some improvements in fuel efficiency, CO_2 emissions from HDTV's rose by some 36% between 1990 and 2010, mainly due to increasing road freight traffic. Projections indicate that, without policy action, total HDV emissions would still be close to current levels in 2030 and 2050.

This is clearly incompatible with the goal of reducing greenhouse gas emissions from transport by around 60% below 1990 levels by 2050. While CO_2 emissions from new cars and vans are being successfully reduced under recent EU legislation, despite the economic importance of fuel consumption, CO_2 emissions from HDVs are currently neither measured nor reported. Strategy for reducing Heavy-Duty Vehicles' fuel consumption and CO2 emissions, adopted in May 2014, is the EU's first initiative to tackle such emissions from trucks, buses and coaches [10].

The proposed strategy, aiming at providing stakeholders with more predictability as regards policy and regulatory developments in this field, consists of short-term actions to bring more transparency to the market and foster emission reductions, being:

- a series of initiatives foreseen in the Transport White Paper reinforcing existing EU policies that directly or indirectly contribute to curbing HDV fuel consumption and CO2 emissions;
- an action to address the identified knowledge gap by measuring HDV fuel consumption and CO2 emissions by means of a computer simulation tool VECTO [vecot-en EE], as well as certifying and reporting newly registered vehicles' CO2 emissions. The Commission is planning to make legislative proposals by the end of 2015.

Once these short-term actions are implemented, and based on the findings of further analytical work, medium term policy options, including the setting of mandatory CO2 emission limits for newly registered HDVs would be considered in order to support the implementation of the EU 2030 climate and energy policy framework. This will contribute to a more transparent and competitive market and the adoption of the most energy-efficient technologies

5. ECO driving

Eco-driving [12] is the operation of a vehicle in a manner that minimizes fuel consumption and CO2 emissions. It includes:

- Optimizing gear changing.
- Avoiding vehicle idling, e.g. by turning the engine off when the vehicle is stationary.
- Avoiding rapid acceleration and deceleration.
- Driving at efficient speeds. The most efficient speed for most cars is between 60 km/h and 90 km/h. Above 120 km/h, fuel efficiency falls significantly in most vehicles.
- Reducing weight by removing unnecessary items from the car, and reducing wind resistance by removing roof attachments such as ski racks.

Used together, these steps could save up to 20% of the fuel used by some drivers and possibly 5% to 10% on average across all drivers on a lasting basis.

In 2012 European Commission adopted the Regulation (EU) No 65/2012 [13] implementing the Regulation (EC) No 661/2009 [14], which stipulates the mandatory fitting of a gear shift indicator (GSI) to all new passenger cars with manual transmission and have a reference mass not exceeding 2 610 kg, as a part of European strategy on reducing CO2 emissions from road vehicles. The GSI is an indicator, which displays shifting up or down signs on the instrument panel to ensure optimal gear changing and thereby improve fuel efficiency.

Under European Union regulations, it is compulsory to teach eco-driving to novice drivers [12]. The implementation of eco-driving training, as a part of the driving license education, can improve fuel economy. Many countries have implemented eco-driving through national and regional eco-driving programmes. 5-10% less fuel consumption of participants of Ecodriving courses

6. Fuel efficient tyres

Roughly 20% of a motor vehicle's fuel consumption is used to overcome rolling resistance of the tyres [15]. The amount of rolling resistance is a function of the level of inflation of the tyres and the technical rolling resistance of the tyre material.

Additional fuel is required when tyres are underinflated. In most real-world driving conditions, tyres are underinflated compared to their optimum performance level. Data presented at the IEA Tyre Workshop in 2005 showed that in the European Union, the tyres in service were underinflated by 0.2 to 0.4 bar on average for passenger cars and 0.5 bar for trucks. It is generally understood that these numbers correspond to an increase in energy consumption and CO2 emissions of roughly 1% to 2.5% for passenger cars, and 1% for trucks. Tyre pressure monitoring systems are a valuable tool for both car safety and fuel economy purposes. Information is sent to drivers when their tyres need inflation, which encourages better vehicle fuel efficiency. Installing tyre pressure monitoring systems could be expected to improve tyre maintenance and lead to an improvement in the range of 1% to 2% in overall non-powertrain vehicle efficiency.

Concerning the technical rolling resistance of tyres, tyres with low rolling resistance are already available on the market. In the European Union, some modern tyres have a rolling resistance of up to 30% lower than the best tyres produced in the early 1980s, while the worst tyres on the market have twice the rolling resistance of the best. Auto manufacturers already carefully minimize rolling resistance of tyres fitted to new cars because this is an effective way to comply with fuel economy standards. However, the rolling resistance of tyres in the replacement market could be higher than those offered on new cars, so the fuel savings from the low rolling resistance tyres could be lost after the original tyres wear out. Consumers may not always purchase low rolling resistance tyres as replacement tyres due to their high initial cost, the lack of clear information provided, and limited market availability [16].

The fitting of the best replacement tyres and the more effective maintenance of tyre pressures could save about 3% of the fuel used in LDVs (equivalent to around 70 Mtoe and 190 Mt CO2 in the medium term worldwide). In the absence of policy intervention, there would be very weak incentives for both manufacturers and consumers, because tyre inflation pressure in the real world and rolling resistance of replacement tyres are not subjected to current fuel economy standards. Therefore, efficiency measures for tyres and proper maintenance of tyre inflation pressure represent important complementary measures to fuel economy standards

The European Union has made major steps forward on tire-related measures in 2009. In July 2009, the European Union adopted the regulation "concerning type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefore" [14] as a part of European strategy to reduce CO2 emissions from road vehicles. Another corresponding regulation to reduce CO2 emissions from new passenger cars initially proposed an emissions' target of 120 g CO2/km; however it faced strong opposition from industry so an "integrated approach" [6] was added to soften the targets. This entailed an average target of 130 g CO2/km emissions for a fleet. Complementary measures are required to contribute a further emissions cut of up to 10 g CO2/km, thus reducing overall emissions to 120 g CO2/km. These complementary measures include efficiency improvements for car components with the highest impact on fuel consumption, such as tyres and air conditioning systems, and a gradual reduction in the carbon content of road fuels, notably through greater use of biofuels. Efficiency requirements for these components are being discussed and will be introduced for these car components.

After many months of discussion and negotiation, the United Nations Economic Commission for Europe (UN ECE) requirements on tyre pressure monitoring systems was finally published on 10th November 2010. These new requirements have been published as an 02 series of amendments to ECE Regulation No. 64.02 [17], which now covers temporary use spare wheels and tyres, run flat tyres and tyre pressure monitoring systems.

The above regulation on the type approval of vehicles and their components contains several measures for tyres including mandatory fitting of tyre pressure monitoring systems (TPMC) and limit of tyre rolling resistance as parts of general vehicle safety measures. Mandatory fitting of TPMS will be required by November 2012 for new passenger cars and by November 2014 for all newly-registered passenger cars. Technical requirements for TPMS will be defined by UNECE regulation 64, as performance-based requirements.

In addition, other measures on the characteristics of the tyre itself, such as the introduction of wet grip requirements and limit values on rolling resistance and tightening noise limits, are also included in the regulation EC 661/2009. Wet grip requirements will be applied to tyres for passenger cars. Limit values on rolling resistance and tightening noise limits will be applied to tyres for passenger cars, light commercial vehicles and heavy-duty vehicles. The rolling resistance of tyres will be measured in accordance with ISO 28580, the same for those in the United States. These measures will be applied to original tyres installed on new vehicles as well as replacement tyres, from 2012-2016, depending on tyre categories. The European Commission will develop implementing measures by the end of 2010.

Furthermore, the European Union also adopted a separate regulation on "the labeling of tyres with respect to fuel efficiency and other essential parameters" (EC 1222/2009) in November 2009 [18]. Fuel efficiency, wet grip and external rolling noise of tyres will be indicated in the label. Similar to measures for tyre rolling resistance and noise limits, this regulation will cover almost all tyres used on public roads, such as tyres for passenger cars, light commercial vehicles and heavy-duty vehicles. Tyre labels will be displayed at the point of sale and in technical promotional literature, including websites, by November 2012. This label will allow consumers to make more informed choices and should result in fuel cost savings, as well as a reduction of CO2 emissions, from vehicles.

7. Vehicle fuel consumption labelling

Comprehensive, high quality information is a prerequisite for sound decision making. In order for customers to purchase the most efficient vehicles on the market, they must first know about the efficiency levels of the vehicles under consideration. Labels showing fuel economy and CO2 emissions values and displayed on vehicles are necessary to inform consumers about the fuel efficiency characteristics of the vehicle in question. However, experience in the European Union shows that labels in isolation do not reduce vehicle emissions. A review of EU labelling policy demonstrated that the highest level of success in influencing consumers' vehicle purchasing behaviour occurred when fuel economy and CO2 emissions labels were combined with fiscal incentives.

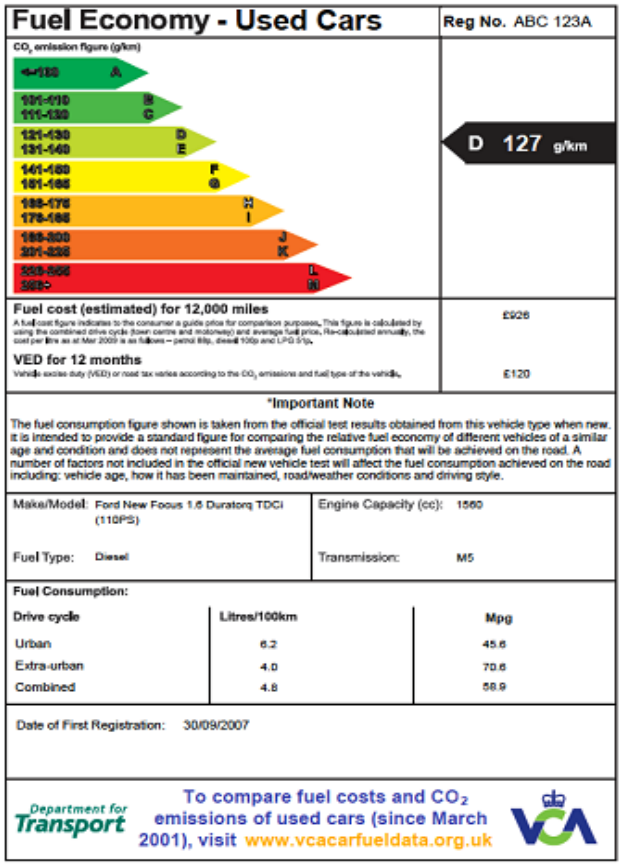

Figure 6. Car label used in UK [21]

Passenger car lebelling is introduced in European Commission Directive 199/94/EC [19]. This consumer information system is to be set up using the following four methods:

1. Attaching a fuel consumption and CO2 emissions label to the windscreen of all new passenger cars at the point of sale;
2. Producing a fuel consumption and CO2 emissions guide for all vehicles in the market;
3. Displaying posters with data on fuel consumption and CO2 emissions for all vehicles in car showrooms;
4. Including fuel consumption and CO2 emissions data in promotional material.

The form of the information is also important because people must be able relate to it. Many people may not appreciate the implications of fuel economy or CO2 emissions from official test procedures. More useful information is often focused on the annual fuel costs. A valuable addition to the vehicle labels is a guide available in showrooms and on the Internet that provides the fuel economy and CO2 emissions values of all vehicles on the market. This enables consumers to view the characteristics of other vehicles that they might not have otherwise considered.

An example of car label is shown in Figure 6.

8. Fiscal incentives

In the first instance financial incentives or penalties, in combination with sound information, intentivise the purchase of more energy efficient vehicles and so can accelerate the deployment of energy efficient technologies [19]. The vehicle tax systems of many countries, in Europe particularly, are now based on vehicle CO2 emissions and research has shown that consumers respond quickly to such financial incentives. For example, in Ireland in the five months after the introduction of the new CO2 emissions differentiated annual motor and vehicle registration taxes on 30 July 2008, the percentage of passenger cars sold in the lowest emissions bands A to C (under 155 g CO2/km) soared from 41% to 83% (O'Gallachoir et al., 2009). The European Commission has for many years called for the "inclusion of a CO2 element in car taxes" Europe-wide; however it has not received approval from the European Council and therefore this element of the European Union strategy remains the responsibility of individual member states.

Tax measures are an important tool in shaping consumer demand towards fuel efficient cars, and help create a market for breakthrough technologies, notably during the introduction phase. CO 2 taxation for passenger cars is well established across the European Union.

In 2007, 11 Member States had CO2-related taxation, 14 in 2008, 16 in 2009, and 17 Member States in 2010. In 2011, the 19 EU countries that levy passenger car taxes partially or totally based on the car's carbon dioxide (CO2) emissions and/or fuel consumption are: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Latvia, Luxembourg, Malta, the Netherlands, Portugal, Romania, Slovenia, Spain, Sweden and the United Kingdom. Now also Croatia. In addition, an increasing number of countries – 16 EU Member States at present – provide purchase incentives and/or tax benefits for electric and/or hybrid electric vehicles [21].

9. Modal shift

An important policy goal in transport energy efficiency is to shift passengers and freight from roads to more sustainable modes of transport such as bicycles, efficient public transport, shipping, and rail (called modal shift). It is estimated that the benefits significantly outweigh the costs in many cases [22]. For example, a recent study in the United States estimated that "high quality public transit typically requires about USD 268 in additional subsidies and USD 104 in additional fares annually per capita, but provides vehicle, parking and road cost savings averaging USD 1 040 per capita, plus other benefits including congestion reductions, increased traffic safety, pollution reductions, improved mobility for non-drivers, improved fitness and health" [3]. Policy intervention is generally needed to encourage modal shift since market failures result in a higher than optimal level of road transport use. Cheaper fuel prices for many years have been partly to blame for the increase in passenger car and road freight transport use. There are also challenges to achieving modal shift caused by unsustainable land use planning, such as urban sprawl and dispersed rural populations with associated car dependency. Additionally, public transport is often perceived as less attractive in terms of the quality and price of services provided. All these issues need to be addressed with policy measures if passenger and freight modal shift is to occur.

Policies for passenger modal shift generally include improving public transport services and infrastructure and increasing its attractiveness to potential passengers through information campaigns and improving practical features, such as integrated ticketing, real time travel information and lower fares. There have been many studies documenting the impact that policies can have on increasing public transport usage [23]. It is often argued in transport strategy consultations that transport policy measures, such as fiscal measures e.g. penalising car travel, should not be implemented unless there are other available modes of transport. Therefore good infrastructure in modes other than road transport is needed if other transport policies are to be implemented.

10. The effects of fuel reducing measures

The introduction of measures for reducing fuel consumption and CO2 emission has led to the reduction of greenhouse gases emission from motor vehicle. Figure 7 show actual situation and targets for passenger cars CO2 emission in different region of the World. Japan and Europe are in the best position, and North America normally has bigeer cars and than higher consumption. However all regions expect that after 2020 CO2 emission should be less than 130 gCO2/km, in Europe below 100 gCO2/km

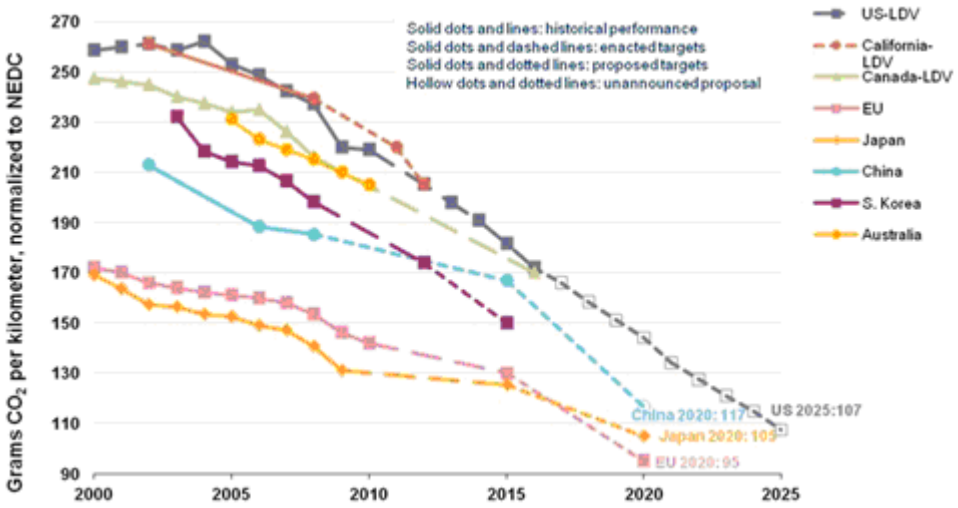

Figure 7. Trends and forecast of passenger cars CO2 emissions [24].

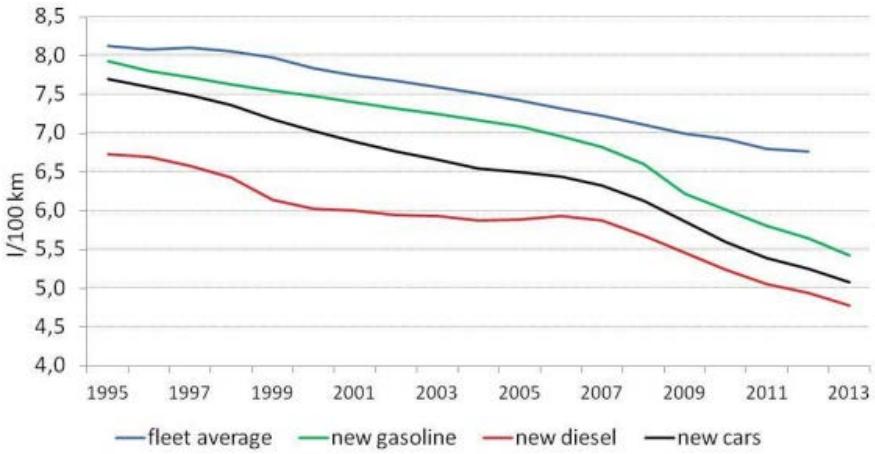

Figure 8. Average fuel consumption of new cars and fleet average in EU [2].

Figure 8 shows the average fuel consumption of new gasoline and diesel cars, as well as of total new cars in EU. The reducing rend is obvious. Normally diesel cars have the advantage. The figure also shows the average fuel consumption of complete fleet of new and old cars in traffic. The average consumption of total fleet is bigger for about 1.5 l/100km.

Figure 9 shows the fuel consumption of new cars sold in different EU countries in 2013. EU average is 6 lit/100km. Portugal is in the best position and Croatia has the highest consumption.

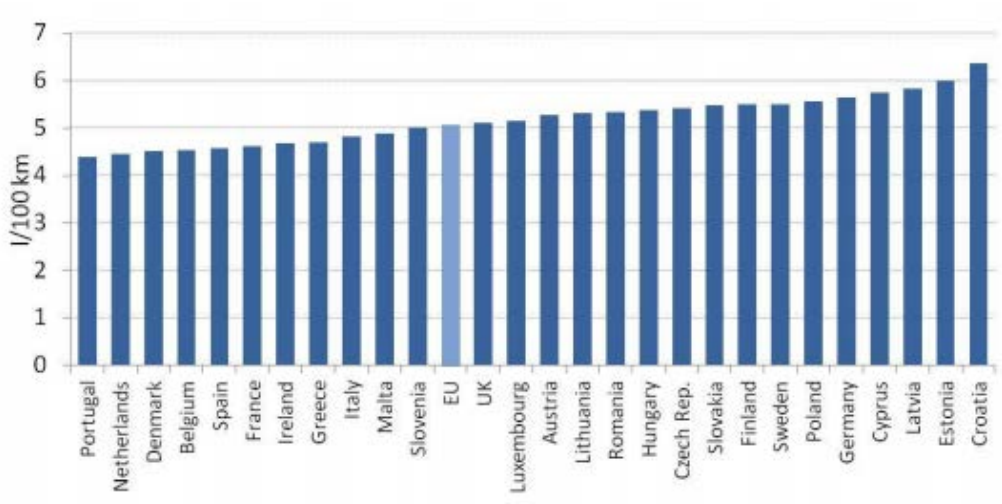

Figure 9. Average fuel consumption of new cars in the different EU counyries (2013) [22].

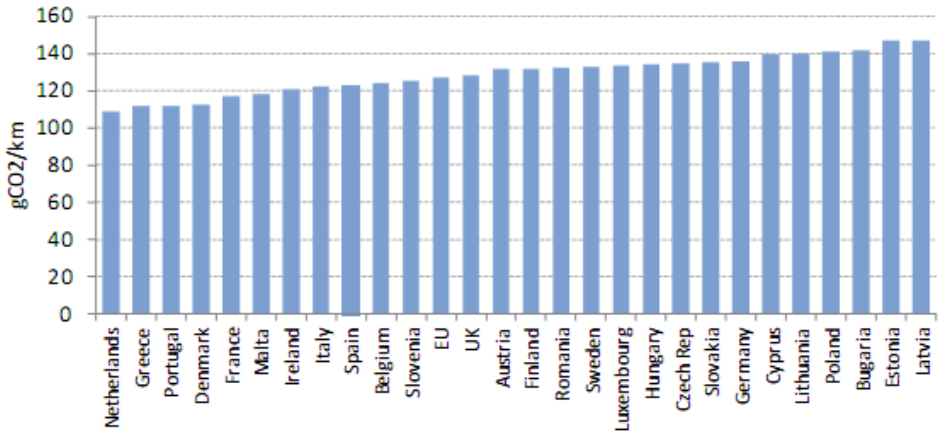

Figure 10. Average CO2 emissions of new cars in different EU countries (2013) [2].

Similar situation, but not the same, is with CO2 emission shown in Figure 10. The CO2 emission depends on fuel type, so Netherlands and Portugal have changed the place, but Baltic countries are still at the top. EU average is bellow 130 gCO2/km, what was the target for 2015. This is also shown in Figure 11.

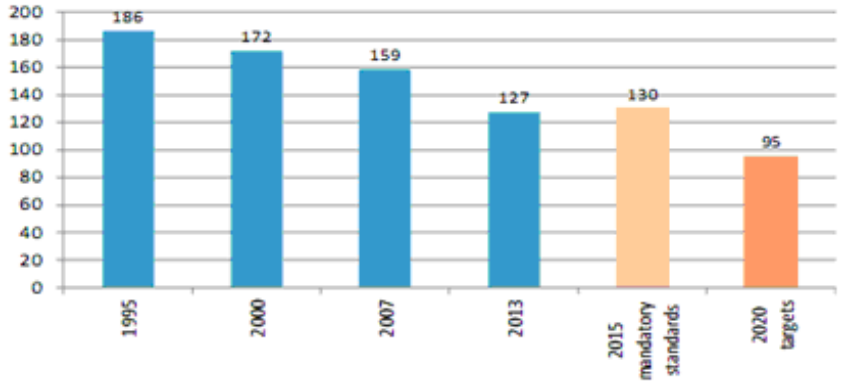

Figure 11. Average CO2 emissions of new cars: observed values and targets [2].

Figure 12 shows the share of different of cars grouped according the level of CO2 emissions. Low emissions cars are dominant in the present and high emission cars are dominant in the past.

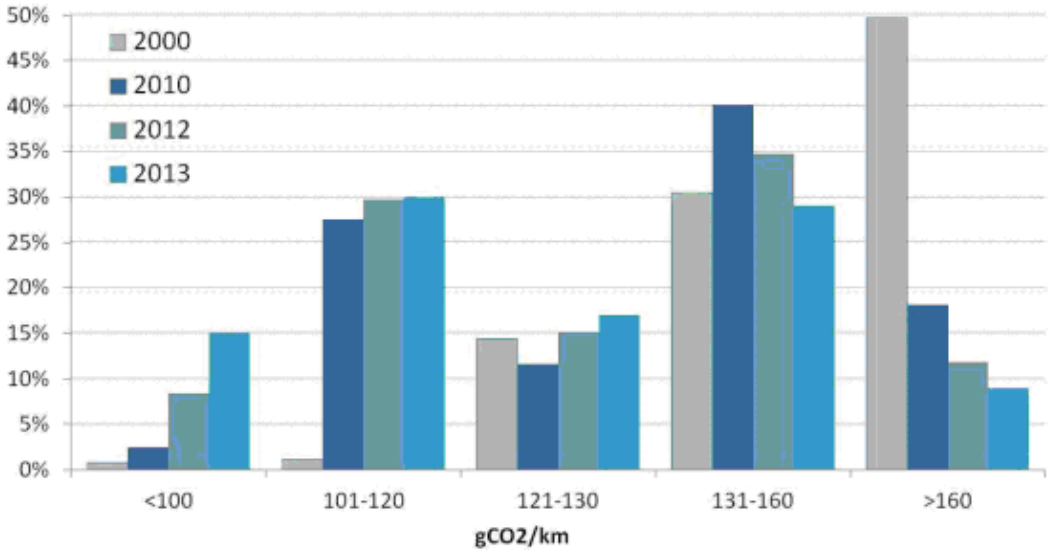

Figure 12. Market share of new low emission cars in EU [2].

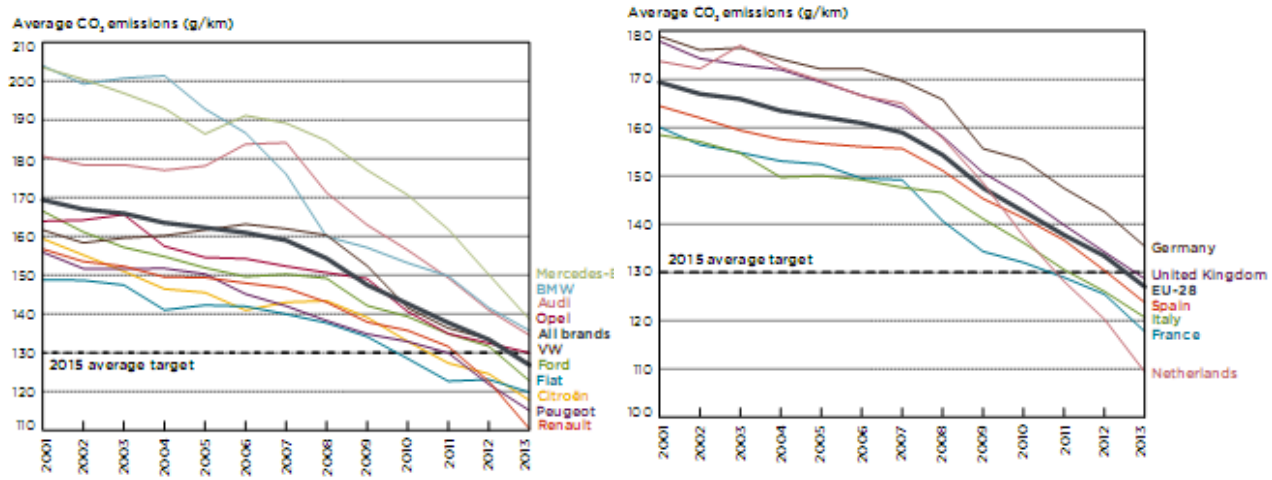

Figure 13. Average CO2 emissions of different manufacturs and different EU countries

Figure 13 shows CO2 emission trends by different manufacturers and by countries. French companies have lowest emission and German highest. Of course, this emission depends on the car size.

11. Conclusions

The European Union has introduced a number of measures for reducing fuel consumption and CO2 emissions. The measures have been mainly address to passenger cars which fuel consumption is steady decreasing. Main maesures are addressing mandatory reduction of average fleet of vehicles for each manufacturer. Other measures are: eco-driving, fuel consumption labelling, use of efficient tyres, fiscal tax, modal shift, efficient tyres etc.

Introduced CO2 emissions targets for passenger cars in 2015 and 2020 should additionally decrease CO2 emissions. The target for 2015 is already achieved and it is expecting also for 2020.

CO2 emissions targets for for light comertial vehicles for 2017 and 2020 have been adopted, but for heavy duty vehicles the targets should be defined by the end of 2015.

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