Action Plan

A report compiled within the European research project

Deriving effective least-cost policy strategies for alternative automotive concepts and alternative fuels-ALTER-MOTIVE

Intelligent Energy – Europe (IEE), STEER
Contract no. IEE/07/807/SI2.499569

Supported by INTELLIGENT ENERGY EUROPE

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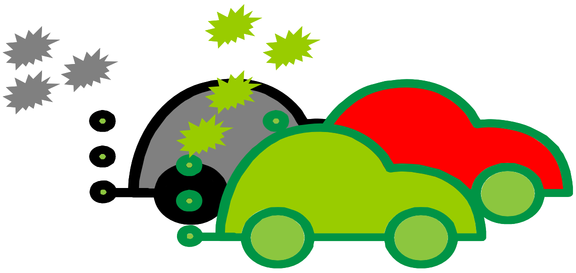
(work package 6 – deliverable D16)



Authors:
Amela Ajanovic, Reinhard Haas – EEG
Ingo Bunzeck, Bas van Bree – ECN
Sandro Furlan – ECU
Felipe Toro – IREES
Lulin Radulov, Vera Genadieva – BSERC
Laurent Cogerino– RAEE
Myrsini Christou – CRES
Adam Gula – KISE
Maria Grahn – CHALMERS
Manuel Fernandes, Mario Alves – CEEETA-ECO
Anne-Mette Wehmüller – EcoCouncil

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Project consortium:

EEG - Vienna University of Technology, Energy Economics Group, Institute of Power Systems and Energy Economics, Austria (Project co-ordinator)

Energy Research Centre of the Netherlands, ECN, The Netherlands

Eni Corporate University S.P.A. (ENI), Italy

Institute for Resource Efficiency and Energy Strategies, Germany

Wuppertal Institute for Climate, Environment and Energy, Germany

AEOLIKI Ltd, (AEOLIKI), Cyprus

Black Sea Regional Energy Center (BSREC), Bulgaria

Rhônalpénergie-Environnement, France

Centre for Renewable Energy Sources (CRES), Greece

The Krakow Institute for Sustainable Energy (KISE), Poland

Chalmers University of Technology, Sweden

Austrian Mobility Research Mobility Telematics & Clean Propulsion Systems

CEEETA-ECO, Portugal

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Contact details:
Project coordinator and lead author of this report:
Amela Ajanovic
Vienna University of Technology, Energy Economics Group (EEG)
Gusshausstr. 25-29/370-3, A-1040 Vienna, Austria
Email: Ajanovic@eeg.tuwien.ac.at

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1. Introduction

This report summarizes the major perceptions and recommendations for action of the EU-funded project ALTER-MOTIVE. The core objective of this project is to derive effective least-cost policy strategies to achieve a significant increase in innovative alternative fuels (AF) and corresponding alternative more efficient automotive technologies (AAMT) to head towards a sustainable transport system.

The major focus of this report is on policies and actions to reduce CO_2 emissions in Europe. Its purpose is to serve as a concise guide-book for action towards a sustainable European passenger car transport system. It addresses and intends to support policy makers and civil servants in EU-27 countries as well as members of the European Parliament and officers of the EU-legislation.

Since this Action Plan encompasses results achieved in the scope of the project ALTER-MOTIVE, the main focus is on the following specific targets:

- achieve a significant increase in innovative alternative fuels;
- achieve a significant increase in corresponding alternative more efficient automotive technologies;
- achieve a significant improvement of efficiency of conventional technologies (and of transport systems in general);

However, for the successful and sustainable reduction of CO_2 emissions a very broad portfolio of different actions and measures is required addressing in addition the following general targets (going beyond the scope of ALTER-MOTIVE):

- reduce traffic in general by implementing transport avoiding measures;
- achieve reduced emissions by changing drivers' behaviour, e.g. eco-driving.
- achieve a shift to more efficient and more environmentally benign transport modes.

1.1. Motivation and European policy targets

In 2008, the EU agreed to a 'climate and energy package' and the so called 20-20-20-targets. This package supports the EU's strategic objective of limiting global warming to no more than 2^o C above pre-industrial temperature, as set out in the 2007 Bali Climate Declaration and included in the 2009 Copenhagen Accord (EC, 2007a; Allan et al, 2007; UNFCCC, 2009).

The ambition of the EU policy is threefold: to combat climate change, reduce dependence on (imported) fossil fuels and to promote rural development, growth and jobs.

The 20-20-20 targets provide concrete goals which state that

- at least 20% renewable fuels should be used in the energy sector;

- at least 20% CO_2 emission[1] reduction (compared to the 1990 level);
- at least 20% energy efficiency improvements by 2020;
- at least 10% renewable fuels for transport (attached to the 20-20-20-target (EC, 2008; EC, 2009b)).

Since transport accounts for about a quarter of EU greenhouse gas (GHG) emissions – the only sector with increasing trend, see Figure 1a – a large part of these targets must be directed to this sector. It is especially important to focus on road transport as it contributes with about 23% to the EU's total emissions of GHG, see Figure 1b. Passenger cars alone contribute to 70% of road transport GHG emissions in the EU (EU, 2011).

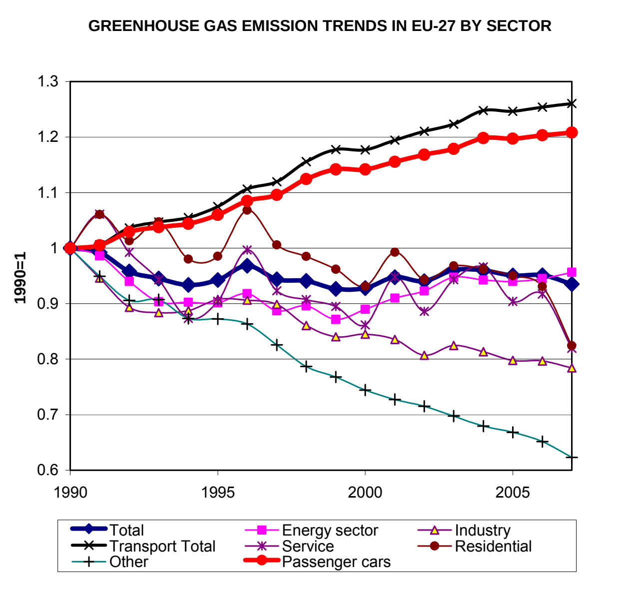


Figure 1a. Greenhouse gas emission trends in EU-27 by sector (EU, 2010)

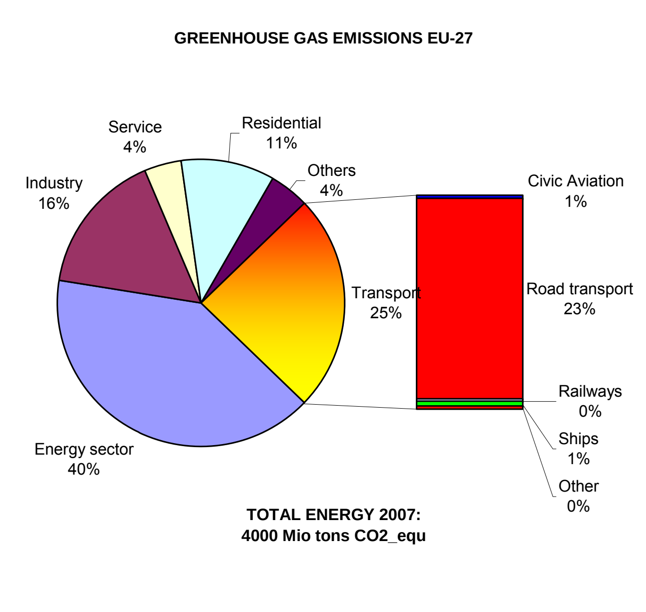


Figure 1b. Share of Greenhouse gas emissions in EU-27 by sector in 2007 (only domestic transport considered) (EU, 2010)

So the major challenges for EU climate and energy policy are to implement effective policies and measures to mitigate global warming, to improve air quality and to reduce energy consumption, see Figure 2. A wide range of EU policies to lower emissions from passenger car transport is already in place, such as emissions targets for new cars; targets to reduce the greenhouse gas intensity of fuels; labelling requirements etc.

For sustainable development in passenger car transport an integrated approach based on cooperation between policy makers, car industry and car users is necessary. This should ensure reduction of GHG emission at lowest costs for all involved sides.

[1] Note that throughout this report the term "CO_2" corresponds to "CO_2-equivalents" of greenhouse gas emissions

Hence, it is obvious that urgent action is required to meet these EU-targets. The motivation for conducting the project ALTER-MOTIVE is to provide a sound base which actions are most effective for CO_2 reduction with lowest burden for the European society.

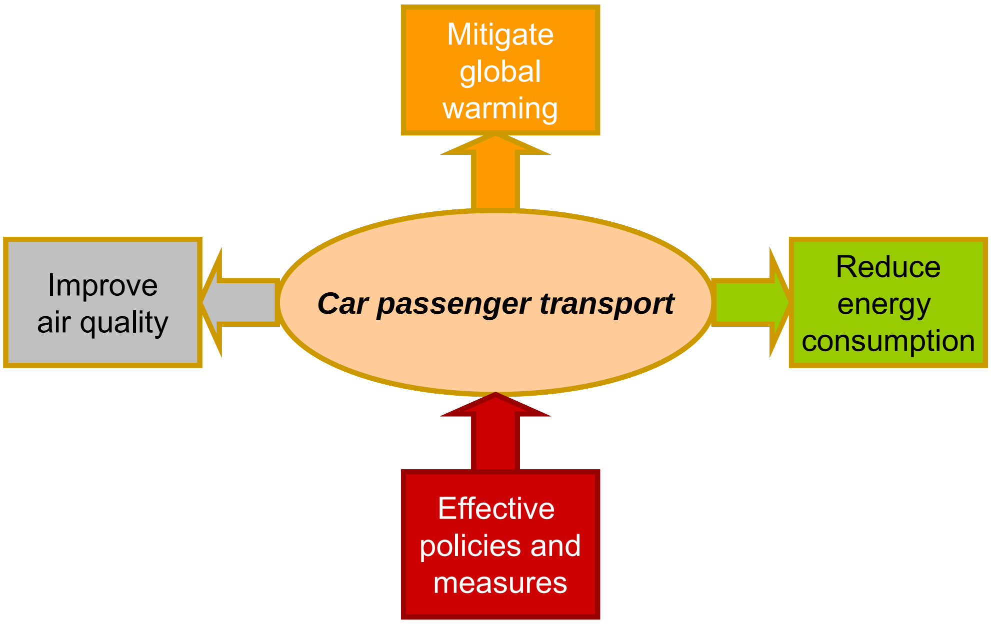


Figure 2. The challenges for EU climate and energy policies

1.2. Objective of the Action Plan and method of approach

The objective of this Action Plan is to provide key findings and targeted recommendations for policy makers and stakeholders (e.g. car manufactures civil servants and officers in transport ministries) regarding the activities that could improve the environmental performance of the transport system and bring EU countries closer to the EU targets for 2020.

To meeting this objective we proceeded as depicted in Figure 3. To provide recommendations for policy makers and stakeholders regarding the activities that could improve the environmental performance of the transport system we have in the scope of the ALTER-MOTIVE project done comprehensive top-down and bottom-up analysis related to AF and AAMT. Within the bottom-up analyses we have collected and documented about 130 individual case studies – see www.alter-motive.org – and investigated around 80 of these case studies in detail from economic, ecological and energetic point-of-view, see Cebrat, Ajanovic (2010).

However, beside our analyses we have also considered stakeholders', policy makers' and experts' opinions. To discuss the proposals of the Action Plan and project results and to receive national feedback, nine national workshops were organised in different EU countries (Sweden, France, Germany, Portugal, Poland, Italy, Austria, The Netherlands, Greece).

Moreover, within the ALTER-MOTIVE website (www.alter-motive.org) an online discussion forum was created to collect feedback on some of our ideas and results.

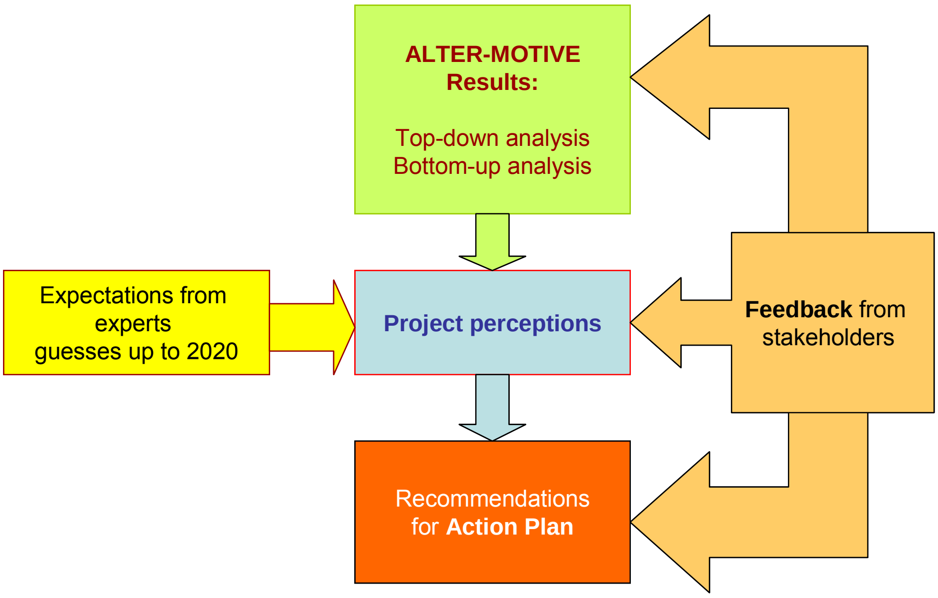


Figure 3. Action plan – method of approach

Finally, to show the impact of different policy actions on the future development in passenger car transport as well as on the reduction of CO_2 emissions we have derived scenarios. These scenarios should help policy makers to visualize short and mid-term effect of implemented policy measures. The scenarios are described in Chapter 5.

1.3. Currently implemented EU policy[2]

The Community strategy for heading towards sustainable transport proposed by the Commission in 1995[3] and subsequently supported by the Council and European Parliament (EC, 2007) has been based on three pillars, see Figure 4.

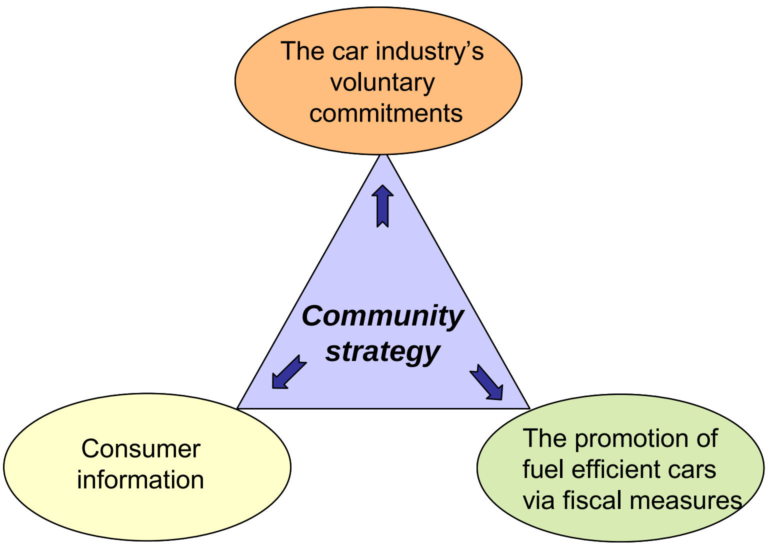


Figure 4. The three pillars of the Community strategy

[2] Close to the deadline of this document, the "White paper" of the EC has been published, see EC: WHITE PAPER – Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, Brussels, 28.3.2011, COM(2011) 144 final. Its content is not yet referred in this work.

[3] COM(95) 689, Council conclusions of 25.6.1996, European Parliament resolution of 22.9.1997.

This structure encompasses both supply (voluntary commitments) and demand (labelling and taxation) measures, and was adopted after a wide ranging analysis of possible options to reduce CO_2 from cars.

First pillar: car industry voluntary commitments

In 2007 the EC adopted a target for reduction of average CO_2 emissions from new cars to 120 gCO_2/km by 2012 - a reduction of around 25% from 2006 levels. However, already in 2010 it could be noticed, that this goal of reducing emissions of new cars was not likely to be achieved (EC, 2010), see Figure 5. This figure shows the development of CO_2 emissions from new passenger cars by association as well as the voluntary commitments undertaken by the car manufacturer associations related to average new car emission targets of 140 gCO_2/km by 2008/2009.

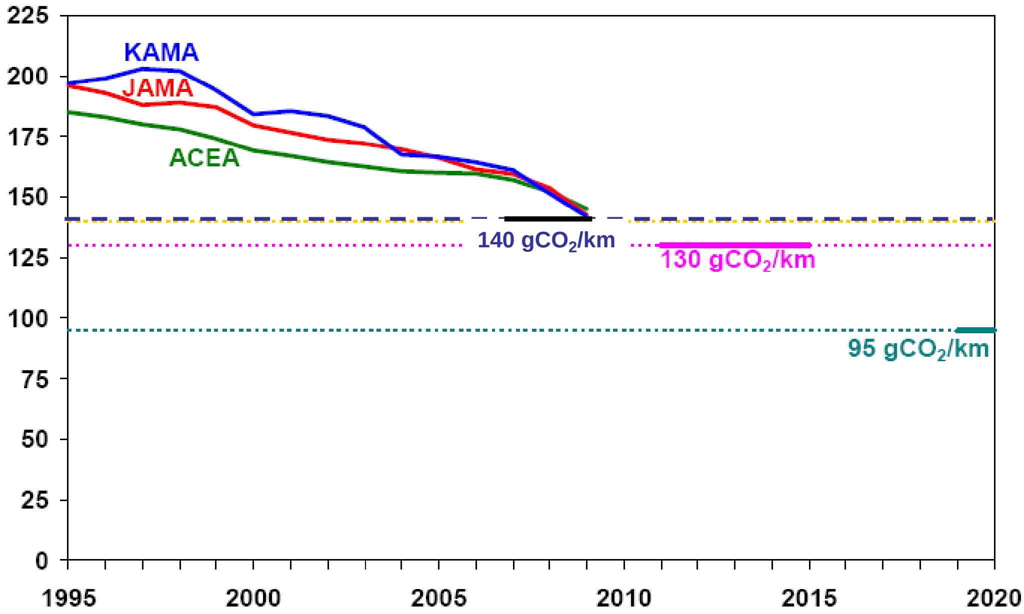


Figure 5. Evolution of CO_2 emissions from new passenger cars by the European (ACEA), Japanese (JAMA) and Korean (KAMA) car manufacturer associations (adjusted for changes in the test cycle procedure) (EC, 2010)

Yet, despite a low probability of achieving the 2012 target, the strategy, and the measures it includes, still plays an important role in reducing CO_2 emissions from light-duty vehicles. So since the achievement of the EU objective of 120 gCO_2/km in 2012 is not likely, a new objective implemented by Regulation (EC) No443/2009 is to achieve 130 gCO_2/km in the period 2012-2015. A target of 95 gCO_2/km announced in the Strategy as a target for further consideration is included for 2020. This reduction of average CO_2 emissions from new cars can be achieved by means of improvements in vehicle motor technology as well as with the increased use of biofuels and by a reduction of the size of vehicles

Second pillar: consumer information

Behaviour oriented measures, such as fuel economy labels, a guide on fuel economy and CO_2 emissions, home location and choice of vehicle and type of transport, etc., are important to increase public awareness regarding the environmental problems caused by car passenger transport. A number of Member States already promote eco-driving, which could have an energy saving potential up to 15% (EC, 2010).

Third pillar: the promotion of fuel efficient cars via fiscal measures

Taxation has a track record as policy instrument. Efficient taxation policies can promote the purchase of fuel efficient cars and could significantly contribute to the reduction of CO_2 emissions in transport sector (EC, 2007). Mostly used fiscal policy measures are registration taxes, annual circulation taxes and excise duties.

The specific actions of the EC linked to the scope of the “Strategy” in the timeline 2010-2020 include review of modalities of reaching the 2020 target of 95 gCO_2/km set out in the cars legislation, and possibly modalities of the long-term target as proposed in the draft regulation on CO_2 from light commercial vehicles. In addition, the EC is committed to propose a new test-cycle to reflect more accurately the real world driving conditions as well as the specific CO_2 emissions and fuel consumption related to it (EC, 2010).

1.4. Organisation of the Action Plan

In this report we first describe the starting point for action by documenting where we are. We document the current situation with respect to CO_2 emissions and energy consumption for EU-15 countries and show the major historical developments and trends.

In Chapter 3 we look at how CO_2 emissions come about and identify the major categories of impact factors which are: vehicle kilometre driven, efficiency of cars, size of cars, CO_2 emission factors of fuels, and individual driving behaviour. For these five categories we further describe in Chapter 4, which policies work and how we can act to change these impact factors. This description of possible action is based on the analyses in different work packages of ALTER-MOTIVE. In this context the major guidelines for action are: switch (to more environmentally benign fuels), reduce (vehicle km driven), improve (efficiency of cars).

Chapter 5 presents the major results of the derived scenarios. The priorities of actions and the way forward are described in the sixth chapter. Conclusions summarizing the key messages complete this Action Plan.

2. The starting point: Recent developments in passenger road transport

First, in this section we present a summary of the major developments in car passenger transport in the EU as the starting point for the analyses in the following chapters. Note that in most figures the major focus is on EU-15. The major reason for this is that reliable data for time series on energy consumption of passenger cars are only available for this subset of countries and not for most of the other countries.

2.1. Energy consumption of passenger car transport

Overall energy consumption of passenger car transport in Europe is continuously increasing, as shown in Figure 6 for EU-15. In 2007 it amounted to about 7 EJ. This is an increase of 28% in comparison to the year 1990. The continuous increase of the market share of diesel fuel can be noticed. As Figure 6 depicts gasoline contributed by 55% in total fuel consumption in 2007 (compared to 81% in 1990), diesel with 41% (17% in 1990), and alternative fuels with 4% (2% in 1990), see also Ajanovic ed., 2009. The share of alternative fuels in car passenger transport in EU is with about 4% very small, but continuously increasing, especially since 2005, see Figure 7. The mostly used alternative fuels are biofuels. The share of CNG, electricity or other alternative fuels is currently low in almost all analysed countries.

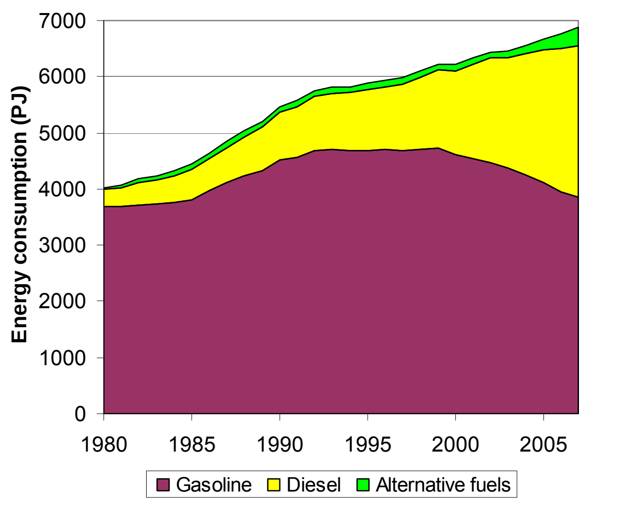


Figure 6. Energy consumption in car passenger transport in EU-15 by fuel, 1980 – 2007

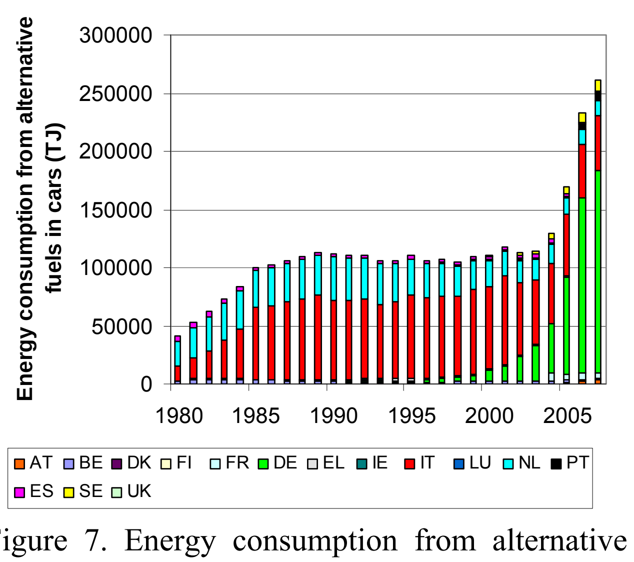


Figure 7. Energy consumption from alternative fuels in car transport in EU-15 by country, 1980 – 2007

2.2. Progress in biofuels production in EU-27

Currently, the most important alternative fuels are biodiesel and bioethanol. The recent developments of biofuels production in European Member States are shown in following figures.

Due to the national targets and EU's biofuels promotion policy, biofuels production has increased significantly in the last few years, see Figure 8a. For 2008 the largest amounts of biofuels are found in Germany, France, Austria and Lithuania. The average for the EU-27 amounted to 3% in 2008 (calculated in proportion to the respective fuel consumption of Member States), (EBTP, 2011). In the European Union by 2020 10% of energy used in transport should be from renewable energy sources, certified biofuels in practical terms.

A comparison of biofuels production in 2009 by country is shown in Figure 8b.

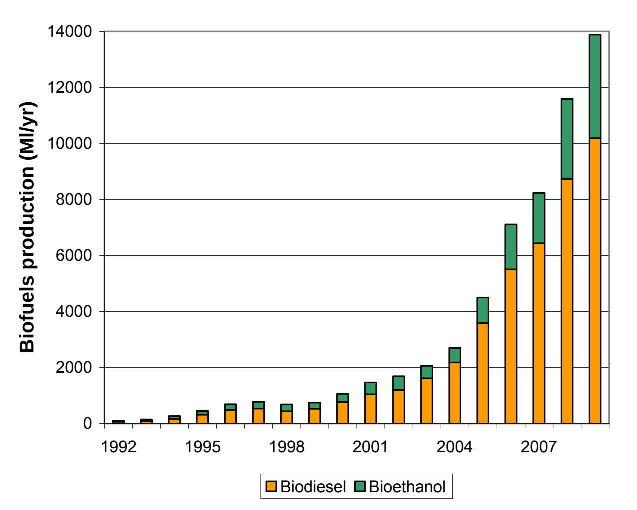


Figure 8a. Recent trends in biofuels production in EU-27 (Data source: EBTP, 2011)

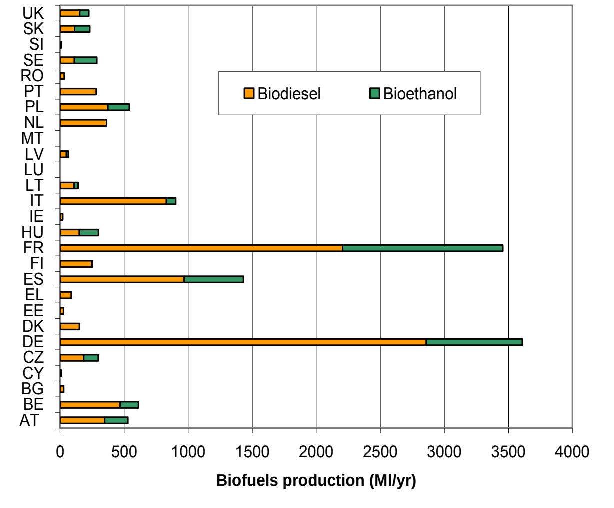


Figure 8b. Comparison of biofuel production in 2009 in EU-27 countries (Data source: EBTP, 2011)

2.3. Development of fuel prices

Fuel prices have a significant impact on travel demand and fuel intensity. They were rather volatile during the last three decades. The development of fossil fuel prices – a weighted average of gasoline and diesel - in selected EU countries for the period 1980 to 2007 is shown in Figure 9. The general characteristics were high price levels in the early 1980s, remarkable drops after 1985, stagnation up to 1999 and finally in recent years since 2003 rather continuous increases. In 2009 prices dropped in all countries – due to the economic crisis – but recovered fast in 2010.

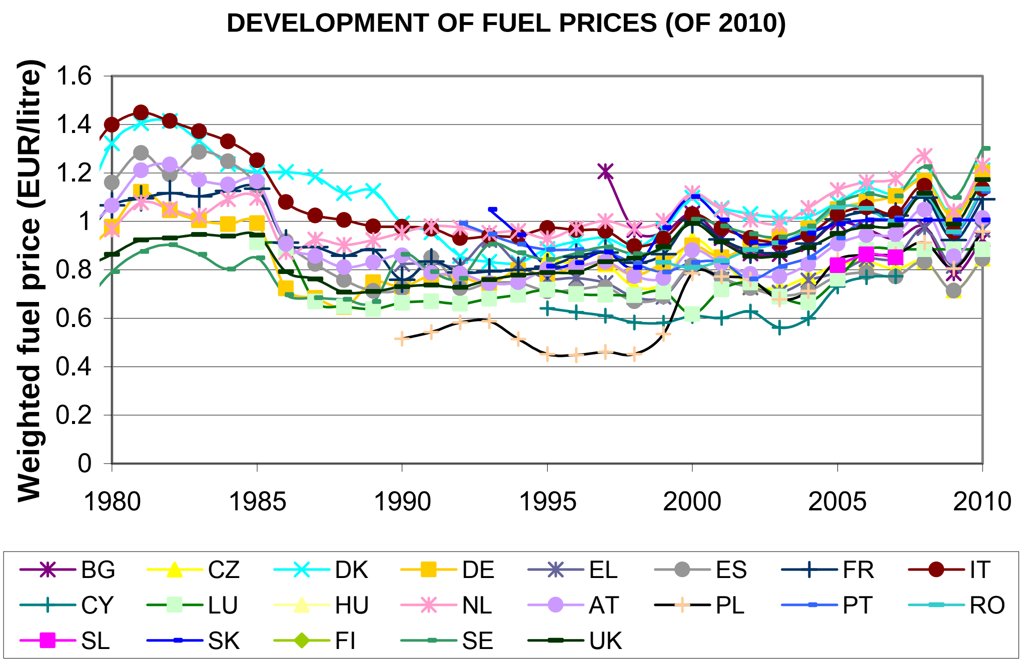


Figure 9. Weighted fuel prices (including all taxes) for EU countries 1980 – 2010 (in prices of 2010, numbers for 2010 preliminary) (Source: EEP; IEA, 2010)

The range of fuel prices vary wide across the analyzed countries mostly due to the different taxes. The share of total tax (VAT and excise taxes) on gasoline is very different across the EU-countries ranging from 40% to 60% of the total gasoline price, see Figure 10. Actually, the largest part of fuel price in most of the countries is tax. Currently, the highest tax on gasoline is in the Netherlands, Germany and Sweden. In eighteen EU countries the share of tax in total fuel price is more than 50%. The lowest tax on gasoline is in Cyprus.

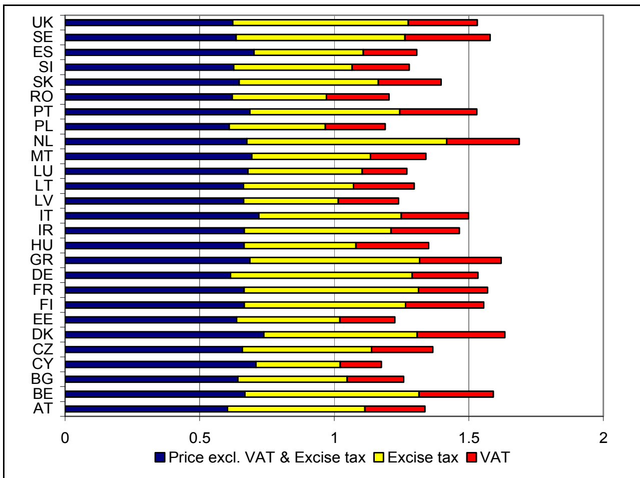


Figure 10. Price structure of gasoline in EU-27 (data source: EEP, 2011 - effective March 2, 2011)

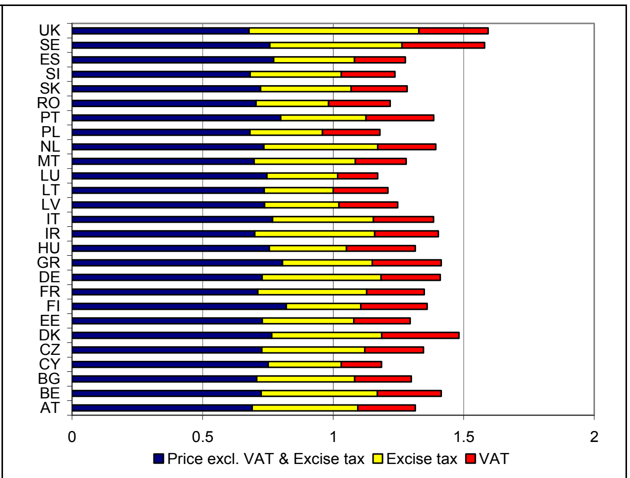


Figure 11. Diesel prices in 2011 for EU-27 (data source: EEP, 2011 - effective March 2, 2011)

The share of tax in total diesel price in 2011 is shown in Figure 11. Currently, the highest tax on diesel fuel is in United Kingdom, 0.92 EUR per litre of diesel. The share of tax in total diesel price is a little bit lower comparing to tax on gasoline. In EU the share of tax on diesel is in range from 36% to 57% of the total diesel price, see Figure 11.

2.4. Development of car stock

One of the main reasons for the increasing energy consumption in car passenger transport is the continuous increase in car ownership in all EU countries, see Figure 12. In 1970 it was ranging between 2 (Romania) and 280 (Sweden) cars per 1000 capita, in 2009 between 200 (Romania) and 685 (Luxemburg) cars per 1000 capita.

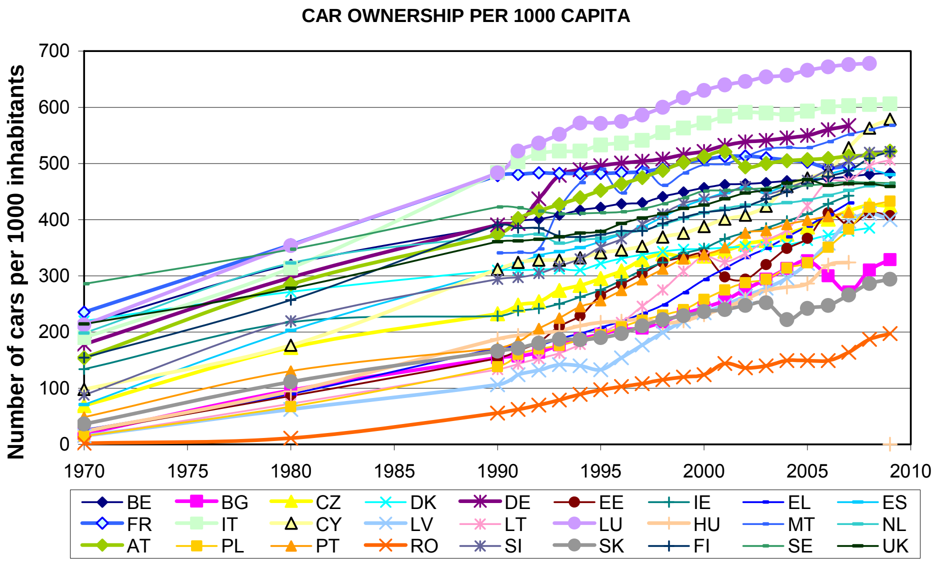


Figure 12. Car ownership per 1000 capita in EU-27 countries 1970 – 2009 (Source: EUROSTAT; ALTER-MOTIVE database)

Aside from the increasing car ownership also an increasing share of diesel cars can be noticed. One of the biggest advantages of choosing a diesel car is fuel economy. A diesel's extra 20 to 30 percent of fuel efficiency makes a difference. Out of town, some emit even less CO_2 than hybrids. This is one reason why diesels are becoming a more and more popular choice (ACEA, 2011).

As shown in Figure 13, in 1998 in most of European countries the share of diesel cars was relatively low. However, already in 2008 in some EU countries the share of diesel was remarkably higher than gasoline share, e.g. in Austria, Belgium, France.

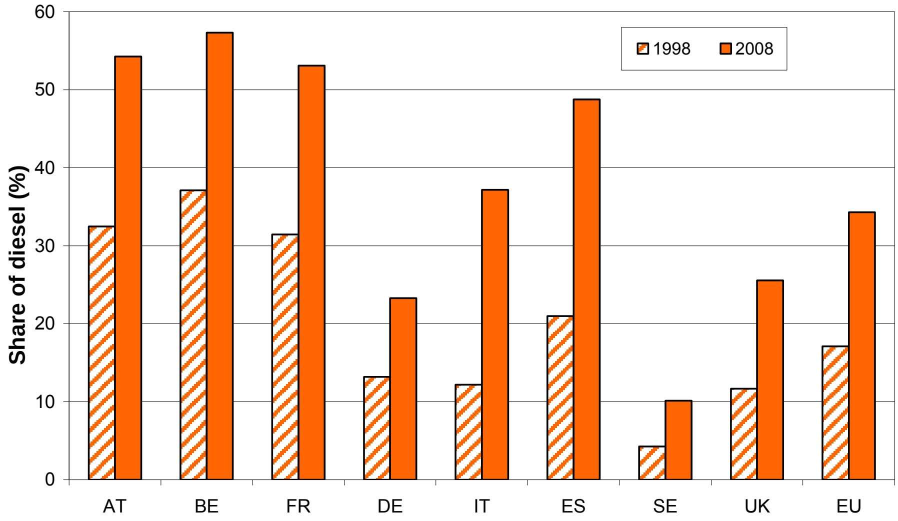


Figure 13. Share of the stock of diesel cars in total fossil fuel consumption, selected EU countries 1998 vs 2008 (data source: ODYSSEE database; ALTER-MOTIVE database)

2.5. Performance of new registered cars

The major features of new registered cars in EU-27 countries regarding fuel intensity, CO_2 emissions and power are depicted in the following figures. Figure 14 documents the wide range of CO_2 emissions of new cars in EU countries in 2009. There is a very broad range: while countries like France, Italy, Malta, Denmark and Portugal purchased on average cars with less than 140 gCO_2 /km the other extreme are Sweden, Bulgaria and the Baltic countries with more than 160 average gCO_2 /km per new car.

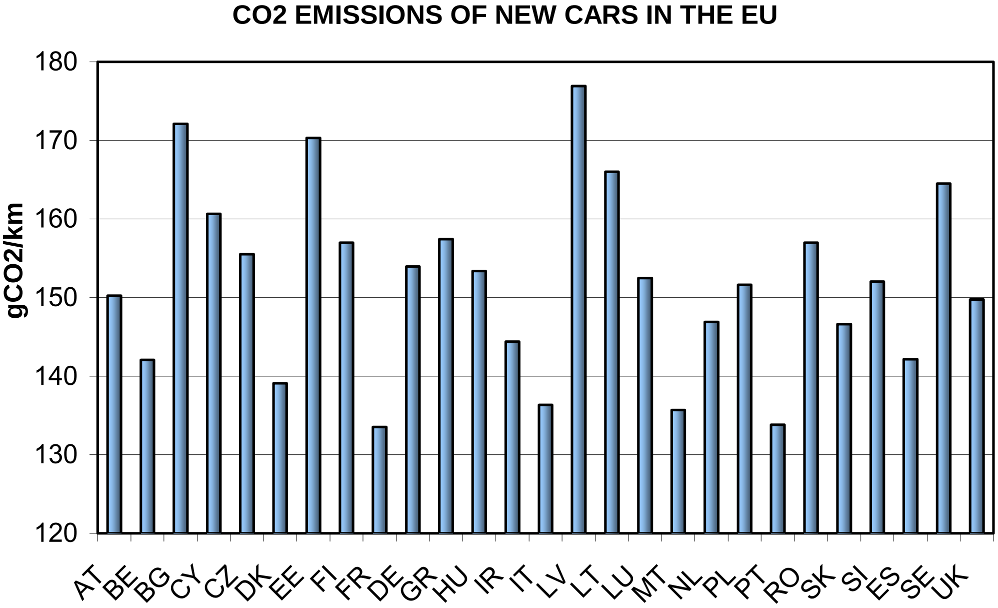


Figure 14. CO_2 emissions of new cars in EU-countries in 2009 (data source: DB, 2009)

The development of average CO_2 emissions from new passenger cars by fuel in EU-27 countries from 2000 to 2009 is shown in Figure 15. Most interesting in this figure is that – due to the switch to larger cars – diesel cars had almost the some emissions than gasoline cars.

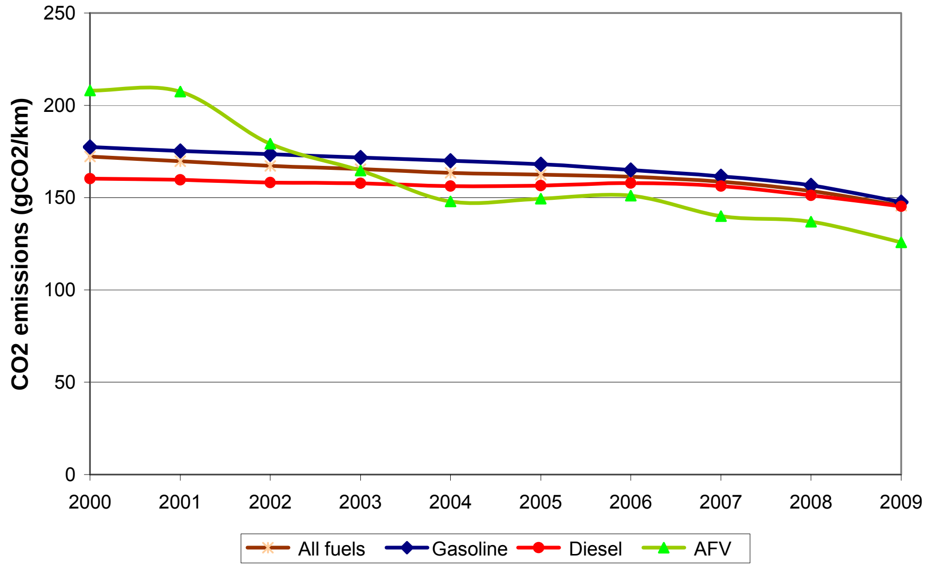


Figure 15. Development of average CO_2 emissions from new passenger cars by fuel in EU-27 countries from 2000 to 2009 (data source: EC, 2010)

Figure 16 shows the development of fuel intensity (FI), power-specific fuel intensity (FIP) and power (kW) of new vehicles in EU-15 from 1990 to 2009. Note, that fuel intensity FI in Figure 16 and Figure 17 does not reflect the real efficiency improvement because it is distorted by the switch to larger cars. To correct this we define a power-specific fuel intensity:

$$FIP = \frac{FI}{kW} \qquad (l/(100km\ kW)) \qquad (1)$$

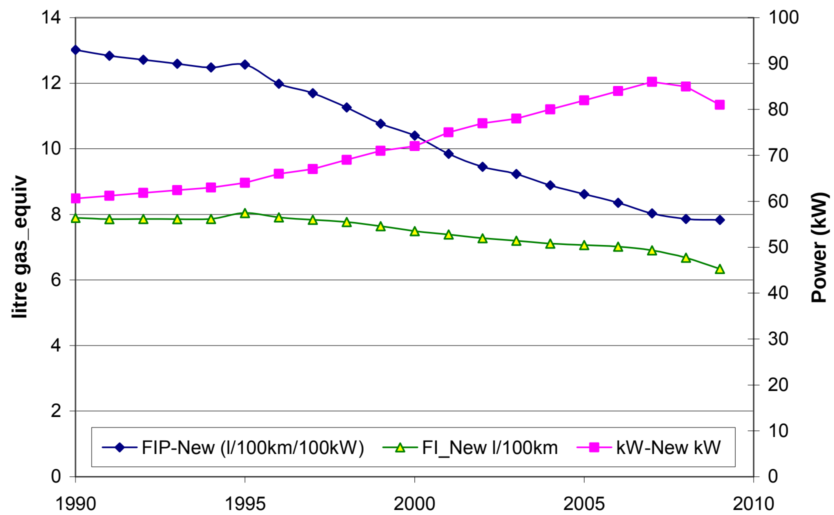


Figure 16. Development of fuel intensity, power-specific fuel intensity and power (kW) of new vehicles in EU-15 from 1990 to 2009

It can clearly be seen from Figure 16 and Figure 17 that the decrease in FIP from 1990 to 2009 was virtually twice as high as the decrease of FI. So actual efficiency was improved twice as much as actual FI developments have performed.

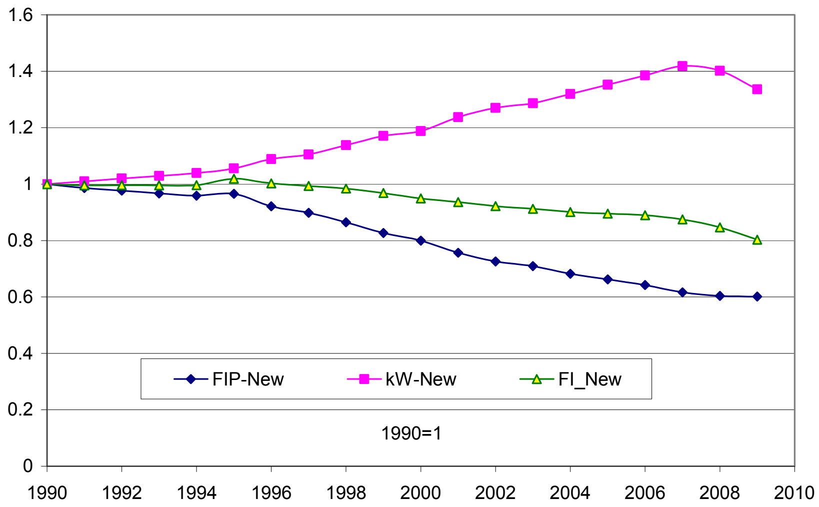


Figure 17. Normalised development (1990=1) of fuel intensity, power-specific fuel intensity and power (kW) of new vehicles in EU-15 from 1990 to 2009

3. Understanding how CO_2 emissions in passenger car transport come about

The core question is: What are the major factors that finally influence CO_2 emissions? Figure 18 shows how CO_2 emissions in passenger car transport come about and how they can be reduced in principle.

CO_2 emissions from passenger car transport depend in principle on energy used for transport and the average specific CO_2 emissions coefficient of different fuels used. The coefficient f_{CO2} can be improved, e.g. better quality of fossil fuels, better ecological performance of biofuels, more electricity from renewable energy sources.

Total energy consumption can be reduced with better on-road fuel efficiency (lower energy consumption per km driven and per kW), lower travel activity (less vkm driven) and smaller cars (less kW).

On-road power specific fuel efficiency is influenced by (theoretical) test-cycle fuel efficiency and the individual driving behaviour.

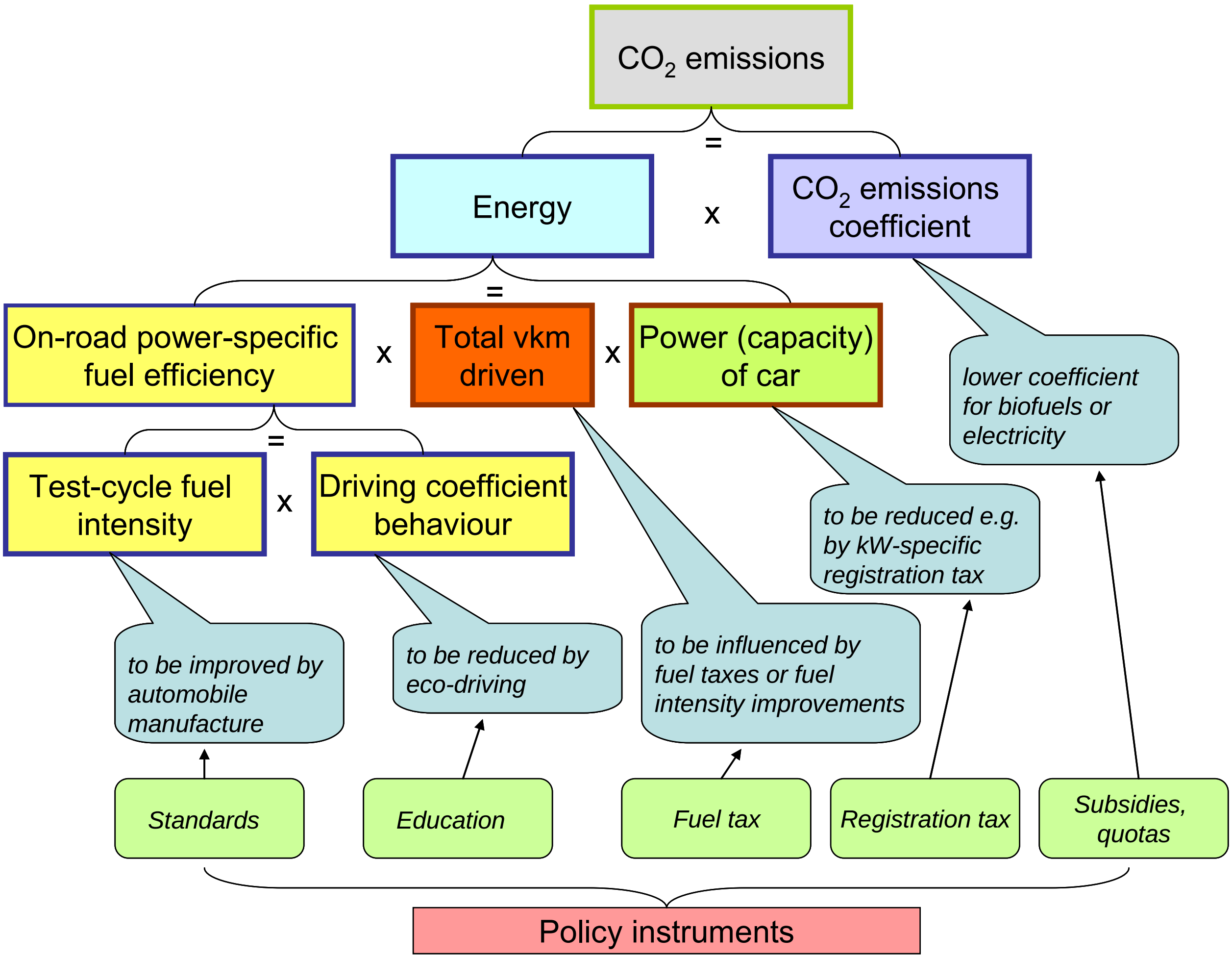


Figure 18. Impact factors on CO_2 emissions in the car passenger transport sector (Source: adapted from JAMA, 2008)

Note that different policies can have multiple and even contradicting impacts! Total vkm driven can be reduced by fuel taxes or increased by FI improvements due to the rebound.

The relationships outlined in Figure 18 regarding which factors influences total CO_2 emissions (CO_2) can be described as follows:

$$CO_2 = f_{driven} \cdot vkm \cdot kW \cdot FIP \cdot f_{CO_2} \qquad \text{(tons } CO_{2\,equ}\text{)} \qquad (2)$$

with

f_{driven}…driving behaviour factor

vkm…Vehicle km driven (km)

kW…..Power of cars (kW)

FIP ….Fuel intensity (litre per km and kW)

f_{CO2} ….Specific CO_2 emissions per litre fuel

$$vkm = f(P_S, Y) \qquad (3)$$

with

P_S….Service price (€/km)

Y…..Income

$$P_S = P_F FI \qquad (4)$$

with

P_F….Fuel price (€/litre)

So we can reduce CO_2 emissions by influencing either

- f_{driven}…(by educating car drivers towards “eco-driving”) or
- vkm (by increasing the price by means of fuel taxes) or
- FIP (by introducing various measures for technical efficiency improvement) or
- f_{CO2} (by using fuels with less carbon, e.g. biofuels or electricity) or
- kW (by switching to smaller cars)

4. What works – and at what cost

In this section we present the major perceptions of the ALTER-MOTIVE project related to alternative fuels, alternative and more efficient automotive technologies and implemented policy measures. Based on the method of approach depicted in Figure 18 we show what works (and at what costs) in which of the above categories.

4.1. SWITCH: Perspectives for current and future biofuels

Biofuels are expected in many policy directives and scientific papers to have the potential to contribute significantly to replacing fossil fuel consumption and corresponding CO_2 emissions. Indeed, in recent years biofuels first generation (BF-1) – biodiesel (BD-1), bioethanol (BE-1), – have entered the market in significant amounts, see above Figure 8a. Of further interest are bio-methane (BM), bioethanol from lignocellulose (BE-1) and BTL-Fischer-Tropsch-Diesel (BD-2).

Yet, biofuels are still under discussion mainly because of their currently poor ecological and energetic performance. In this context it is very important to consider the whole fuel chain by means of a so-called Well-to-Wheel (WTW) assessment for the ecological assessment. The WTW-balance adds Well-to-Tank (WTT) and Tank-to-Wheel (TTW)[4], see Figure 19. In 2010 BD-1 and BE-1 had overall only about 45% lower CO_2 emissions (on a WTW basis) than the corresponding fossil fuels.

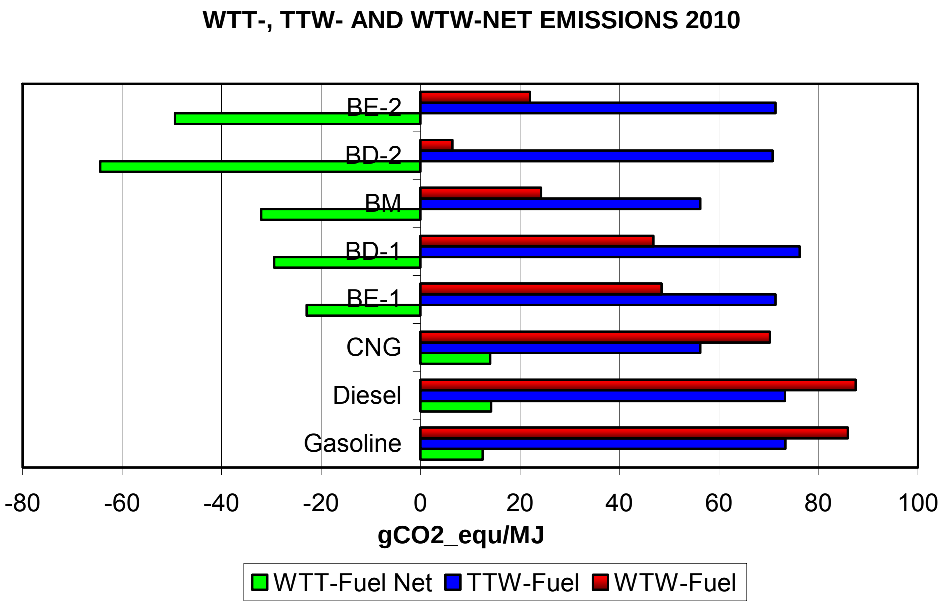


Figure. 19. WTT-, TTW- and WTW net CO_2 emissions of fossil fuels vs biofuels in 2010 for the average of EU-countries on a WTW basis (Details see Appendix A)

Figure 20 depicts the expected development of CO_2 emissions of fossil fuels and biofuels in 2010 and 2020 for the average of EU countries on a WTW basis[5]. For the ecological and

[4] For the calculation of the net WTT-emissions, see Appendix A.
[5] In Appendix C a table on the main properties of fuels is provided.

economic analysis it is important to note that for all fuels by-products were considered in all cases and they result to have a positive influence on costs and emissions performance.

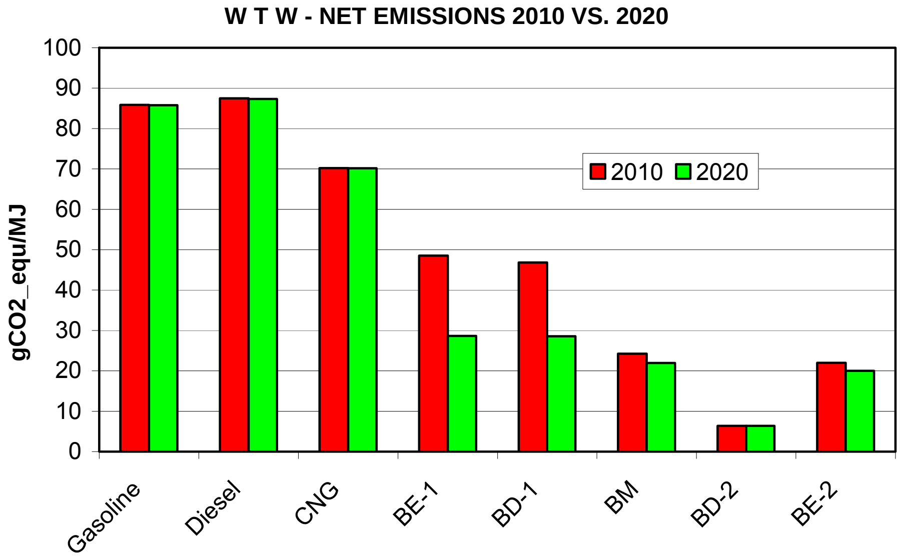


Figure 20. CO_2 emissions of fossil fuels versus biofuels in 2010 and 2020 for the average of EU countries on a WTW basis (Source: CONCAWE, 2008a; own assumptions based on EC, 2009c)

The major reason for the recent market share increases is that biofuels were so far exempted from excise taxes, see Figure 22. In this context it is important to identify the shares of cost categories.

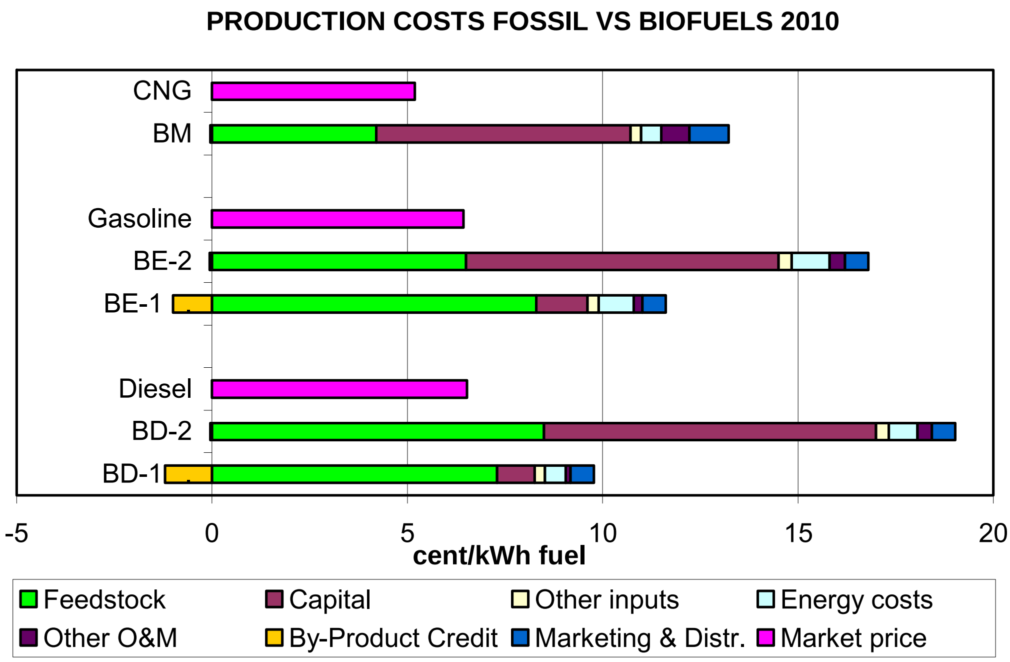


Figure 21. Production costs of fossil fuels versus biofuels excl. taxes in 2010 for the average of EU countries (Source: Toro et al, 2010)

Figure 21 provides a snapshot of the production costs of fossil fuels and biofuels excluding taxes in 2010 for the average of EU countries compared to fossil fuels. The costs documented also reflect the current size categories installed. Especially for BM, BD-2 and BE-2 the currently small sizes contributes to rather high specific capital costs. Scaling could bring the costs down. As can be seen clearly from Figure 21 the by far largest cost share of BD-1 and BE-1 are feedstock costs. Feedstock costs for BE-2 are rather low mainly because of straw is used. We can see that biofuels are still considerably more expensive than fossil fuels. So it is clear that their economic performance has to be improved.

Figure 22 depicts the costs of fossil fuels and biofuels inclusive and exclusive taxes in 2010 versus 2020 for the average of EU countries. We can see that when the excise tax is replaced by a CO_2 based tax – given the assumptions in Figure 20 for 2020 – the economic attractiveness of all biofuel fractions – except BE-1 – increases. Note that for biogas the costs are a mix of biogas from grass, green maize and manure.

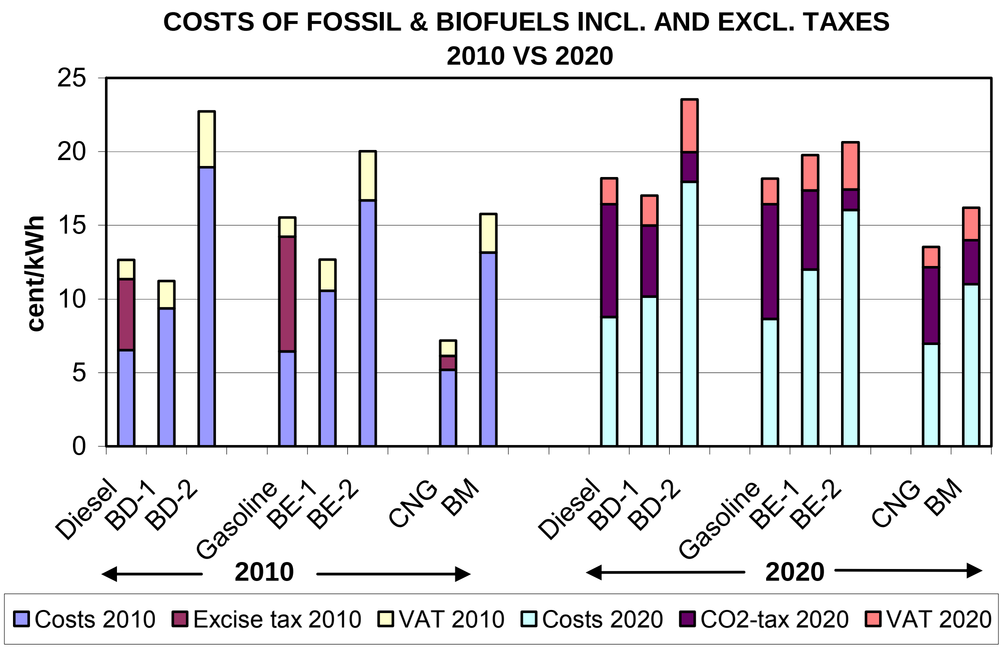


Figure 22. Cost of fossil fuels vs biofuels incl. and excl. taxes in 2010 vs 2020 for the average of EU-countries (based on assumptions in Chapter 5)

Figure 23 shows an aggregated picture of the development of fossil fuels versus biofuels production costs and WTW CO_2 emissions [g CO_{2eq}/MJ] from 2010 to 2020. We can see that only the costs of BF-2 can be expected to decrease moderate, while BF-1 will become slightly more expensive. Yet, the potential for ecological improvements is highest for BF-1, see Figure 23.

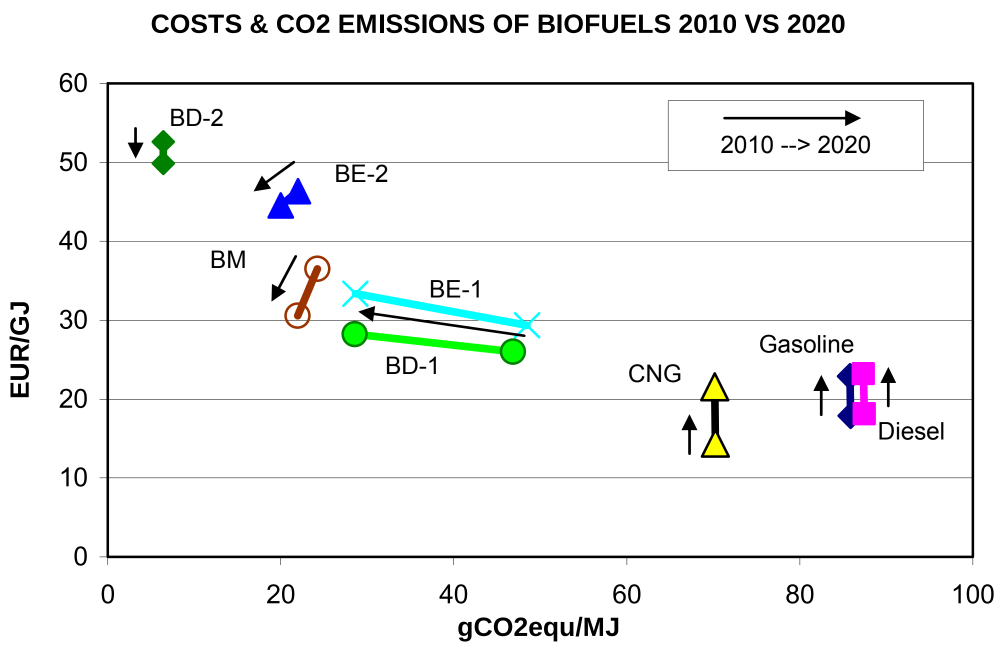


Figure 23. Fossil vs. Biofuels production costs (exclusive taxes) and WTW CO_2 emissions [gCO_{2equ}/MJ] 2010 and 2020 (Source: Toro et al, 2010; own calculations based on assumptions in Chapter 5)

The results are: With respect to the ecological performance of BF-1 the best option corresponds to biogas with lowest specific emissions. BD-2 performs better than BE-2 in terms of CO_2 emissions per Megajoule (MJ). The values provided here for 2nd generation biofuels are still disputable as they are based on R&D or demonstration figures, but still no scalable experience has been obtained. BTL has the prospect to offer lower emissions in this case due to the co-generation assumption covering high energy inputs; however, the capital requirements observed are very high. Along the whole chain biodiesel from rapeseed and bioethanol from wheat are exhibiting the higher CO_{2eq} emissions per delivered MJ of fuel due mostly by cultivation and fertilizers use as well as the use of fossil based inputs.

4.2. IMPROVE: The relevance of alternative and more efficient powertrains

Battery electric vehicles (BEV), fuel cell cars and more efficient internal combustion engines (ICE) may to some extent contribute to a relief of the overall CO_2 emissions. The former ones may especially in cities contribute to the improvement of the air quality.

Yet, currently high costs – mainly of batteries and fuel cells – and other limitations (e.g. driving range) state a major barrier for a broader market penetration of BEV and FCV.

In addition, it is important to recognize that the overall ecological performance of BEV strongly depends on how electricity is generated, how the battery performs ecologically and whether actually conventional passenger cars are substituted or additional transport is triggered.

Figure 24 provides a comparison of specific CO_2 emissions of conventional and hybrid gasoline and diesel vehicles with pure BEV based on different electricity generation mixes and FCV with hydrogen from natural gas versus renewables. It can clearly be seen, that in the case where electricity is generated with the current mix in the UCTE (Union for the Co-ordination of Transmission of Electricity) or from natural gas power plants no clear advantage compared to conventional or hybrid vehicles can be revealed. So we can clearly see that the environmental benignness of BEV and FCV depends solely on which source electricity or hydrogen is produced. Only if the electricity for BEV and FCV is produced from renewable energy sources (RES) a undoubtedly ecological advantage can be expected.

So it is very important to consider that "green" electricity for E-mobility is not available self-evident now and not indefinite available in the future and not for free. Hence, in lockstep with the market introduction of BEV the corresponding deployment of new RES-E capacities must be ensured and proven by certificates without forgetting the problems of time of charging, linked to other storages and smart grids.

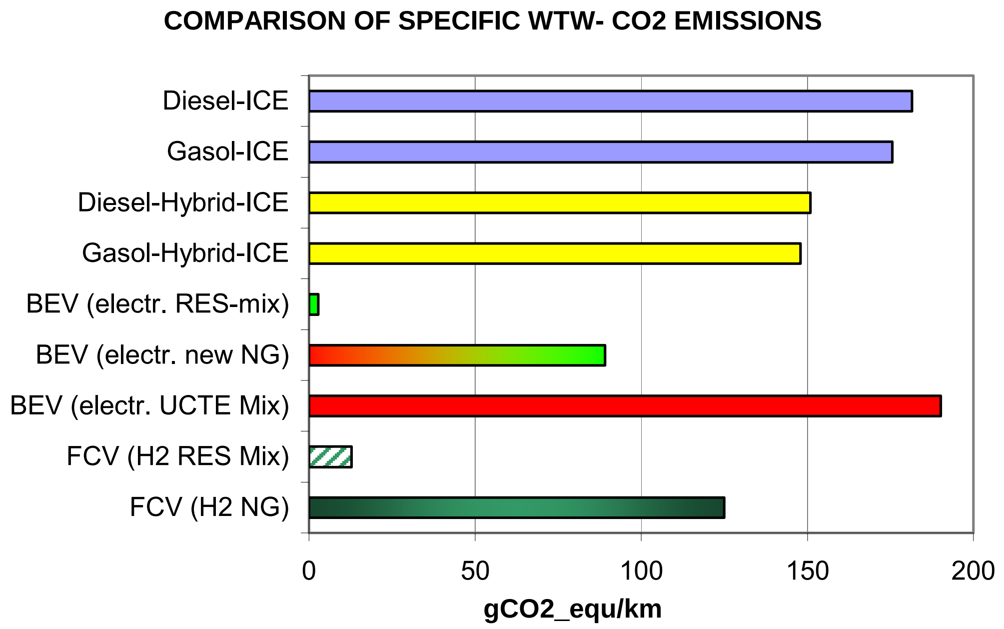


Figure 24. Comparison of specific CO_2 emissions of conventional and hybrid gasoline and diesel vehicles with pure BEV based on different electricity generation mixes and FCV with hydrogen from NG and RES (Source: Toro et al, 2010)
(*H2: Hydrogen, ICE: Internal Combustion Engine, FCV: Fuel Cell vehicle, BEV: Battery Electric Vehicle, NG: Natural gas*)

With respect to a state of the art assessment of AAMT, the modification of the existing internal combustion engine to run on alternative fuels, able to be blended with fossil diesel and gasoline or natural gas performs differently in terms of emission reductions stating better for biodiesel and biomass-to-liquids than for gasoline or flex-fuel vehicles running on ethanol mixtures.

Hybrid vehicles may serve as a bridging technology. They do not have most of the disadvantages of pure BEV: They are economically almost competitive, use less fuel than conventional gasoline and diesel vehicles and can compete environmentally with BEV except those based on pure RES, see Figure 24 and 25.

Figure 25 provides a comparison of specific CO_2 emissions and costs of conventional and hybrid gasoline and diesel vehicles with pure BEV based on different electricity generation mixes and FCV with H_2 from RES or natural gas.

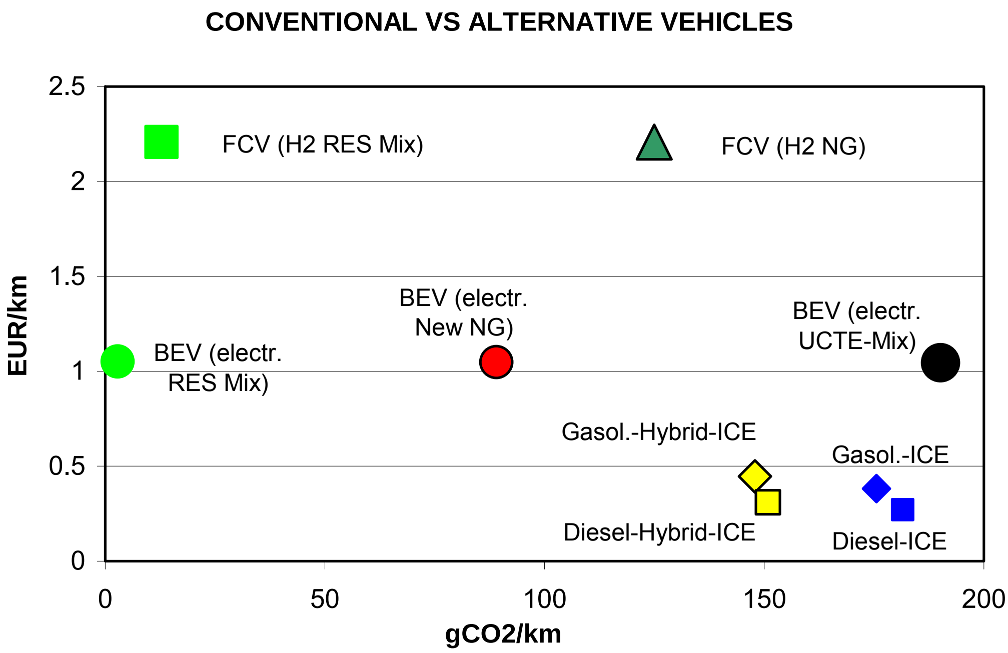


Figure 25. Comparison of specific CO_2 emissions and driving costs of conventional and hybrid gasoline and diesel vehicles with pure BEV based on different electricity generation mixes and FCV with hydrogen from NG vs RES (Source: Toro et al, 2010)
(H2: Hydrogen, ICE: Internal Combustion Engine, FCV: Fuel Cell vehicle, BEV: Battery Electric Vehicle, NG: Natural gas)

The major perceptions of Figure 25 are: (i) Hybrid ICEs are an alternative with slightly higher costs but clearly better performance than conventional vehicles; (ii) BEV as well as FCV are only preferable to conventional cars if they are fully based on RES.

Yet, it is important to note that there are considerable technical improvement potentials for AAMTs – see Toro et al (2010) for further details – which include:

- BEVs are still an immature technology. Major R&D and demonstration activities relate to further development of battery technologies and technology improvements indicate a wide range of weight and costs reduction potentials until 2020 probably explained by the different scaling factors for battery and cell sizes;
- Technical improvements for fuel cells include power density and platinum loading which are necessary to go on commercial scale. The cost evaluation of fuel cells for automotive power trains suggests, that in future significantly lower costs of fuel cell systems can be expected due to scale production and technology learning, see Figure 29;
- Until 2020, the contribution from hydrogen as a transport fuel remains limited and several technical improvements remain at research, development and demonstration with promising

potentials after 2020. Major challenges include reduction of energy and resource losses in over-all conversion chains, to make the production process cheaper as well as to enhance the reliability and life-time of fuel cells and to bring the learning curve of costs.

Aside from switching to completely new technologies like BEV or FCV continuous improvements of conventional cars will play an important role in the future CO_2 reductions.

Major improvements to be considered are:

- The internal combustion engines exhibit important technical improvements with the potential to increase efficiency and reduce emissions with moderate extra costs. Several of these technologies are highlighted and among others include the application of engine test bed, optimised fuel injection and electronic systems, modern valve controlling and innovative gear drives (e.g. duplex clutch, continuous automatic gearbox, hydraulic impulse store);
- Further improvements include chassis suspension and brake technology, reduction of rolling resistance of tyres (e. g. innovative materials or optimised tyre profiles), improved aerodynamics, light weight constructions (e. g. substitution of steel by plastics and carbon fibres, substitution of conventional headlights by light-emitting diodes), material from renewable raw materials and optimisation of the power train;
- Integration and use of advanced accessories such as tire pressure monitoring system (TPMS), gear shift indicators (GSI), navigation systems, radio based traffic monitoring and update systems are few other measures that will add to vehicle / system efficiency;
- Additional modification on ICE include the adaptation of motors to run on low or high blend biodiesel or bioethanol which offer a potential to reduce emissions while making few changes in the technology.

4.3. REDUCE: The effects of taxes and standards

4.3.1. Results from governments' policy analyses

An important issue was to analyze the effect of policies (top-down and bottom-up) implemented by national governments or at EU-level. The recommendations for policy makers derived from these comprehensive analyses of innovation and fiscal policies are:

- Policy measures to support the introduction of an alternative fuel or technology need to be well-timed according to their current technological status. Therefore, the technology status should be carefully analysed before the introduction of measures. As sometimes the technological development and learning curve move ahead fast, close technology monitoring and flexible policies are suited best. The biggest pitfall from a policy maker perspective can be tax exemptions without budget restrictions which become (very) expensive when the market shares of the technology or fuel in case grows more rapidly than expected.

- Each of the fuels under consideration in ALTER-MOTIVE requires a tailor-made approach, but also different framework conditions in the EU member states need to be considered in the choice of the policy instruments. For example, due to the specific economic importance of car manufactures in Germany the development of more efficient cars such as electric and fuel cell vehicles plays an important role in designing polices. On the other hand, due to a high share of agriculture in the Polish economy, biofuel developments are much more important.

- The key stakeholders involved in introducing a particular alternative fuel should develop a common vision. Policy measures should result from this common vision and offer enough perspective to the other stakeholders for a viable future market.

- Generic policies like CO_2 based fuel taxes are effective to achieve overarching goal of emission reductions, however the market will decide upon the cheapest technological option. This option does not necessarily entail the biggest carbon abatement potential in the long-term.

- Fiscal policies currently applied for conventional vehicles need to be distinguished between one time measures such as vehicle purchase tax (also called registration tax) and annually levied road taxes. Vehicle purchase taxes have proven to be influential on the magnitude of car sales and the choice by the consumer for a certain model. Annual taxation schemes based on vehicle's CO_2 emissions (and the car footprint, not weight) are seen as a more direct way of influencing consumer decisions. In this case, a limit needs to be defined for maximum allowed emissions level together with penalties that are imposed if the limit is exceeded. Favourable company car depreciation schemes do currently weaken the impact of purchase taxation schemes, therefore more personalized schemes targeting the behaviour of the individual motorist (e.g. incentivising reduction of kilometres driven per car through fuel taxation) are seen as a next step.

- Biofuels 1st gen.: Main barrier for the 1st generation of biofuels is cost and debate on environmental impact. The scope for cost reductions in the 1st generation of biofuels is limited, so policy measures to increase the market share of biofuels are likely to be expensive. The basic choice is which stakeholder is going to bear these costs. When tax exemptions are applied, the costs are borne by the national government and eventually all tax payers. When an obligation is applied, the costs are born by the fuel providers and fuel consumers.

- Biofuels 2nd gen.: Their costs are currently too high to allow the development of an early market, see Figure 21. Policy should for now focus on support for R&D and demonstration projects. This is currently the case at EU level; R&D results should lead to demonstration and early commercial stages. Despite of the fact that technology learning is expected to contribute to reduce the costs, simulations from Toro et al., 2011 indicates that this effect might be very limited also for routes for high energy scenarios.

- CNG requires a significant fuel price discount over conventional fuels and a shared vision by the relevant market actors that a viable market for CNG can be developed. Since CNG is currently more popular in new vehicles than in conversions and because CNG infrastructure is relatively expensive (compared to LPG), measures aimed at direct support for vehicles and infrastructure development may be considered to accelerate early market development.

- Hybrid electric vehicles (HEV): Main barrier are high vehicle costs in comparison to conventional vehicles. Support measures that bring the costs of vehicles down are successful, especially measures that make the private use of company cars (lease) more attractive.

- Hydrogen: Main barriers are the initial cost of fuel cell vehicles (consumers) and high upfront investments in infrastructure (industry). The costs of vehicles can be brought down by (i) R&D and learning-by-doing in demonstration projects and (ii) reaping scale advantages of mass production. This requires support for R&D and demonstration projects on the one hand and direct support to bring down the costs of the first batches of vehicles on the other hand. Infrastructure investments can be triggered by implementing measures that offer a viable long-term perspective to fuel providers, but also by more direct measures such as investment subsidies and accelerated depreciation. Locally initiated hydrogen implementation projects (bottom-up) provide first experiences with technology and grow out into corridors (links) to other hydrogen application centres. With limited availability of hydrogen passenger cars, public transport buses or niche applications can be a starting point.

- BEV: Main barriers are high initial vehicle cost (in particular for batteries) and limited driving ranges. Support should aim to lower cost through battery R&D and demonstration projects (learning by doing and volume effects). More experiences are needed regarding what coverage of charging infrastructure is really required (and will be utilized) by end-users. Consumer incentives are suitable to provide a financial relief to reduce initial high vehicle cost, either in form of tax incentives or as a direct subsidy.

- Although providing incentives and other amenities for particular fuels & technologies is often regarded as ‘picking winners’ from which policy makers should refrain, the risks from choosing certain innovations are outweighed by the risk of not attaining climate policy targets at all.

- In order to achieve the GHG emission reduction target of -80% in 2050, the transport sector will need to contribute its share. Most emission reduction potential is expected to come from the de-carbonization of transport fuels (through electric vehicles and hydrogen fuel cells powered by energy from sustainable sources) which represents a big challenge for policy makers in the next decade. Therefore, framework conditions need to be shaped now in order to prepare for a successful market introduction of those innovative transport technologies with high carbon abatement potential.

For more details about effective policy instruments see Bunzeck et al, 2010.

4.3.2. Perceptions from econometric analyses

There is often the argument that car drivers are not sensitive to fuel prices and hence a tax does not have an impact on fuel consumption and does not lead to fuel savings. There are at least two arguments against this statement:

- Fuel demand in Europe is significantly lower than in the USA (where fuels are not taxed);
- Analyses by several authors in the literature (e.g. Sterner, 2007) show that price elasticity is in a range of -0.3 to -0.6 leads to energy savings of 30% to 60% due to the introduction of a tax.

We think that these two arguments are sufficient to justify the introduction of a higher tax.

Yet, to provide sound evidence for the impact of price, income and fuel intensities (as a proxy for efficiency) in Europe we conducted econometric time series analyses, see Ajanovic/Haas, 2011.

We extracted a long-term price elasticity of about -0.42 for the service vehicle km driven. This result has the following implications: Let us first look what happens if we improve the fuel intensity e.g. due to technical standards. The result is that the service price for vkm driven decreases and driving gets cheaper. Straightforward the price elasticity of -0.42 implies a so-called rebound effect of 42%. That is to say, if efficiency is improved by 1% the number of km driven is enhanced by 0.42% and the remaining energy conservation effect is only 0.58% (see ΔE_η in Figure 26)[6].

This effect can be compensated more or less, by the simultaneous introduction of a fuel tax, as shown in Figure 26. In this case an additional tax – increasing the price P_{s1} to P_{s2} for the service km driven – would fully compensate the rebound and for the owner of a new car the service price would remain the same ($P_{s2} = P_{s0}$).

[6] Example: Assume FI of old car was 60 kWh/100 km. If it is improved by 10 % and we have initially 10000 km driven we calculate theoretical savings of 60/100 * 0.1 * 10000 = 600 kWh. Yet, due to the rebound – now we drive 420 km (=10000 * 0.42 * 0.1) more, this is 10420 km – we now save only 348 kWh (=58% of 600 kWh).

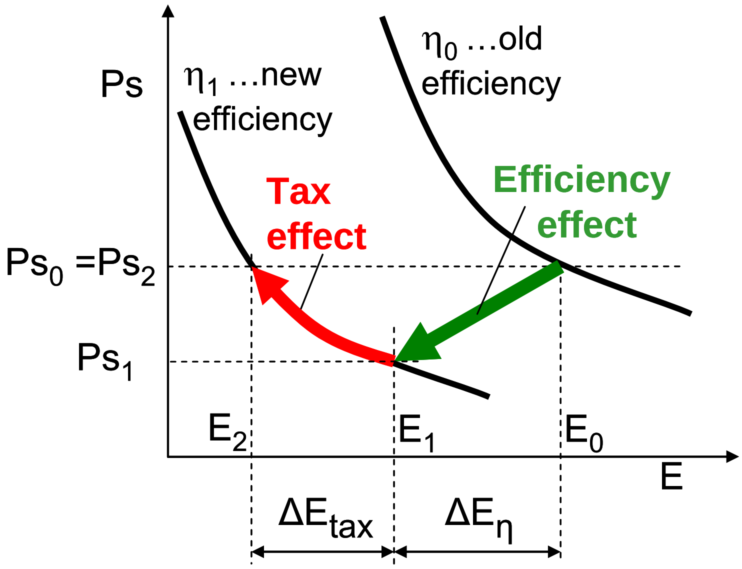


Figure 26. How taxes and standards interact and how they can be implemented in a combined optimal way for society

5. Scenarios: How 2020 could look like

A major objective of the project ALTER-MOTIVE was to develop so-called internet-based scenarios. This tool provides an on-line possibility for stakeholders to design own policy scenarios and to get an indication for the effect of various types of policies[7]. These policies are described in detail in section 5.1.

For extracting the impact of these policy types we use a dynamic model which is based mainly on econometric estimates of service demand (number of new vehicles by category, vehicle km driven by country and category) from time series compiled in WP2 (see Ajanovic (2009)).

The basic approach is :

$$S_t = S_{t-1}\left(\frac{P_{S_t} - P_{S_{t-1}}}{P_{S_t}}\right)^{\alpha}\left(\frac{Y_t - Y_{t-1}}{Y_t}\right)^{\beta}\left(\frac{IC_t - IC_{t-1}}{IC_t}\right)^{\gamma}\prod_{i=1}^{n}\left(\frac{X_{i_t} - X_{i_{t-1}}}{X_{i_t}}\right)^{\delta_x} \tag{5}$$

With:

X_i … various additional variables covering cross-price and cross-investment costs effects

From these service figures the resulting energy consumption (E) and CO_2 emissions are calculated by using the fuel intensities (FI) and the fuel-specific CO_2 emissions (f_{CO2}) (see also outline in Chapter 3):

$$E = vkm \cdot FI \tag{6}$$

$$CO_2 = f_{CO_2} FI\ vkm \tag{7}$$

Based on this formal framework and the assumptions documented in the following chapter finally the scenarios will be derived.

5.1. Major assumptions for price, income, cost and technological developments

In this chapter we summarize the major assumptions regarding price, income, cost and technological developments up to 2020.

Note that in the scenario analyses the major focus is on EU-15. The major reason for this is that reliable data for time series on energy consumption of passenger cars are only available for this subset of countries and not for the all EU-27 countries.

The starting points for the analyses are the years 2007-2010 depending on the data available by country and parameter type. As far as possible we used the latest available data from

[7] These internet-based scenarios are available on www.alter-motive.org under "Play policy maker". Currently, for eleven countries – Austria, Bulgaria, Czech Republic, Denmark, France, Germany, Italy, The Netherlands, Poland, Portugal, Sweden and the EU-15 as a whole. It is possible to test the policies described above online.

2009/2010 (e.g. for personal consumption expenditures (PCE), prices, new registrations and CO_2 emissions of new registered cars). From our analyses by the end of 2010 about 200 million cars were on roads in EU-15 countries. Of these there were about 60000 BEV and about 140 fuel cell cars. About 13.5 million new cars were registered in 2010.

Major specific assumptions in the BAU-scenario

Based on these figures a Business as usual (BAU) scenario is developed. In this context the following assumptions are of specific interest:

- Conversion of excise tax to CO_2 tax;
- For km-specific CO_2 emissions (and implicitly fuel intensities) the EU aims to set a target of 95 g CO_2/km for 2020. However, the EU has not reached recent targets in this sector (120 gCO_2/km by 2010, see above) and not in other sectors e.g. targets of the RES-E-directive. So we define a so-called "target fulfilment factor" (TFFF) and use a value of 65% for the difference between starting value 2010 (130 g CO_2/km) and the announced target of 95 g CO_2/km. This result in a BAU-scenario value of 107 g CO_2/km which we expect to be met by 2020, see Appendix B, Table B-1. Because in the BAU-scenario no other policies are implemented this figure must be brought about by pure technical efficiency improvements (and voluntary size reductions). As can be seen from Figure 40 it leads to about 3 million tons CO_2 reduction up to 2020.

Figure 27 depicts the historical fuel price developments and the assumptions for price development in the scenarios up to 2020.

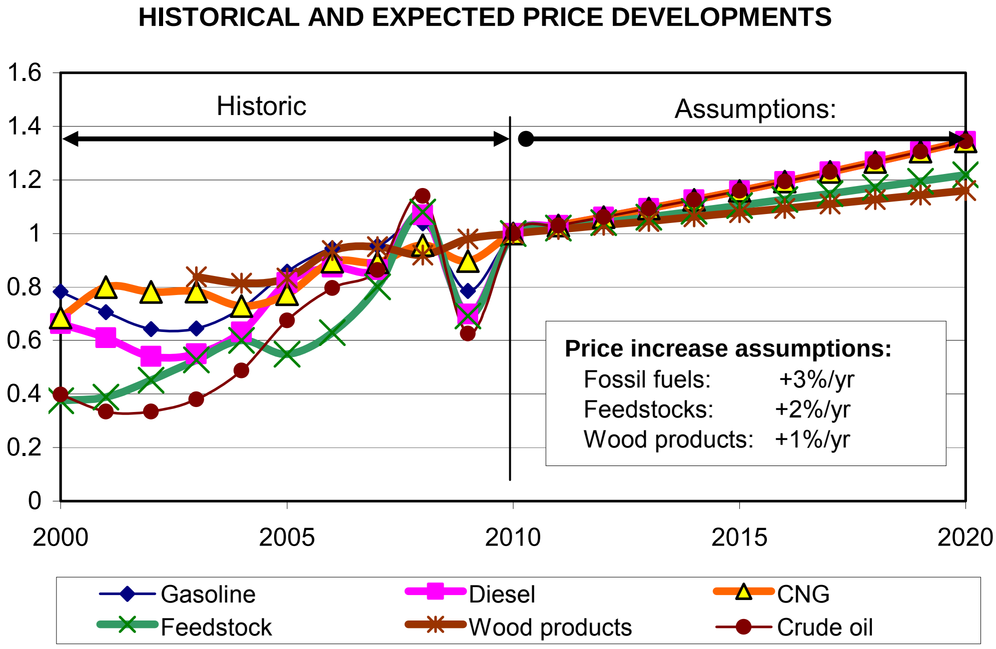


Figure 27. Historical price developments and assumptions for price development in the scenarios up to 2020 (own calculation)

Figure 28 describes the historical developments of passenger cars' fuel intensities and assumptions for development in the scenarios up to 2020 (for average car size of 80 kW).

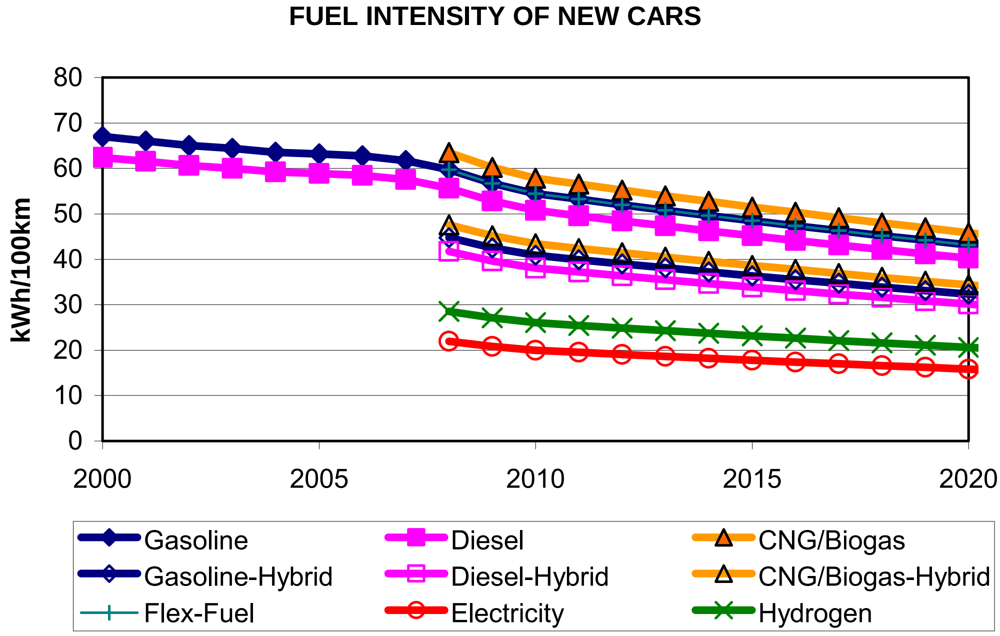


Figure 28. Historical developments of passenger cars' fuel intensities and assumptions for development in the BAU scenarios up to 2020 (for average car size of 80 kW) (Source: EC,2010; Toro et al, 2010; CONCAWE, 2008, DB, 2009)

Figure 29 shows the developments of car investment costs in the scenarios up to 2020 (for average car size of 80 kW).

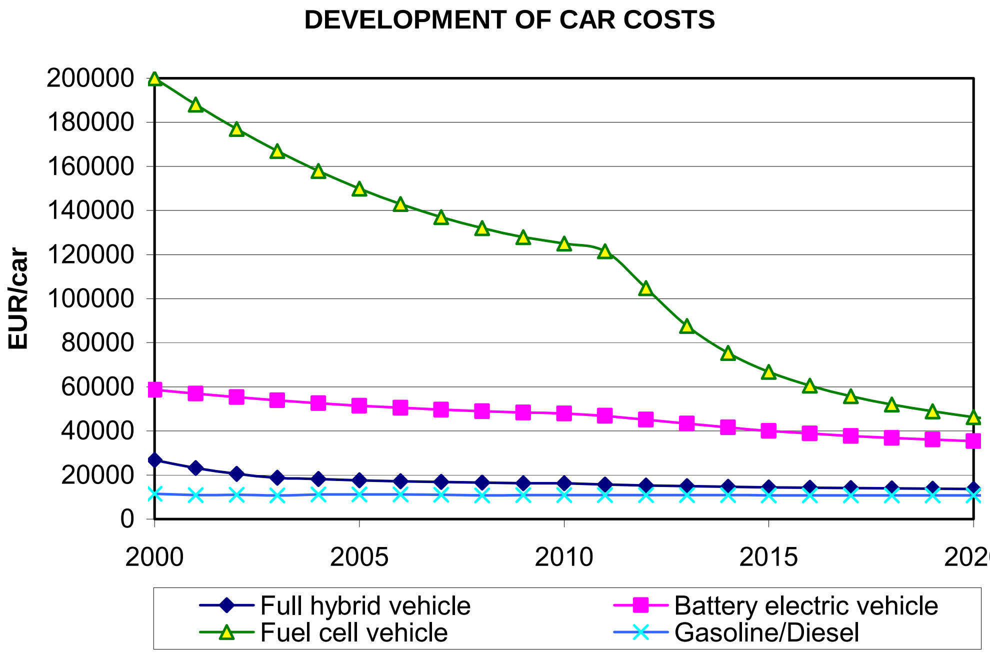


Figure 29. Developments of car investment costs in the BAU scenarios up to 2020 (for average car size of 80 kW) (own calculation)

Major assumptions in the policy scenarios

To extract the effects of different policies we proceed as follows:

First, we calculated separate scenarios for the following categories of policies (note that all policies in all scenarios become effective from 2011 on):

- **Fiscal policy scenario:**

➢ fuel tax: we introduce a CO_2 based fuel tax and a car size-dependent registration tax. The fuel tax increases – based on the initial excise tax of gasoline, which is equivalent to 0.29 EUR/kg CO_2 (0.68 EUR/litre gasoline) – by 3 cent/kg CO_2 / year (this is an increase of 7 cent/litre gasoline). For the other fuels the tax is calculated and increases relative to their CO_2 emissions compared to gasoline see Figure 30. Note that all calculations of specific emissions are based on gasoline.

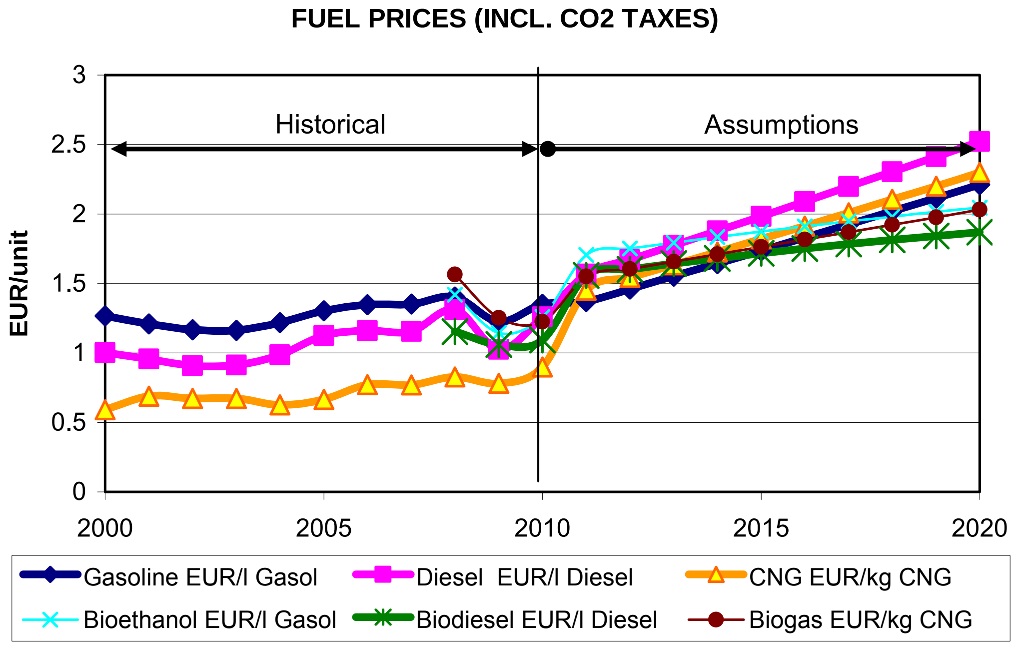


Figure 30. Historical developments of prices incl. and excl. taxes and development in the fiscal policy scenarios up to 2020 (Source: Own calculation, ALTER-MOTIVE database)

➢ registration taxes: furthermore we introduce a differentiated scheme of registration taxes depending on the size of cars: for small cars (up to 60kW) tax increases by 2%/year as in BAU-scenario. For medium-size cars (60-100kW) the increase is 4% per year and for cars with larger power than 100 kW the increase is 8% per year.

- **Technical standards scenario:**

➢ we introduce a 5%/year improvement of technical efficiency up to 2020 starting in 2011. This lead finally to CO_2 emission standards to 87 gCO_2/km by 2020.

- **Fuel switching scenario:**

➢ procurement of biofuels: we increase the amount of biofuels in a quota-based stile by 8%/year compared to 4% in the BAU-scenario; for biogas we use a different path resulting in a biogas use of 5 PJ in 2020. Moreover the specific CO_2 emissions of biofuels decrease by 5%/year compared to a decrease of 0.5% in the BAU-scenario. This leads by 2020 to 70% lower CO_2 emissions than fossil fuels.

➢ procurement of BEV and FCV: for BEV we start with a procurement of 5000 BEV in 2011 and reduce this amount by 1000 over the following years (compared to 2000 in the BAU-scenario and a reduction of 500 per year); for FCV we start with a procurement of 500 FCV in 2011 and reduce this amount by 50 over the following years (compared to 200 in the BAU-scenario and a reduction of 20 per year).

- **Ambitious policy (AP) scenario:**

➢ all policies described above are implemented simultaneously.

The results of these single different policies are depicted in Figure 41.

5.2. Major results of the scenarios

The results of the BAU-scenario compared to the ambitious policy (AP) scenario up to 2020 are shown in the figures 31 to 40.

The major perceptions are:

- In the BAU-scenario energy consumption as well as CO_2 emissions remain fairly stabile while in the AP-scenario both decrease to an about 20% lower level in 2020;
- Within the alternative fuels mainly due to increases in BD-1 and BE-1 in the AP-scenario by 2020 100PJ more AF are used; However, it must be noted that with about 700 PJ the potential for BF-1 with a limitation of BD-1 and BE-1 to 30% of arable land is almost exhausted (see Appendix D).
- The vehicle stock as well as new registered cars increase very moderate in BAU while they decrease slightly in AP-scenario;
- Regarding alternative powertrain vehicles in total they grow less than in BAU-scenario (following the over-all trend for new vehicles) but due to procurement policies BEV and FCV increase in absolute numbers.

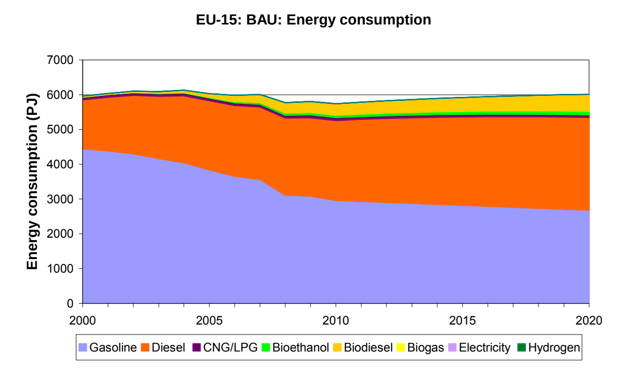


Figure 31a. Energy consumption in the BAU-scenario

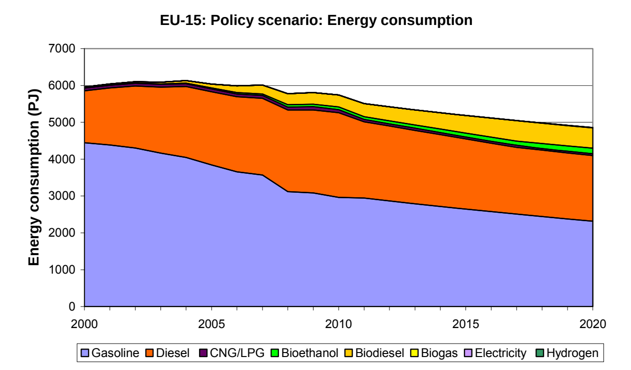


Figure 31b. Energy consumption in the AP-scenario

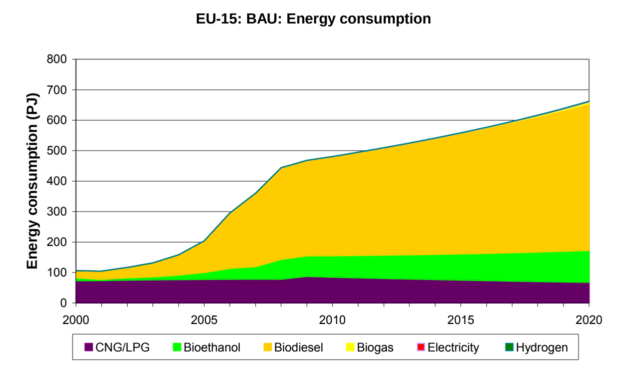


Figure 32a. Alternative energy consumption in the BAU-scenario

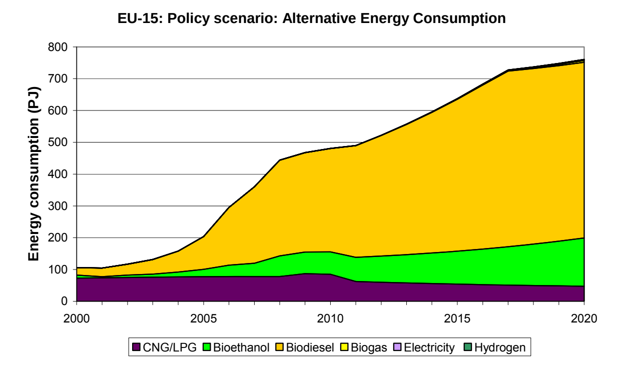


Figure 32b. Alternative energy consumption in the AP-scenario

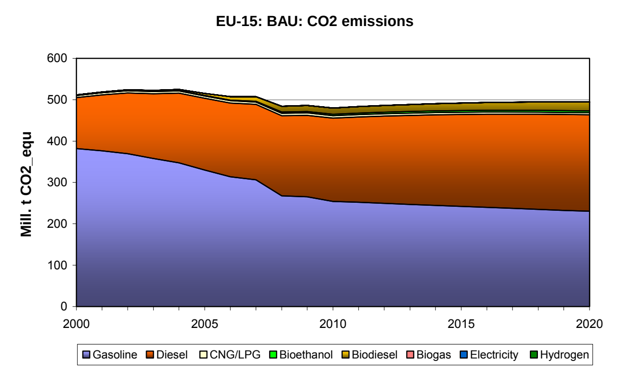


Figure 33a. CO_2 emissions in the BAU-scenario

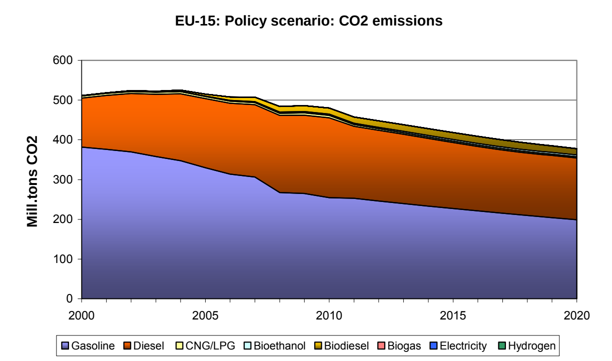


Figure 33b. CO_2 emissions in the AP-scenario

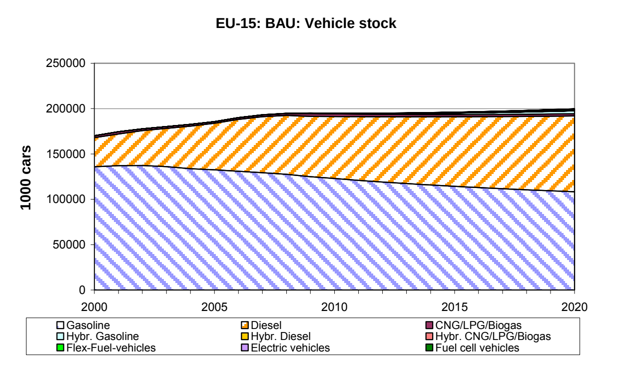


Figure 34a. Development of vehicle stock in the BAU-scenario

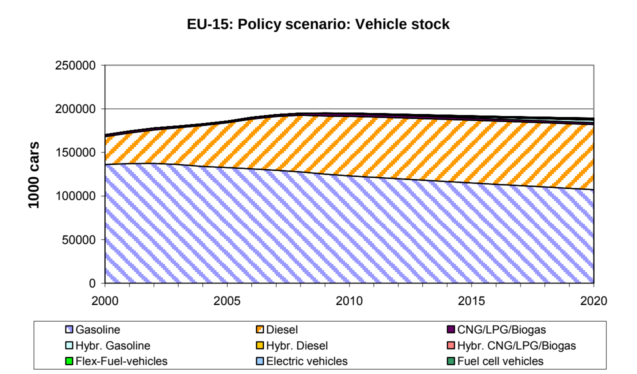


Figure 34b. Development of vehicle stock in the AP-scenario

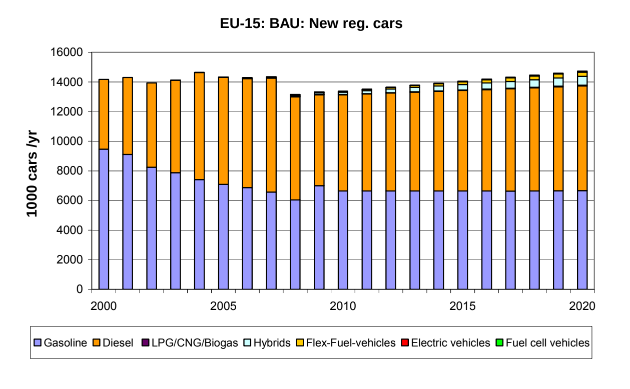


Figure 35a. Development of new registered cars in the BAU-scenario

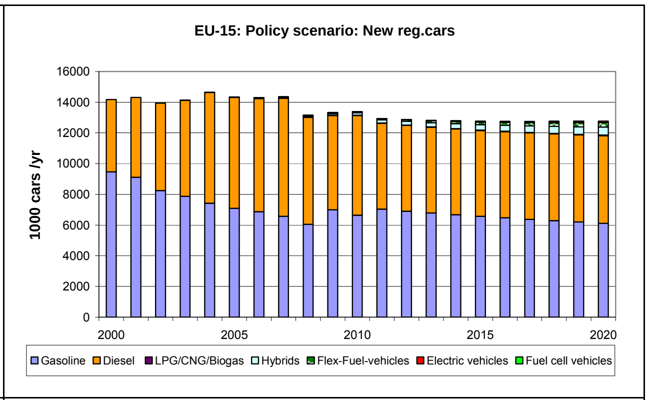


Figure 35a. Development of new registered cars in the AP-scenario

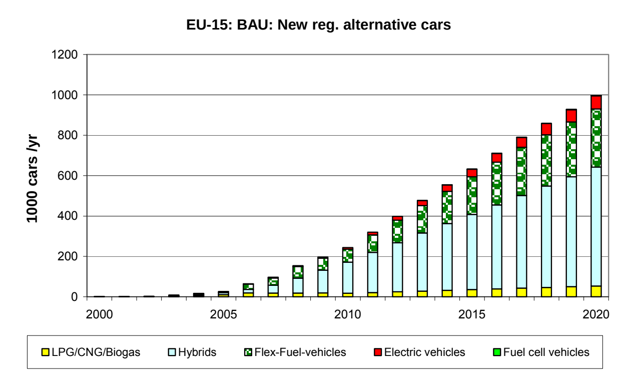


Figure 36a. Development of new registered alternative cars in the BAU-scenario

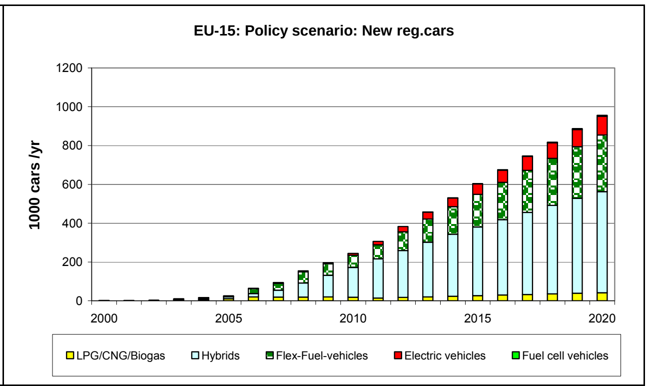


Figure 36a. Development of new registered alternative cars in the AP-scenario

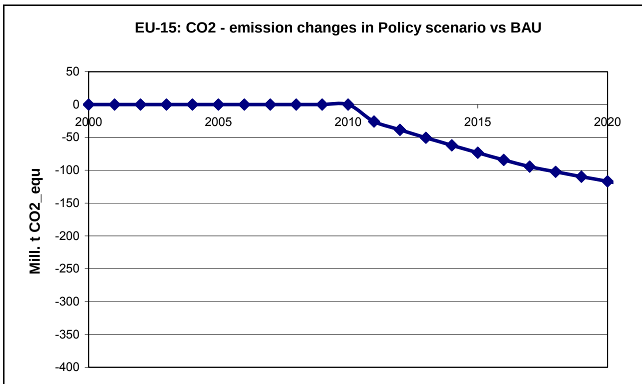


Figure 37. Comparison of CO_2 emission changes in the BAU-scenario and in the AP-scenario

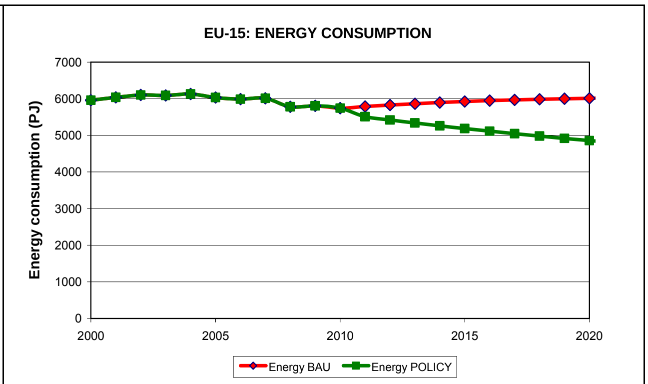


Figure 38. Comparison of energy consumption in the BAU-scenario and in the AP-scenario

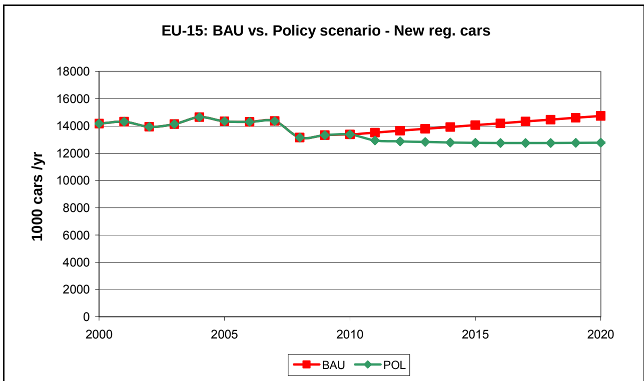


Figure 39. Development of new registered cars in the BAU-scenario and in the AP-scenario

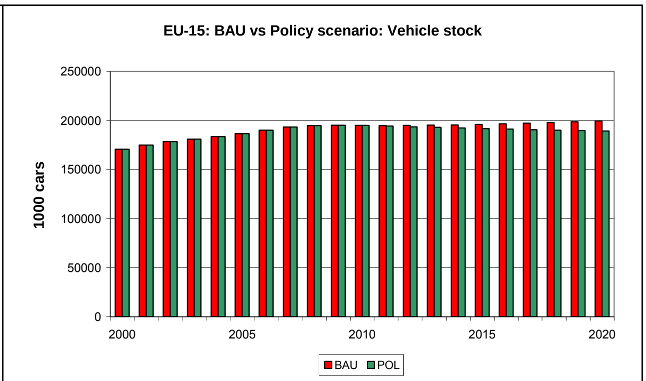


Figure 40. Comparison of vehicle stock development in the BAU- and the AP-scenario

5.3. Which measures contribute to CO_2 reduction ....

A comparison of the measures, which contribute to CO_2 reduction in BAU-scenario and in the ambitious policy scenario, is shown in Figure 41[8]. We can see that fiscal measures, standards and switch to biofuels contribute about the same amount.

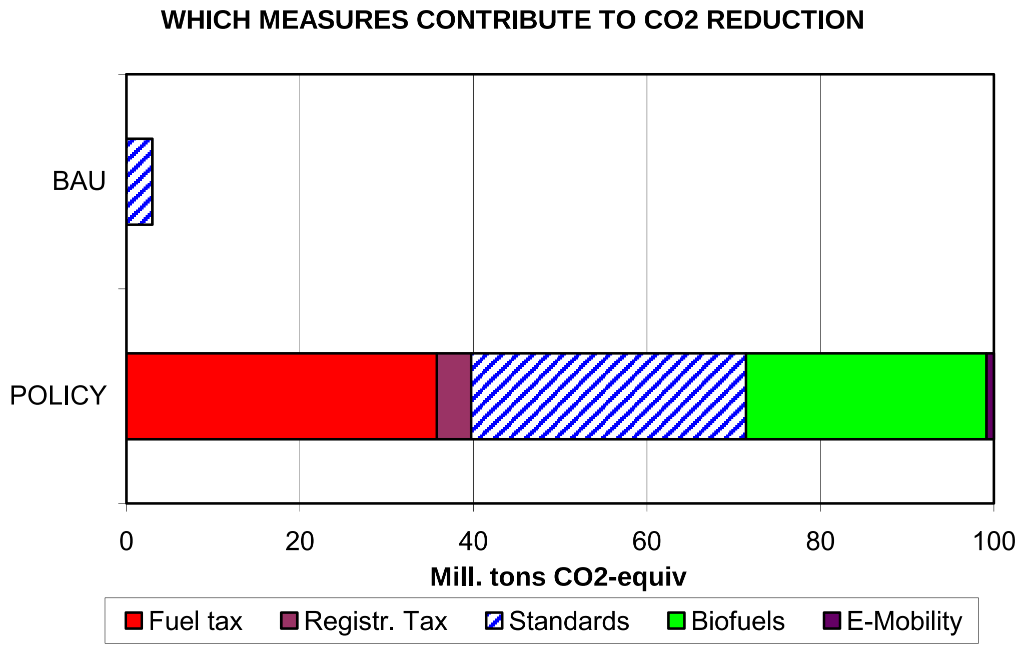


Figure 41. Comparison of which measures contribute to CO_2 reduction in BAU-scenario and in the Policy scenario

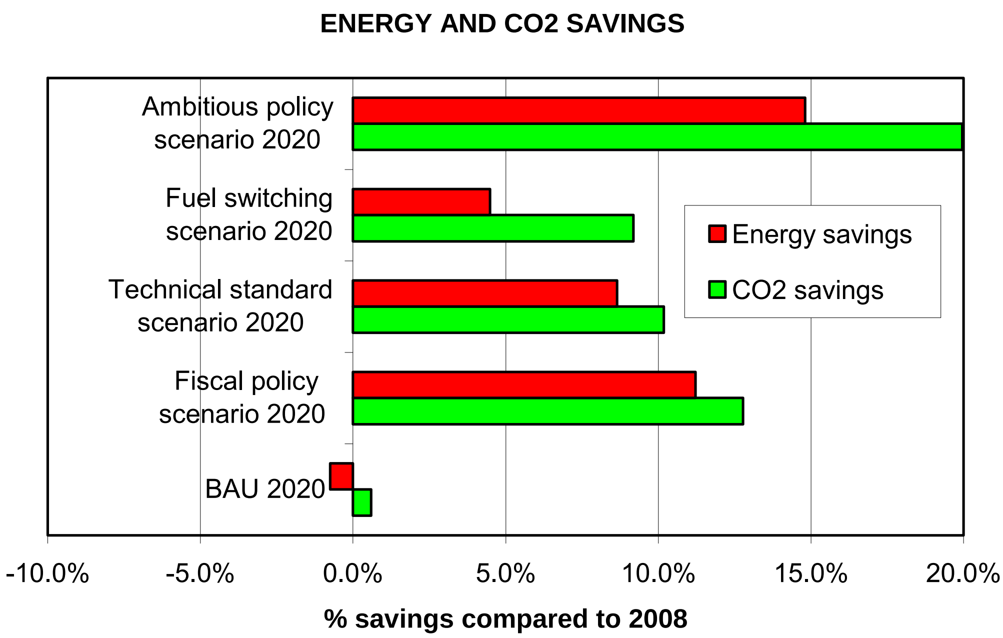


Figure 42. Comparison of which measures contribute to CO_2 reduction in different scenarios

[8] Note that all comparisons regarding CO_2 savings are calculated compared to 2008 because this was the last year for which we think that we can rely on sound data.

Figure 42 provides a comparison of the measure which contributes to CO_2 reduction in different scenarios. In the single scenarios we have the highest reduction in the Fiscal policy scenario followed by the Technical standard scenario and the Fuel switching scenario. The detailed results for the different scenarios are documented in the Appendix B, Table B-2.

5.4. … and at which costs?

Finally the crucial question is of course “How much do European citizens have to pay for achieving these goals?”

In this chapter we give a survey on the costs of various measures to head towards a least-cost approach. Figure 43 shows the basic principle of a least-cost approach. The different measures are put in a least-cost order including the possible saving potentials up to 2020 for achieving finally 100 million tons CO_2 reduction which corresponds to about 20% CO_2 reduction compared to 2008.

The method of approach of identifying these costs is based on calculation of total costs for society and resulting CO_2 reductions[9]:

- For taxes these costs are the over-all welfare losses for society due to a tax divided by CO_2 savings;
- For the technologies we consider the additional investment costs of the technology and the energy cost reduction for the customers (purchasers of cars) respectively the increased producer surplus if the technology is produced in the region;
- For alternative fuels we have to consider the additional production costs minus the increased producer surplus if the technology is produced in the region.

For the last two categories it is furthermore important to consider the technological learning effect. Moreover, we have assumed that 75% of the value chain of new technologies are produced within the EU countries and hence these additional costs are converted into producer surplus.

The CO_2 reduction effects and the corresponding costs of the measures considered in the above categories for the aggregate of EU-15 countries are depicted in Figure 43.

The major result of this analysis – for further details see Ajanovic et al (2011) – is that the costs of taxes up to 36 million tons CO_2 reduction at a price of about 40 EUR/ton CO_2 are cheapest for society. So reducing especially the vkm driven and valuing the corresponding welfare loss has the first priority. Next cheapest is switch to biofuels first generation – biodiesel, bioethanol and biogas. This implies that by 2020 biofuels save at least 70% CO_2 compared to fossil fuels. Based on this pre-condition these biofuels in our scenario save 28 million tons CO_2 at costs between 180 and 350 EUR/ton CO_2. Measures of technical efficiency improvements –

[9] For details of the cost calculations see Ajanovic et al (2011)

starting with start/stop automatics, over electric power assistants (mild hybrids) to power splits (full hybrids) and efficiency improvements of the classical gasoline and diesel engine – are in the range of about 1000 to 1500 EUR/ton CO_2. The most expensive measures are to promote fuel cell cars and battery electric vehicles with saving costs above 2000 EUR/ton CO_2. This is the reason why neither BEV nor FCV show up in this figure for least-cost reduction of 100 million tons CO_2. Also BF 2nd generation are not among the least-cost solutions up to 2020 and do, hence, not show up in Figure 43.

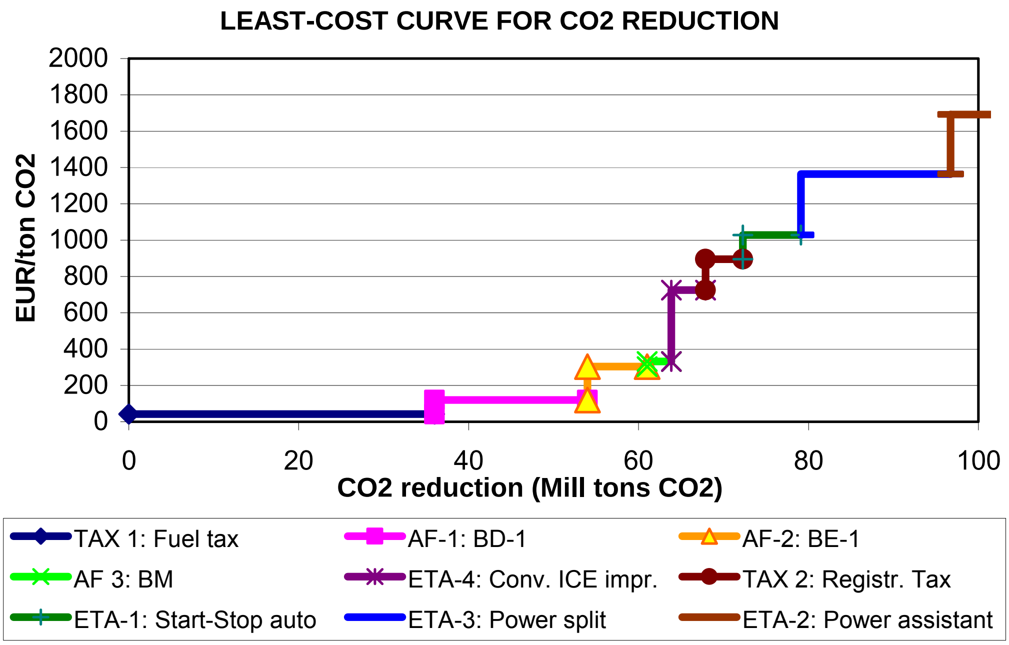


Figure 43. Least-cost curve for CO_2 reduction in passenger car transport in the EU-15 in 2010

Yet, most of these technological solutions are still in the early phase of market introduction. Given that a continuous adaptation of these technologies takes place up to 2020 a remarkable cost reduction of these technologies is possible. However, even if this takes place up to 2020 fuel tax will remain the cheapest solution for CO_2 reductions.

A result of Figure 43 is that the quantities of the measures fits very good with the shares of our ambitious scenario analysis.

Finally, an important aspect is that a specific least-cost measure could be the voluntary change to smaller cars. However, this measure must be brought about by changes in awareness and not only by financial incentives.

6. The way forward: Priorities of actions today, up to 2020 and beyond

Derived from the perceptions described above our suggestions for action lead to the following recommendations:

First, actions that should be implemented immediately are:

- *Introduce a green bonus scheme for CO_2 reduction in passenger transport*

Aside from the technology analyses conducted in ALTER-MOTIVE one major perception emerged regarding direct monetary incentives for individuals to change their personal short-term and long-term behaviour.

It is to introduce a green bonus/malus system for every citizen that provides monetary incentives for car sharing, turning-in or not owning a car (incl. scrapping scheme), using low-emission highly efficient vehicles and including (plus and minus) links to an ownership tax and to the use of public transport.

This system will work like an annual tax declaration and can be seen as a forerunner for a personal carbon allowances system.

- *Convert fuel taxes to CO_2 based tax and adapt at a 5% higher level per year*

Fuel taxes in Europe has been a reason why fuel consumption as well as CO_2 emissions of passenger cars compared to e.g. USA has been lower.

We suggest that all excise taxes are converted to a CO_2 emissions based tax system. This tax should be on a 5% higher level per year and take into account the WTW CO_2 emissions of the corresponding fuels.

Moreover, these additional tax revenues should be used to:

* reduce taxes on wages and ensure balanced burden for different social groups;

* provide incentives for using zero-emission transport modes (walking, biking …);

* improve performance of public transport.

- *New vehicles: tighten requirements to the car manufacturing industry*

Standards for the aggregate of all segments of sold vehicles in every country should be enforced by 6% per year. This is linked to an emission target of 87 g CO_2/km by 2020 based on the test cycle monitoring approach.

Yet the major effect could mainly come about from a switch to smaller cars. In this context it is important that car producers are further committed to market a higher share of smart cars with less kW and lower CO_2 emissions.

- *Implement a size-dependent registration fee for cars and limit depreciation of company cars by size*

A size-dependent registration fee for cars would provide a monetary incentive for customers to purchase smaller cars. Moreover, for company cars there should be a clear size-dependent limitation for depreciation to medium-size car costs and taxes.

- *Continue to procure case studies*

Our analysis of more than 130 case studies practically implemented on local level shows that virtually all of these initiatives received very positive feed-back and contribute to further acceptance and learning about AF and AAMT. This is many cases especially a sign that the public is a fore-runner regarding these new technologies. We encourage local authorities and initiatives from NGOs strongly to pursue such projects further. The collection of examples on the A-M homepage is a very good starting point for this, providing ideas for what can be done and documenting lessons learned regarding empirical performance.

Second, actions that should be implemented up to 2020 are:

- *Develop infrastructure for "emission free" vehicles*

Battery electric vehicles and fuel cell vehicles may to some extent contribute to a relief of over-all CO_2 emissions and may especially in cities contribute to improve air quality.

Yet, the potentials for market penetration and CO_2 reduction up to 2020 are very limited for all three major technologies (BEV, FCV and FFV). In an optimistic scenario the number of BEV in EU-15 will grow to a stock of about 528.000 cars in 2020 leading to less than 1% CO-reduction (because the overall stock of cars remains at about 200 millions).

In addition, the overall ecological performance of BEV strongly depends on how electricity is generated, how the battery performs ecologically and whether actually conventional passenger cars are substituted or additional transport is triggered. Moreover, in parallel to the market introduction of BEV the corresponding deployment of new renewable electricity capacities must be ensured and proven by certificates.

Regarding infrastructure for E-mobility: In most cities an infrastructure sufficient for the needs of the next years already exist. No further financial public support is needed. There should rather be an agreement between the electricity supply of the industry and (local) policy makers to provide a minimum reliable infrastructure at connection points to public transport, park & ride, airports and other crucial locations. Hence, it is recommended that the electricity supply industry and municipalities design joint roadmaps for an efficient development of infrastructure.

Regarding infrastructure for hydrogen vehicles: Experts - especially from Germany - expect that up to 2020 the market introduction of H_2 based vehicles will have started at least in some parts of Europe. We suggest that based on the model region concept for specific areas road-maps considering infrastructure and market introduction of cars will be developed.

- *Biofuels first generation: tighten standards – ensure better ecological performance*

Biofuels are expected in many policy directives and scientific papers to have the potential to contribute significantly to reducing fossil fuel consumption and corresponding CO_2 emissions. Yet, they are still under discussion mainly because of their currently poor ecological and economic performance. To cope with this problem, measures must be implemented that ensure that the ecological performance of these BF-1 improves and net specific CO_2 emissions are reduced significant up to 2020.

An important strategy to cope with these problems is to pursue a strict path towards an improvement of BF-1 to “Renewable fuels” (see EC, 2009) leading to 70% less CO_2 emissions of BF-1 by 2020 compared to about 45% today. This is strongly recommended along with certification and monitoring schemes.

In addition passenger cars might not be the priority target for biofuels. We recommend to revisit very carefully, whether the use of biofuels in other sectors where less alternatives exist, e.g. freight transport could make more sense.

Third, actions that focus on the long run, after 2020 are:

- *Emphasize efficient R&D for second generation biofuels and hydrogen*

The time horizon of this project is 2020. Within the remaining period, it is very unlikely that either 2^{nd} generation biofuels or hydrogen enter the market in a significant quantity. Yet, to harvest the benefits of these fuels in the time after 2020 it is important to undertake the necessary steps in the next years.

For hydrogen it is important that the preparation of the ideal infrastructure is planned and forced continuously. Moreover, it is very important that R&D is intensified focussing especially on a more efficient conversion of feedstock and primary energy carriers into these alternative fuels. This should finally also lead to more cost-effective production paths and market competitiveness beyond 2020.

THE CORE RULES OF ALTER-MOTIVE:

- Introduce a green bonus scheme for CO_2 reduction in passenger transport
- Convert fuel taxes to CO_2 based tax and adapt at an 5% /year higher level
- New vehicles: tighten requirements to the car manufacturing industry
- Implement a size-dependent registration fee for cars and limit depreciation of company cars by size
- Extend the procurement of case studies
- Develop infrastructure for “emission free” vehicles
- Tighten standards and ensure better performance of biofuels first generation
- Emphasize efficient R&D for second generation biofuels and hydrogen

7. Final key messages

The EU aims to reduce CO_2 emissions by 20% in 2020. Car passenger transport is one of the few sectors with continuously increasing CO_2 emissions and, hence, must deliver a remarkable contribution to meeting this goal. Yet, given this recent trend and the slow response of the car park to technical solutions it is clear that this is a very tough challenge.

The core objective of this project was to contribute to meeting this target. In this context we state that since the start of this project in 2008 many conditions changed and actions which are proposed in this report and which are the outcomes of our investigations has in similar ways in the meantime been proposed by others, e.g. also by the EC.

Our key message for European policy is: Be rigorous and set clear priorities for the following two targets that have to be pursued now: **improve energy efficiency** and **reduce energy consumption**. This statement is important for the following reasons: To meet the 2020 target a major policy of the EU is to implement lower CO_2 emission standards. Indeed, we consider this enforcement of standards as a very important policy measure to reduce fuel consumed and CO_2 emitted per km driven.

But improving energy efficiency alone does not necessarily lead to an equivalent energy and CO_2 saving effect. We have seen this problem in recent years in passenger car transport from two major features:

- Europeans purchased larger cars which reduced savings that were expected due to efficiency improvements by about half;
- car owners increased vehicle km driven – to some extent due to lower service prices due to lower fuel intensity (but also due to increase in income);

As a consequence, these CO_2 emission standards will also lead to cheaper costs per km driven and hence, as one response, to more driving activities and larger cars. So a very important aspect is that accompanying to standards there is an additional focus on energy conservation by introducing fuel taxes.

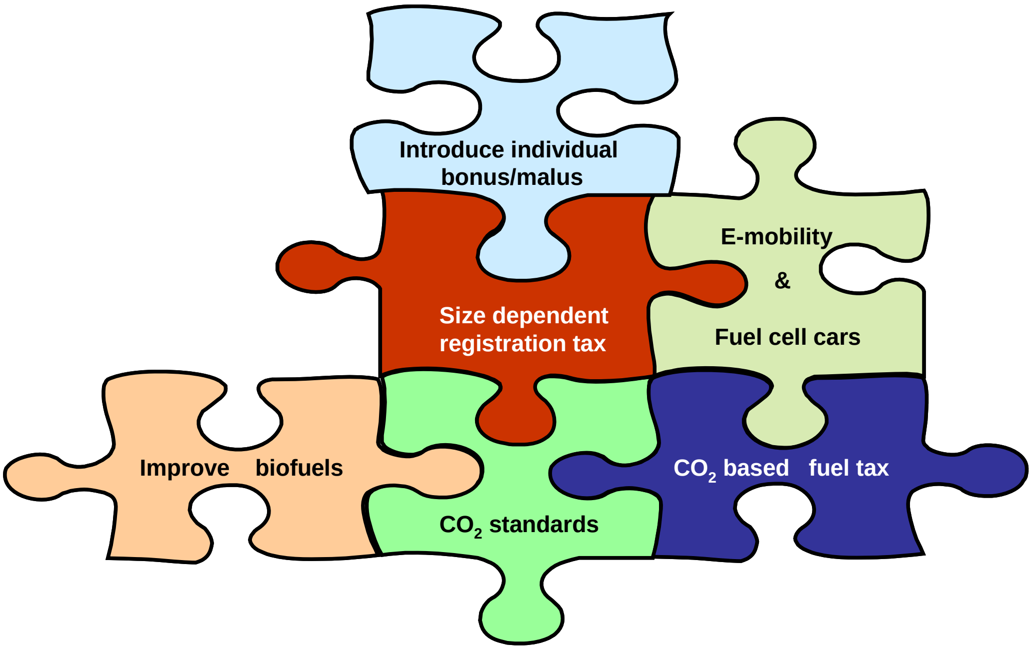
The measures described are also important because of the following sobering conclusions with respect to the future contributions of AF and AAMT. These are:

Regarding biofuels the potentials of BF-1 are to a large extent already exhausted, especially for BD-1 and BE-1. Moreover, they have to prove a better ecological performance up to 2020 to be considered seriously as CO_2 mitigating fuels. The market prospects of BF-2 today are very uncertain. The major problems are the currently still very high capital costs and the lack of continuous deployment of large production plants. Up to 2020 there are no signs that they will enter the market in considerable amounts.

With respect to AAMT the potentials for market penetration and CO_2 reduction of BEV and FCV up to 2020 are very limited. If they may reach in a very optimistic scenario 1% market share by 2020 they will straightforward only contribute at the maximum in the same range to CO_2 reduction. This will not provide a significant contribution to the EU's 2020 CO_2 reduction target.

So two final statements are important:

- Firstly, of course, in the long-term only a very broad portfolio of policy instruments (taxes, standards, quotas, emissions free-zones…) and new technologies (BEV, FCV …) can reduce energy consumption and straightforward CO_2 emissions significantly. Yet, there will not be any measure or technology that has the capability to solve all problems alone;



- Secondly, it is currently of **urgent importance** that there is a clear **focus** on implementing the two instruments with highest short-term effects: **standards and taxes**. Regarding these two instruments the simple but very important key message is that the intended targets and policies must be pursued more strictly and more tight and continuous pressure is put on the involved stakeholders: European and national policy makers, car manufacturing companies and also European citizens regarding their driving and car purchase behaviour.

Only if we manage to implement very soon the above described **urgent** measures and if we pave the way towards the **long-term goals** the vision of a sustainable transport system will come closer to reality – even before 2020.

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APPENDIX A: Calculation of WTT emissions

The calculation of WTT-net CO_2 emission balances as described in Figure A-1 is based on CONCAWE, 2008 and on Toro at al 2010.

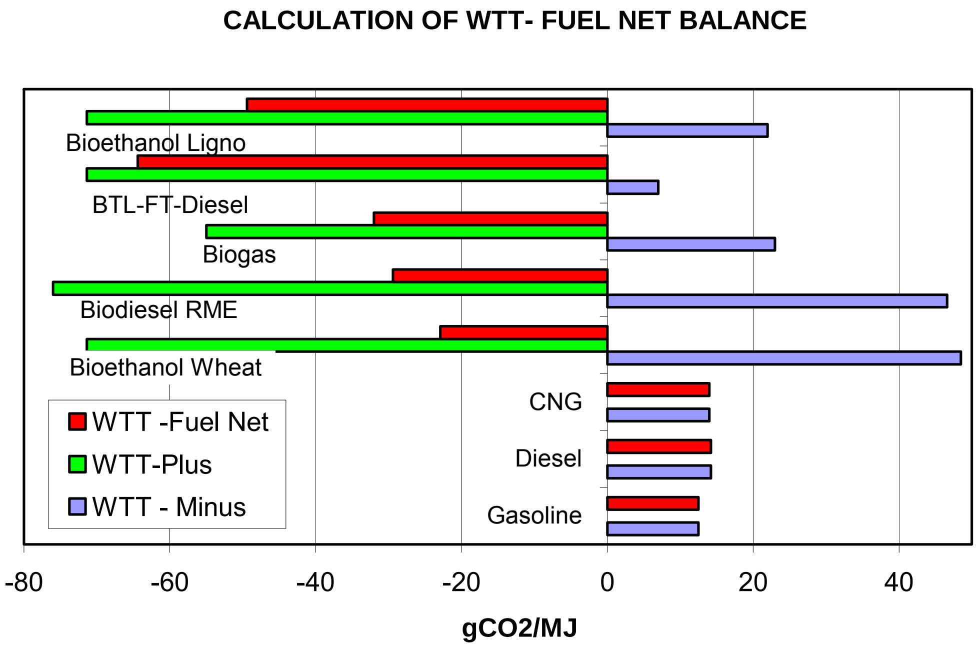


Figure A-1: How WTT CO_2 emissions are calculated

Calculation of net WTT emissions:

$$WTT_{net} = WTT_{minus} + WTT_{plus}$$

With

WTT_{plus} ….. CO_2 Fixation due to biomass planting

WTT_{minus}… CO_2 emissions during Fuel production

Note that in this calculation no land-use changes are considered.

APPENDIX B: Assumptions and results of different scenarios

Table B-1. Assumptions of different scenarios

	BAU	Fiscal policy scenario	Technical Standard scenario	Fuel switching (Biofuels, E-mobility, H2)-scen.	Ambitious policy scenario
Assumptions:					
Income	+2.5%/yr	+2.5%/yr	+2.5%/yr	+2.5%/yr	+2.5%/yr
Gas price	+3.0%/yr	+3.0%/yr	+3.0%/yr	+3.0%/yr	+3.0%/yr
Dies price	+3.0%/yr	+3.0%/yr	+3.0%/yr	+3.0%/yr	+3.0%/yr
CNG price	+3.0%/yr	+3.0%/yr	+3.0%/yr	+3.0%/yr	+3.0%/yr
Ele. price	+3.0%/yr	+3.0%/yr	+3.0%/yr	+3.0%/yr	+3.0%/yr
Fuel tax increase	0	3.5 cent/l/yr (=1.5 cent/kg CO_2/yr)	0 cent/ litre/yr	0 cent/ litre/yr	3.5 cent/l/yr (=1.5 cent/kg CO_2/yr)
Registration tax increase	All: 2%/year	Small: 2%/yr Med: 4%/yr Large: 8%/yr	All: 2%/year	All: 2%/year	Small: 2%/yr Med: 4%/yr Large: 8%/yr
Specific CO_2 emissions of Biofuels	-0.5%/yr	-0.5%/yr	-0.5%/yr	-5.0%/yr	-5.0%/yr
Increase of biofuels / year	4 % /yr	4 % /yr	4 % /yr	8 % /yr	8 % /yr
Specific emissions (gCO_2/km) of new cars 2020	107 g CO_2/km	107 g CO_2/km	87 g CO_2/km	87 g CO_2/km	87 g CO_2/km
Reduction in spec. CO_2 emissions of new cars up to 2020	-2.3 %/yr	-2.3 %/yr	-5.0%/yr	-5.0%/yr	-5.0%/yr
Procurement of BEV in 2011	2000	2000	2000	5000	5000
Procurement. of BEV in 2012-2020	1800, 1600, 1400, …	1800, 1600, 1400, …	1800, 1600, 1400, …	4500, 4000, 3500, …	4500, 4000, 3500, …
Procurement of FCV in 2011	50	50	50	100	100
Procurement of FCV in 2012-2020	100, 150, 200 …	100, 150, 200 …	100, 150, 200 …	200, 300, 400 …	200, 300, 400 …

Table B-2. Results of different scenarios

	BAU	Fiscal policy scenario	Technical Standard scenario	Fuel switching scenario (Biofuels, E-mobility, H2)	Ambitious policy scenario
Results:					
Stock of BEV 2020	382 000	380 000	401 000	512 000	528 000
Biofuels by 2020	586 PJ	586 PJ	586 PJ	710 PJ	710 PJ
CO_2 2008	501 Mill. tons CO_2	501 Mill. tons CO_2	501 Mill. tons CO_2	501 Mill. tons CO_2	501 Mill. tons CO_2
CO_2 2020	498 Mill. tons CO_2	437 Mill. tons CO_2	450 Mill. tons CO_2	455 Mill. tons CO_2	401 Mill. tons CO_2
Effect CO_2 (%): Compar. 2020-2008	-0.6%	-12.8%	-10.2%	-9.2%	-20.0%
Effect CO_2 (%) Compar. policy scenario with BAU	0.0%	-12.2%	-9.6%	-8.6%	-19.5%
Energy 2008	5970 PJ	5970 PJ	5970 PJ	5970 PJ	5970 PJ
Energy 2020	6015 PJ	5340 PJ	5495 PJ	5745 PJ	5124 PJ
Effect Energy (%): Compar. 2020-2008	0.8%	-10.6%	-8%	-3.8%	-14.2%
Effect Energy (%): Comparison policy scenario with BAU	0.0%	-11.2%	-8.7%	-4.5%	-14.8%

APPENDIX C: Main properties of fuels by 2010

	Density	**Lower heat value**	**Energy content**	**CO_2-content**		**CO_2-WTW**
Fuel:	kg/m3	MJ/kg	kWh/litre	kg/kg	gCO_2/MJ	g CO_2/MJ
Gasoline	745	43.2	8.70	3.17	73.38	85.9
Diesel	835	43.1	10.00	3.16	73.32	87.5
CNG	1.008	45.1	0.01	2.54	56.32	70.2
LPG	550	46.0	7.03	3.02	65.65	73.7
Bioethanol Wheat	794	28.0	6.18	1.91	68.21	48.5
Biodiesel Rapeseed	890	36.8	9.10	2.81	76.36	46.8
Biogas	1.003	30.0	0.01	2.54	84.67	24.2
Bioethanol Ligno	794	28.0	6.18	1.91	68.21	22.0
Biodiesel BTL-FT	890	36.8	9.10	2.81	76.36	6.4
Hydrogen RES	0.09	120.1	0.003	0.00	0.00	14.0
Hydrogen Natural gas	0.09	120.1	0.003	0.00	0.00	112.0
Electricity RES					0.00	7.0
Electricity New Natural gas					0.00	126
Electricity UCTE Coal Mix					0.00	269

Sources: CONCAWE, TTW-Report 2008, own calculations

APPENDIX D: Potentials for biofuels by 2020

In the following tables we summarize the major findings regarding potentials for BF-1. Note that the area potentials are to some extent exchangeable. All arable land can be used in principle for growing feedstocks for BE-1, BE-2, BM and BD-2. Due to the fact that BF-2 will not contribute remarkably to fuel supply up to 2020 the potentials for these fuels which are mainly based on lignocelluslosic materials are not documented here.

The major sources for the tables in this appendix are Toro et al (2010), EEA (2006) and Panoutsou (2009). See also the comprehensive documentation for references in Toro et al (2010)

Table D-1. Potential for biodiesel from oil seeds (mainly rapeseed) in the EU by 2020

	Area oil seeds available for BD-1	**Rapeseed oil**	**Primary energy**	**Biodiesel**	**Biodiesel**
	(1000 ha)	(Mill. Tons)	PJ (PE)	PJ (BD-1)	Mill tons BD
EU-15	12293	38	549	384	10
EU-27	18674	58	834	584	16

Assumptions: Oil seed area for biofuels is 17% from total arable land by 2020; On average 3.1 tons/ha are harvested; energy content of oil is 14.4 MJ/kg

Table D-2. Potential for bioethanol from wheat and maize in the EU by 2020

	Area other crops available for BE-1	**Wheat, maize**	**Primary energy**	**Bioethanol**	**Bioethanol**
	(1000 ha)	(Mill. Tons)	PJ (PE)	PJ (BE-1)	Mill tons BE
EU-15	9401	71	1043	678	24
EU-27	14280	107	1585	1030	37

Assumptions: Other crop area for biofuels is 13% from total arable land by 2020; On average 7.5 tons/ha are harvested; energy content of wheat or maize is 14.8 MJ/kg

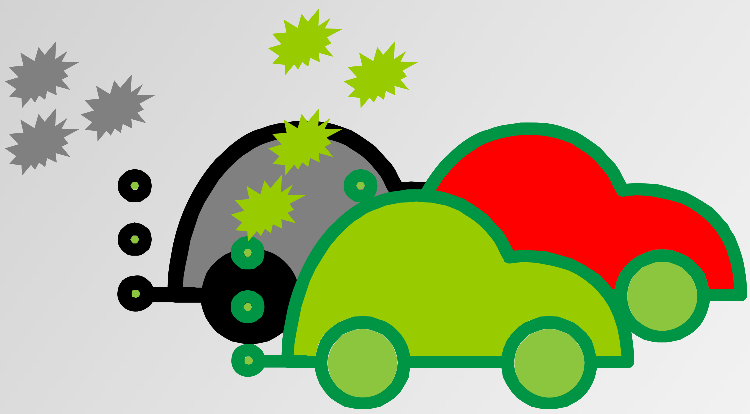
Table D-3. Potential for biomethane from grass in the EU by 2020

	Area grass land available for BM	**Grass odm**	**Primary energy**	**Biomethane**	**Biomethane**
	(1000 ha)	(Mill. Tons)	PJ (PE)	PJ (BM)	Mill tons BM/yr
EU-15	1694	5	131	72	2
EU-27	2345	7	182	100	3

Assumptions: From cultivated meadows&pastures (see FAO for further details) 87% are estimated to be grassland wherefrom 10% are assumed to be available for biomethane; On average 3.6 tons odm/ha are harvested; energy content of grass is 18 MJ/kg

Table D-4. Potential for biomethane from manure and waste fat in the EU by 2020

	Manure & waste fat available for BM	**Primary energy**	**Biomethane**	**Biomethane**
	(Mill. Tons)	PJ (PE)	PJ (BM)	Mill tons BM/yr
EU-15	26	372	279	8
EU-27	20	289	217	6



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