On the impact of policy measures on cars' CO_2 emissions in the EU

Amela Ajanovic
Energy Economics Group
Vienna University of Technology
Gusshausstr. 25-27/370-2
Vienna, Austria
ajanovic@eeg.tuwien.ac.at

Reinhard Haas
Energy Economics Group
Vienna University of Technology
Gusshausstr. 25-27/370-2,
Vienna, Austria
haas@eeg.tuwien.ac.at

Franz Wirl
Department of Economics
University of Vienna
Vienna, Austria
franz.wirl@univie.ac.at

Keywords
cars, emissions, transport policies and measures

Abstract
Reducing CO_2 emissions from cars is essential in order to curtail global temperature increases. In this paper we analyze how the following measures contribute to reducing CO_2 emissions: (i) voluntary agreements with car manufacturers; (ii) mandatory standards on specific CO_2 emissions; (iii) fuel taxes; (iv) registration taxes; (v) subsidies. Our core objectives are: (i) to provide a survey on the implementation of these policy measures for car transport in EU countries; (ii) to analyze their impact on energy consumption and CO_2 emissions, and (iii) to extract the most promising policies to reduce emissions. The approach builds on a formal framework based on the decomposition of energy into service and intensity and on conducting econometric analyses for energy consumption as well as kilometers driven. The major results and conclusions are:

- Despite the fact that there are many parameters that constitute a formal framework to explain energy consumption and CO_2 emissions, there is one key parameter which influences final CO_2 emissions and this is the service price elasticity. Our results for the service price elasticity of car driving in Europe are about -0.4 to -0.45;
- The service price elasticity impacts fuel taxes, standards as well as registration taxes;
- This result leads to the situation that a mix of policies is preferable. A combined tax-standard policy will lead to a win-win situation for the environment and car drivers. A simultaneously introduced fuel tax will compensate for the rebound effect without hurting car drivers due to service vkm driven remaining at same service price. The fuel tax should compensate the standard to an extent so that finally the service price before and after policy introduction remains the same. Yet, because registration taxes work as standards, a fuel tax must also accompany an intended introduction of registration taxes.

Introduction
The transport sector, which is primarily based on fossil energy, is the second biggest source of greenhouse gas emissions (GHG) in the EU-28, see Figure 1. The second largest part of these emissions is caused by road transport. Road transport contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2).

This is a key reason while over the last decade different policy measures have been implemented on road transport, especially on car passenger transport. The most important implemented measures are fuel taxes, registration taxes, ownership taxes, and CO_2 standards for new cars. In spite of implemented policies emissions from road transport were continuously increasing until 2007. A slight reduction can be noticed starting from 2008 partly also due to the economic crisis, see Figure 2.

The objective of this paper, which builds on Ajanovic and Haas (2014), is to discuss advantages and problems related to the implemented policy measures. In this paper we will (i) provide a survey of policy measures in car transport in EU countries; (ii) analyse their impact on energy consumption and CO_2 emissions, and (iii) extract the most promising policies to reduce emissions.

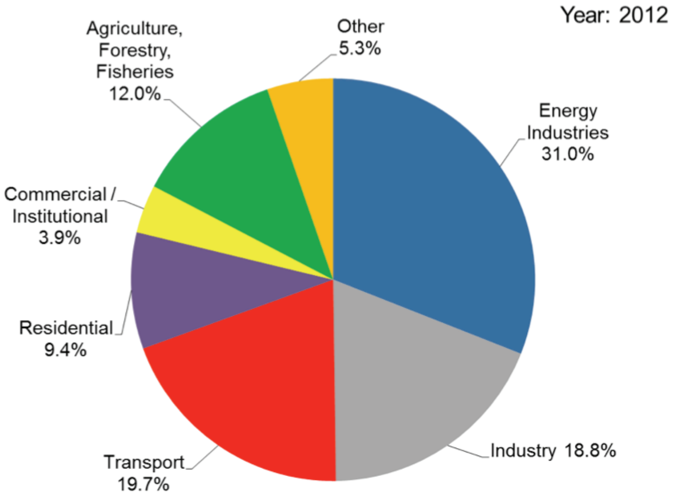

Figure 1. GHG emissions by sectors, EU-28, (Data source: EC, 2014).

Major developments in car transport in the EU

The largest part of the total GHG emissions from road transport is due to cars. Although the fuel efficiency of passenger cars has significantly improved in the last decade, trends towards more powerful vehicles and additional services in cars have reduced the possible benefits of fuel efficiency improvements. At the same time, the vehicle ownership level is continuously increasing in all EU countries. These developments have significant impacts on the EU's progress in cutting overall GHG emissions.

In this section the major recent developments in car transport are documented for twelve EU countries: Austria, Denmark, Finland, France, Germany, Greece, Italy, The Netherlands, Portugal, Spain, Sweden and United Kingdom.

Firstly, car ownership trends (stock of passenger cars per capita) are shown in Figure 3 for the period 1990–2012. In all countries, the car ownership level was increasing. However, there are significant differences between EU countries (e.g. in 2011 the lowest car stock per capita was in Spain, 0.36, and highest in Italy, 0.62). In some countries such as France, Finland and Spain stock of cars per capita is stable over the last few years.

Due to the implemented policy measures in the EU, average specific energy consumption of cars has been reduced in the last decade. In 1990 average fuel intensity of passenger cars in analysed countries was between about 7.5 and 9.5 litres per 100 kilometres. Already in 2010 fuel intensity is in the range between 5.8 and 8.3 l/100 km, see Figure 4. However, the fuel intensity shown in Figure 4 is distorted because intensity has been diluted by more powerful cars leading to lower reduction of energy consumption per km driven, Ajanovic/Haas (2014a). Impact of car size on fuel intensity is analysed by Ajanovic et al. (2012).

European CO_2-emission targets for new passenger cars have significantly contributed to emission reduction in the last decade. Figure 5 shows the development of CO_2 emissions of new passenger cars for the period 1995–2012. In all analyzed countries, considerable emissions reductions have been achieved. In 1995 average emissions of new cars have been in the range of 224 (Sweden) and 175 (Spain) gCO_2/km. In 2012, the lowest emissions were seen in Portugal (117 gCO_2/km) and highest in Germany (142 gCO_2/km). The strongest decrease can be noticed after 2008, (Ajanovic/Haas 2014a).

Implemented policy measures in EU countries

In this paper we analyze the following policy measures implemented in EU countries which can contribute to reducing CO_2 emissions: (i) voluntary agreements with car manufactures; (ii) mandatory standards on specific CO_2 emissions; (iii) fuel taxes; (iv) registration taxes; (v) subsidies/incentives for electric vehicles.

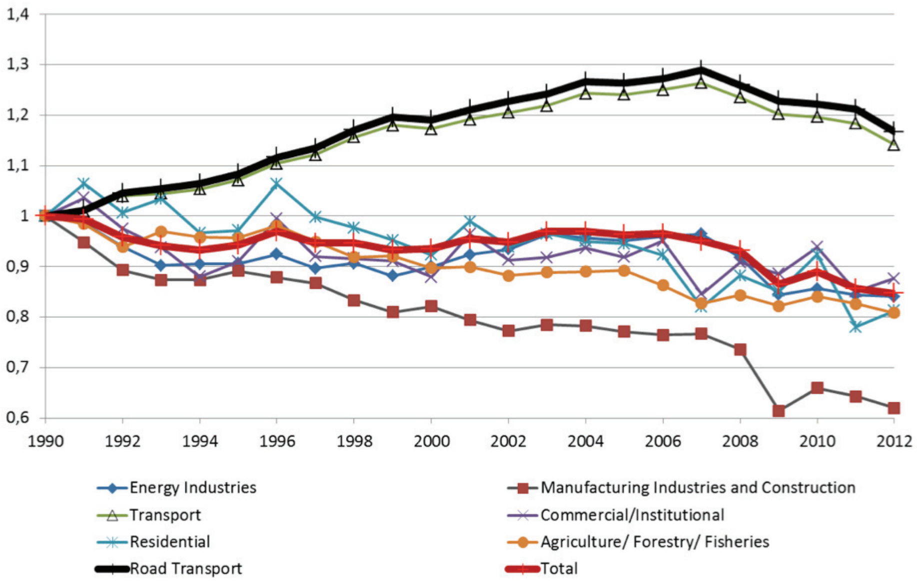

Figure 2. Development of GHG emissions in EU-28 countries (1990=1), (Data source: EC, 2014).

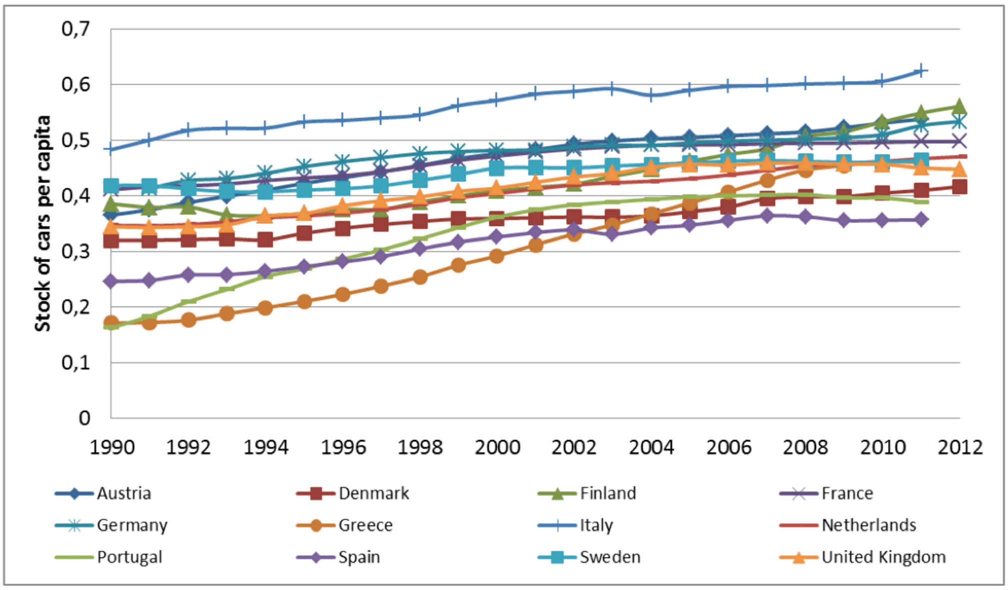

Figure 3. Stock of passenger cars per capita (Data source: ODYSSEE Database).

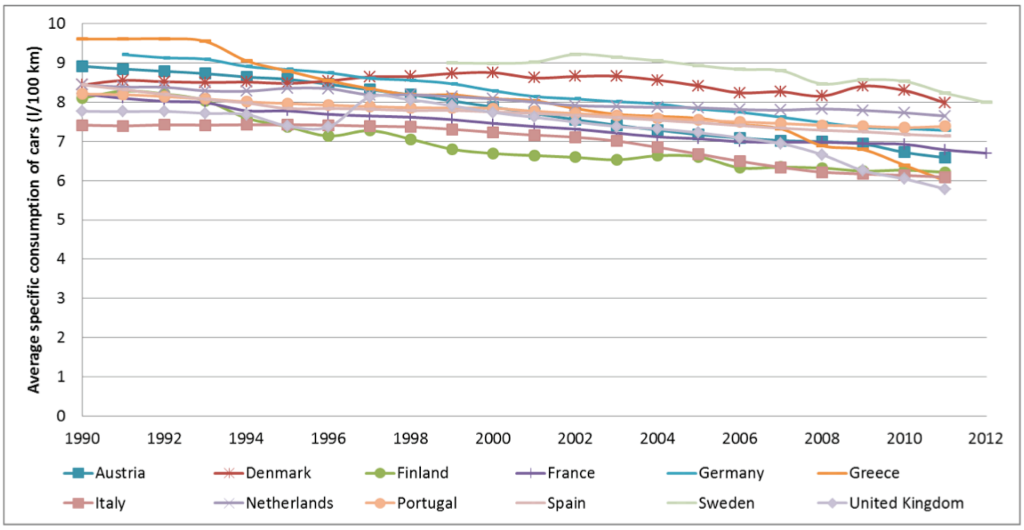

Figure 4. Average fuel intensity of passenger cars (Data source: ODYSSEE Database).

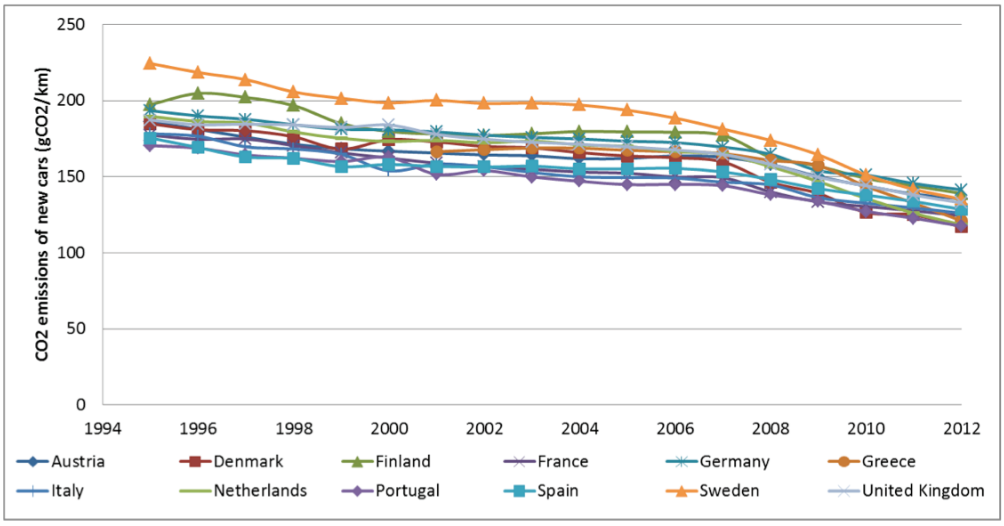

Figure 5. Average CO_2 emissions of new passenger cars (Data source: ODYSSEE Database).

STANDARDS FOR CO_2 EMISSION OF NEW PASSENGER CARS

Unlike taxes and subsidies/initiatives which are set on the local/national, standards for CO_2 emissions of new cars are determined at the EU level, and car manufacturers must meet the standards or pay penalties for noncompliance, see EU Regulation (EC, 2009). According to the Regulation, average CO_2 emissions from cars should not exceed 130 grams CO_2 per km by 2015 and should drop further to 95 g/km by 2020. The 130 grams target will be phased in between 2012 and 2015.

At first, agreements with car manufacturers were on a voluntary basis. However, since the initial target of 140 gCO_2/km for 2008 was not met on time (the average for the whole car market for 2008 was 153.7 g/km), in 2009 the first mandatory CO_2 emission standards for cars were adopted in the EU (de Wilde and P. Kroon, 2013), see Figure 6. The target for 2015 is 130 gCO_2/km, and for 2020 95 gCO_2/km. In practice this means that each manufacturer gets an individual annual target based on the average mass of all its new cars registered in the EU in a given year. Since targets for 2015 and 2020 are mandatory, manufacturers will have to pay penalties if their average emission levels are above the target set by the limit value curve. The penalties will be based on the calculation of the number of grams per kilometre (g/km) that an average vehicle registered by the manufacturer is above the target, multiplied by the number of cars registered by the manufacturer. A premium of EUR 5 per car registered will apply to the first g/km above the target, EUR 15 for the second g/km, EUR 25 for the third g/km, and EUR 95 for each further g/km. From 2019 every g/km of exceedance will cost EUR 95 (EU, 2014).

Monitoring reports have already showed significant improvement of CO_2 emissions on new passenger cars, see Figure 7.

PASSENGER CAR TAXATION

According to ACEA (2014) there are three major categories of passenger car taxation: (i) taxes on acquisition, (ii) taxes on ownership, and (iii) taxes on motoring. In addition Value Added Tax (VAT) is also applied to all taxes in the range of 18 % to 25 % across EU countries.

A tax on acquisition is a tax paid once, by each vehicle owner, for each vehicle purchased and entered into service. This tax is also called sales tax or registration tax. The criteria for acquisition taxes are different across EU Member States. Most of the criteria are based on fuel consumption, cylinder capacity, CO_2 emissions and price.

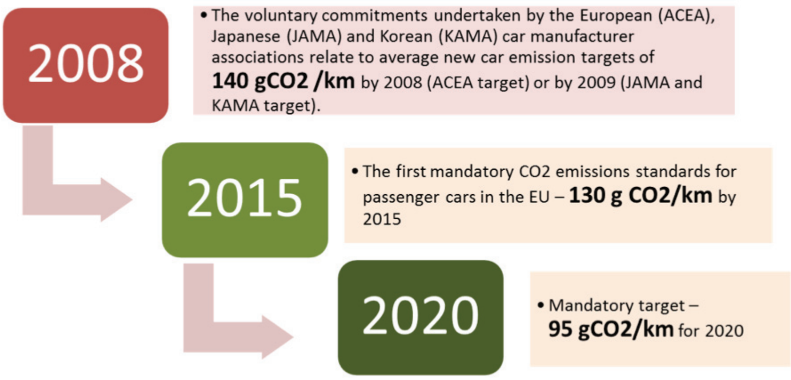

Figure 6. Emission targets for new passenger cars in the EU up to 2020 (Ajanovic and Haas, 2014a).

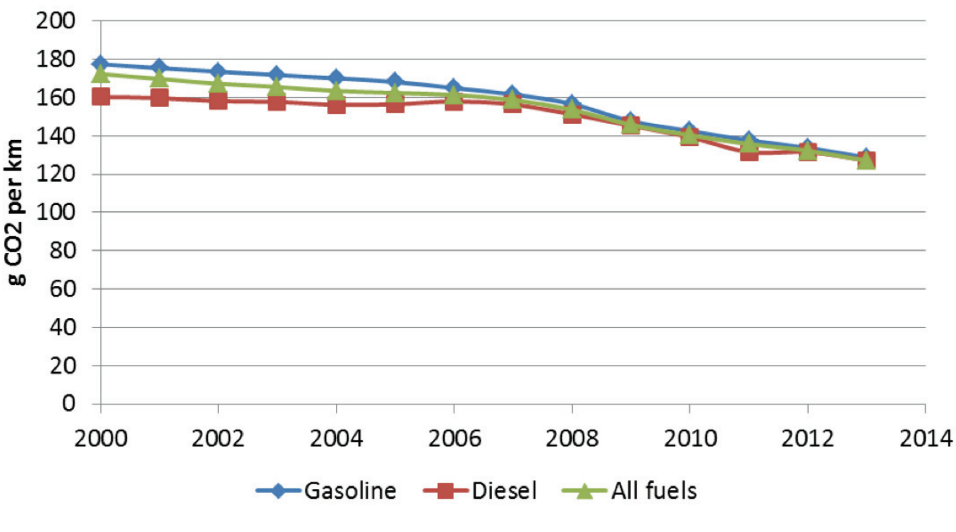

Figure 7. Evolution of CO_2 emissions from new passenger cars by fuel in EU-27 (Data source: EEA, 2014).

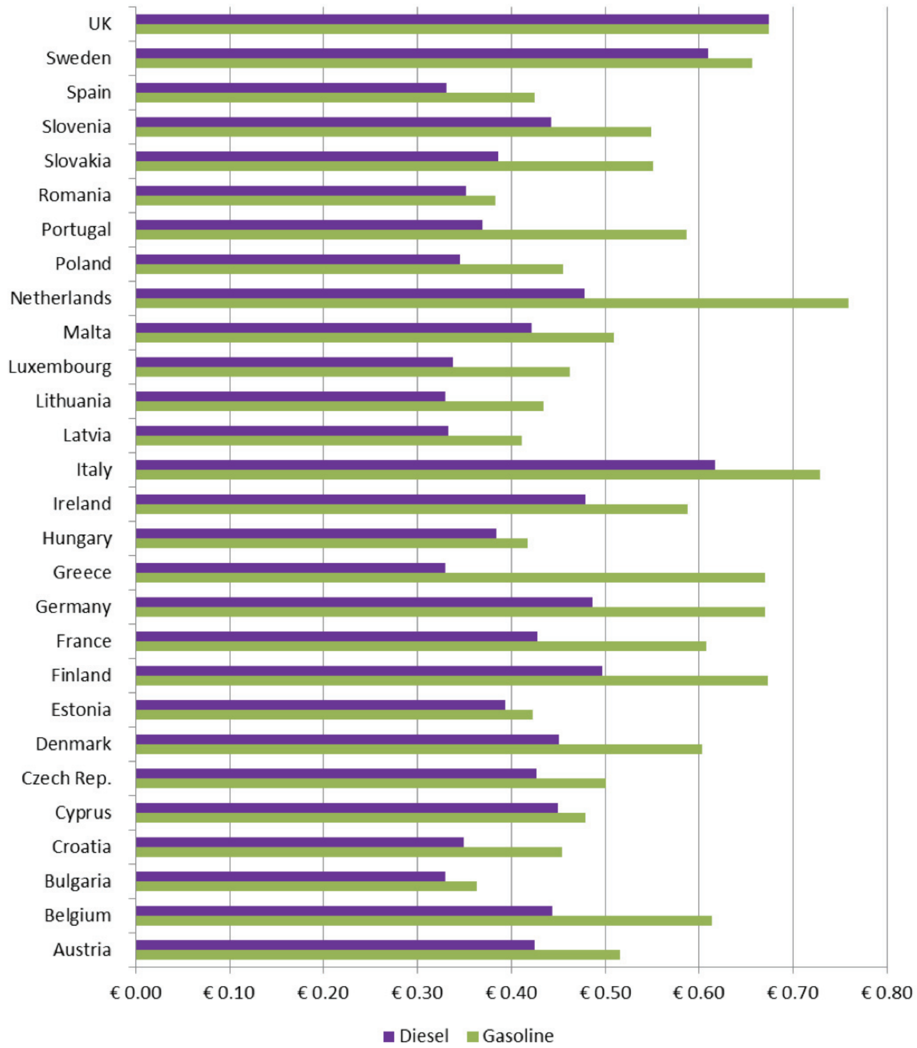

Figure 8. Excise duties on gasoline and diesel (Data source: EEP, 2013).

Taxes on ownership are paid annually, regardless of how often the vehicle is used. These taxes are mostly based on CO_2 emissions, weight, cylinder capacity, power and fuel consumption. Also this tax is not applied in all countries (e.g. Czech Republic, Estonia, France, Lithuania, Poland and Slovakia).

Taxes on motoring are taxes on fuels. The different excise duties on gasoline and diesel in EU countries are shown in Figure 8.

SUBSIDIES AND TAX INCENTIVES FOR ELECTRIC VEHICLES

One possibility to reduce CO_2 emissions is to increase the use of alternative fuels and alternative automotive technologies. In recent years a major focus was put on biofuels. However, relatively moderate environmental benefits of biofuels and competition with food production, have made 1st generation biofuels less attractive than initially presumed.

In recent years interest in electric vehicles has significantly increased. This increase is due to improvements in the technology as well as purchase and tax incentives for electric vehicles which have been implemented in many EU countries.

Table 1 provides an overview of the incentives for the purchase and use of electric vehicles which are currently implemented in some EU countries.

In spite of supporting policies, at the end of 2012 the global stock of rechargeable electric cars – battery electric vehicles (BEV), range extenders (REX) and plug-in electric vehicles – was circa 180,000, representing just 0.02 % of the total passenger car stock (IEA, 2013). The share of rechargeable electric vehicles in the total EVs stock is just 5 %, 95 % of all EVs are non-rechargeable hybrid electric vehicle (HEV) (Ajanovic, 2015).

Figure 9 shows market share of pure battery electric vehicles. In all analyzed countries the share is very low, under 1 %. In 2013 the highest market share in the EU was in the Netherlands (0.83 %) followed by France (0.79 %). This is relatively low compared to Norway (5.75 %).

The plug-in hybrid market share in 2013 was the highest in the Netherlands with 4.72 %, followed by Sweden (home of the popular Volvo V60 plug-in hybrid) 0.41 %, see Figure 9.

Acceptance of electric vehicles is dependent on the supporting policy measures which have been implemented but also on prices of electricity and fossil fuels. The countries with low electricity price and high gasoline price (e.g. the Netherlands) are basically more interested in electric vehicles. Figure 10 shows differences in gasoline and electricity prices across the EU.

Table 1. Incentives (ACEA, 2014).

Country	Incentives
AT	Electric vehicles are exempt from the fuel consumption tax and from the monthly vehicle tax.
DE	Electric vehicles are exempt from the annual circulation tax for a period of ten years from the date of their first registration.
FI	Electric vehicles pay the minimum rate (5 %) of the CO_2 based registration tax.
FR	Hybrid vehicles emitting 110 g/km or less of CO_2 benefit from a premium of €3,300. Electric vehicles are exempt from the company car tax. Hybrid vehicles emitting less than 110 g/km are exempt during the first two years after registration.
DK	Electric vehicles weighing less than 2,000 kg are exempt from the registration tax. This exemption does not apply to hybrid vehicles.
GR	Electric and hybrid vehicles are exempt from the registration tax, the luxury tax and the luxury living tax. Electric passenger cars and hybrid passenger cars with an engine up to 1,929 cc, are exempt from the circulation tax. Hybrid cars with a higher engine capacity pay 50 % of the normal circulation tax rate.
IT	Electric vehicles are exempt from the ownership tax for a period of five years from the date of their first registration. After this five-year period, they benefit from a 75 % reduction of the tax rate applied to equivalent petrol vehicles in many regions.
NL	Electric vehicles are exempt from the registration tax. Other vehicles including hybrid vehicles are also exempt from the registration tax if they emit maximum 85 g/km (diesel) or 88 g/km (petrol) of CO_2 respectively.
PT	Electric vehicles are exempt from the registration tax ISV and from the annual circulation tax. Hybrid vehicles benefit from a 50 % reduction of the registration tax.
ES	None
SE	Five year exemption from paying annual circulation tax: Electric vehicles with an energy consumption of 37 kWh per 100 km or less are exempt from the annual circulation tax for a period of five years from the first registration. The same five year exemption applies to electric hybrid and plug-in hybrid vehicles that fulfill the new green car definition applied for new registrations from 1 January 2013. Moreover, for both electric cars and plug-in hybrids the electrical energy consumption per 100 km must not exceed 37 kWh to be regarded as a green car. Reduction of company car taxation: For electric and plug-in hybrid vehicles, the taxable value of the car for the purposes of calculating the benefit in kind of a company car under personal income tax is reduced by 40 % compared with the corresponding or comparable petrol or diesel car. The maximum reduction of the taxable value is SEK 16,000 per year. Super green car premium new cars: A so called subsidy “Super green car premium” of SEK 40,000 is available for the purchase of new cars with CO_2 emissions of maximum 50 g/km. The premium is applied both for the purchase by private persons and companies. For companies purchasing a super green car, the premium is calculated as 35 % of the price difference between the super green car and a corresponding petrol/diesel car, with a maximum of SEK 40,000. The premium will be paid for a total of maximum 5,000 cars.
UK	Purchasers of electric vehicles and plug-in hybrid vehicles with CO_2 emissions below 75 g/km receive a premium of £5,000 (maximum) or 25 % of the value of a new car or £8,000 (maximum) or 20 % of the value of a new LCV meeting eligibility criteria (for example, minimum range 70 miles for electric vehicles, 10 miles electric range for plug-in hybrid vehicles). Electric vehicles are exempt from the annual circulation tax. This tax is based on CO_2 emissions and all vehicles with emissions below 100 g/km are exempt from it. Electric cars are exempt from company car tax until April 2015 and electric vans are exempt from the van benefit charge until that date too. Electric vehicles and other vehicles emitting less than 95 g/km of CO_2 can claim a 100 % first-year allowance for depreciation.

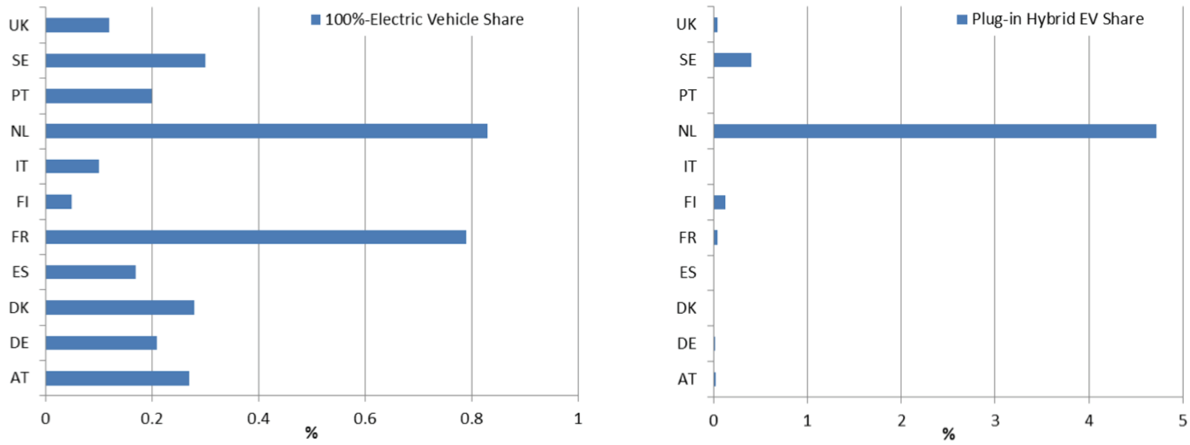

Figure 9. Share of electric vehicles (Data source: Shahan, 2014).

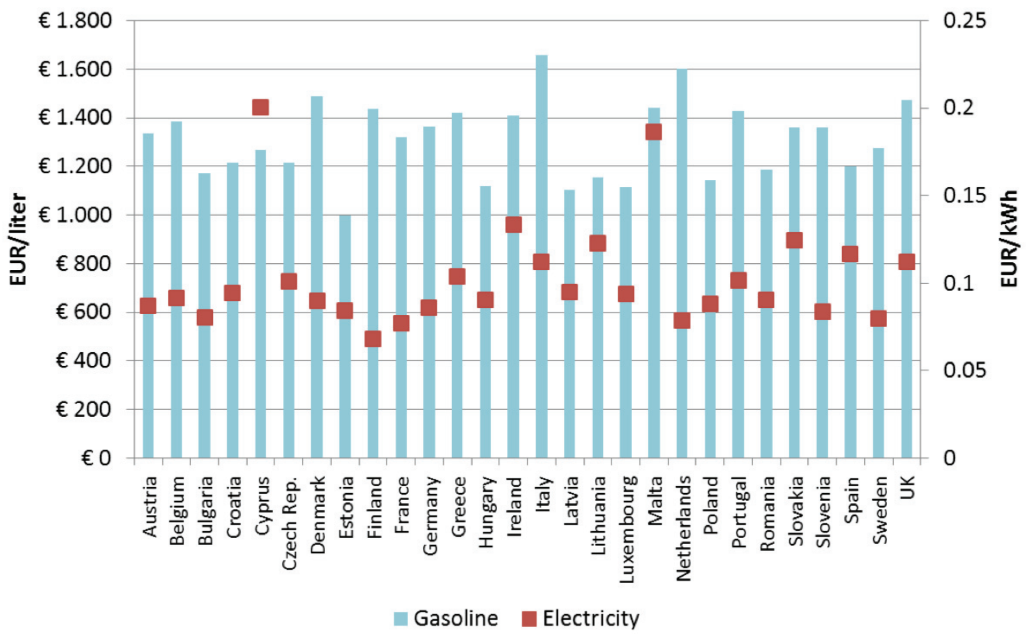

Figure 10. Prices of gasoline and electricity by country (Data sources: EEP, 2013;WB, 2014).

Impact of policy measures on reduction of CO_2 emissions

To analyse the impact of various policies on overall CO_2 emissions, a formal framework based on technical relations between CO_2 emissions, energy and service demand is used. It builds on work by Wirl (1992), Walker/Wirl (1993), Haas (2009) and Ajanovic/Haas (2014b).

The basic presumption is that consumers do not demand energy or technology per se, but energy services (S), in this case mobility – vehicle kilometres driven (vkm). They enjoy utility from consuming a particular service, which is in general provided by combining different inputs of energy, technology, human and physical capital, and environment (including natural resources). Given the fact that human and physical capital is largely accumulated in the technical efficiency of the technologies used, conversion technologies as well as infrastructure, the energy service (vkm) can be defined in a technical way as a function of the energy input (E) needed to provide energy service and the efficiency (η) of the technology which facilitates the required services, see Wirl (1993). Based on contributions by Walker/Wirl (1993) and Haas et al (2009) vkm in a technical definition is:

$$vkm = f(E, \eta(T)) \tag{1}$$

where E is energy, and η(T) is the efficiency of the technology. More precisely Eq. (1) defines that the service mobility (vkm) is provided by the input of energy and technology. If there are no congestion limits Eq. (2) can be simplified as:

$$vkm = E \cdot \eta(T) \tag{2}$$

Instead of efficiency η(T), its inverse, fuel intensity (FI) is often used. Total energy used which is mostly dependent on fuel intensity of cars and number of kilometres driven per year (vkm) can then be written as:

$$E = vkm \cdot FI \tag{3}$$

Emissions from passenger cars depend, in principle, on total energy used in cars as well as on the type of energy used. Different fuels (e.g. gasoline, diesel, biofuels, etc.) have different specific CO_2 emissions coefficients. The average specific CO_2 emissions coefficient (f_{CO_2}) can be improved with better quality fossil fuels, higher share of biofuels with better ecological performance, more electricity from renewable energy sources, etc. CO_2 emissions (CO_2) from passenger cars can be described as:

$$CO_2 = E \cdot f_{CO_2} = vkm \cdot FI \cdot f_{CO_2} = vkm \cdot CO_{2\_SP} \tag{4}$$

where CO_{2_SP} is specific CO_2 emissions in kg CO_2/km.

To understand how policies work we have to know how consumers make decisions. In principle, consumers try to maximize the benefits they enjoy from the consumption of a specific service or good and to minimize the monetary and other efforts related to the consumption of this good or service, see Wirl (1992) and Walker/Wirl (1993).

Consumer decisions can be affected by policy measures, e.g. fuel tax (τ_f), efficiency standards (η^*) and registration tax (τ_R). Basically, consumers strive for service demand, and service demand depends on energy service price (P_s), income (Y), investment costs (IC) and quality (q) from other possible attributes (x):

$$S = f(P_s, Y, IC, q(x)) \tag{5}$$

However, the impact of quality q(x) is neglected in this paper. In the short-term service demand – in this case vkm – can be described as:

$$vkm = f(P_S, Y) \tag{6}$$

with

$$P_s = P_f \cdot FI \tag{7}$$

This service price can be changed with policies:

- by raising the fuel tax τ_f which increases P_f and consequently P_s or
- by reducing fuel intensity by means of a standard (FI^*) which decreases P_s

$$P_S^* = (P_f + \tau_f) \cdot FI^* \tag{8}$$

The level of short-term service demand with respect to kilometres driven depends on available income (Y)[1] and the service price of a km driven (P_S). In other words we assume that once a car is purchased there are no other attributes for driving more or less than lower or higher energy service prices and income. The impacts on vkm driven is analysed in Ajanovic/Haas (2012) by applying a cointegration approach to the following model:

$$\ln vkm_t = C + \alpha_s \ln P_{S_t} + \beta \ln Y_t \tag{9}$$

Where C is intercept, vkm is service demand (e.g. vehicle km driven in year t), P_s is weighted average price of service (calculated by means of weighted fuel prices), and Y is real private final consumption expenditures.

The most interesting coefficients are the energy service price elasticities – α_S – because they contain information on the impact of both price and efficiency.

Empirical analyses of the magnitude of price elasticities have been conducted in many papers, e.g. Dahl (2012), Dargay (1993) and Goodwin et al. (2004). Investigations conducted by the authors of this paper – see e.g. Ajanovic/Haas 2010, 2011 and 2012 – have resulted in long-term service price elasticities of about (-0.4) to (-0.45). Related to the above reflections this leads to the following interpretations: the increase in fuel prices due to a fuel tax of 1 % would result in energy savings of about 0.4 % to 0.45 %. With a standard which decreases CO_2 emissions by 1 % the savings would be between 0.55 % and 0.6 %. About the same effect would result from a CO_2-dependent registration tax.

The principle of how changes in prices, due to taxes, affect energy consumption is depicted in Figure 11. For a fuel tax the reduction in energy consumption ΔE_τ results from higher service price $P_{s_{2\tau}}$ remaining on the same efficiency level of the technology used – curve η_0.

Due to the implementation of mandatory CO_2 emissions standards, cars are expected to become more energy efficient – to consume less fuel per km driven.

Also a CO_2 based registration tax leads to the purchase of more energy efficient cars with lower specific CO_2 emissions per km driven. The higher the registration tax, the lower are the specific CO_2 emissions of the average car sold. For every required emission standard, a corresponding registration tax ($\tau_{R\_CO_2}^*$) could be implemented to meet this standard and vice versa. It should be noted that the relationship between a registration tax and the specific CO_2 emissions will also depend on the elasticity of investment costs (γ).

A high registration tax will lead to the purchase of cars with lower specific CO_2 emissions. Cars with lower specific CO_2 emissions have lower fuel intensity. If we introduce specific CO_2 emissions the corresponding fuel intensity (FI^*) will affect service price Ps:

$$P_S^* = (P_f + \tau_f) \cdot FI^* \tag{10}$$

Where FI^* is a function of specific CO_2 emissions: $FI^* = f(CO_{2\_SP}^*)$

Since $FI^* = f(CO_{2\_SP}^*)$ and $CO_{2\_SP}^* = f(\tau_{R\_CO2}^*)$ this leads to the following reflections:

$$P_S^* = P_S(\tau_f, \tau_{R\_CO_2}^*) \tag{11}$$

Therefore, the service price does not just depend on the fuel tax τ_f but also on the registration tax τ_{R_CO2}.

Finally, from Eq. (6) we obtain:

1. Note, that further on in the empirical analyses of this paper we use Private Consumption Expenditures (PCE) as a proxy for income.

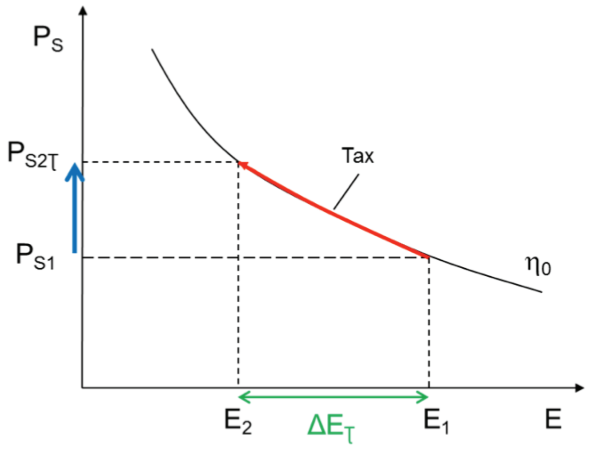

Figure 11. How a tax works (based on Ajanovic/Haas 2014b).

$$vkm^* = f(P_S^*) = f(\tau_f, \tau^*_{R\_CO_2}) \qquad (12)$$

From this equation it is clear that a registration tax based on CO_2 emissions will also have an impact on service demand - vehicle kilometer driven. In principle a CO_2 based registration tax works like a standard and leads to the same effect. With a higher CO_2 based registration tax, demand for cheaper and more energy efficient vehicles rises. Due to the higher efficiency of cars, service price decreases and leads to a direct rebound effect caused by more km driven.

The principle of how changes in efficiency due to standards and/or registration taxes affect energy consumption is depicted in Figure 12. When a standard is implemented we switch from less efficient vehicles η_0 to more efficient alternatives η_1 leading to a reduction ΔE_η in energy consumption. However, due to a lower service price $P_{s2\eta}$ this saving is lower than what is theoretically possible, due to rebound effect.

Interactions of policies

The rebound effect is one of the most critically discussed issues with respect to the implementation of standards for fuel intensity or corresponding CO_2 emissions as well as registration taxes. Fuel cost savings usually lead to the changes in driving behavior, e.g. cars are used more frequently and/or on longer distances. The behavioral response to the introduction of a new, more efficient technology or other measures implemented to reduce energy use is called the direct rebound effect.

In the case that a standard for maximal fuel intensity (FI*) is introduced, theoretical savings due to a standard are reduced due to the rebound effect, so that practical energy saving is lower:

$$\Delta E^{pr}_{save} = \Delta E^{th}_{save} - \Delta E_{REB} \qquad (13)$$

with:

$$\Delta E_{REB} = FI^*(vkm_2 - vkm_1) \qquad (14)$$

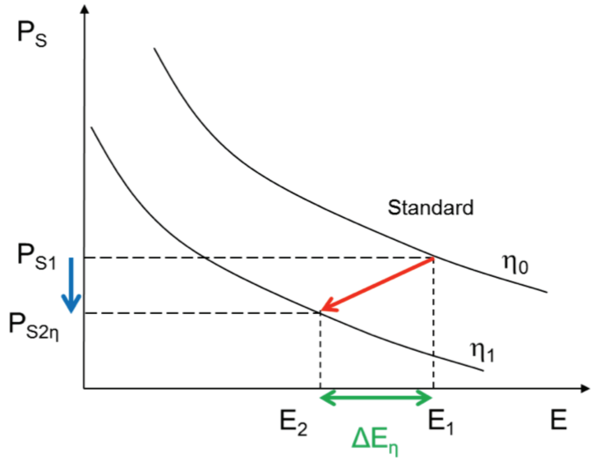

Figure 12. How a standard works (based on Ajanovic/Haas 2014b).

Using the definition of the service price elasticity, the difference in vkm driven caused by the rebound effect is calculated as:

$$\Delta vkm_{REB} = \alpha_{vkm,P_s} vkm_1 \frac{\Delta(P_f FI)}{P_f FI_1} \qquad (15)$$

Where $\alpha_{vkm,Ps}$ is the elasticity of vehicle kilometres driven with respect to service price P_S.

Using previous equations and the fundamental definition described in Greene (1997), the elasticity of energy consumption with respect to a change in fuel intensity is derived, (for detail see Ajanovic/Haas, 2012):

$$\gamma_{E,FI} = 1 + \alpha_{vkm,P_S} \qquad (16)$$

From Eq. (16) it can be seen that the elasticity of energy consumption with respect to a change in fuel intensity ($\gamma_{E,FI}$) is one plus the elasticity of the energy service (in our case vkm) with respect to service price (P_s).

Figure 13 depicts the effect of a fuel tax versus a standard depending on the service price elasticity. For example, if a tax in the magnitude of 100 % is introduced and the price elasticity is (-0.3) then the energy saving effect is 30 %. If a standard in the magnitude of 100 % is introduced and the price elasticity is e.g. (-0.3) then the energy saving effect is 70 % and the rebound effect due to more km driven is 30 %.

The preference for taxes versus standards depends solely on the magnitude of the service price elasticity α_{vkm}. However, the best result could be reached with a combination of taxes and standards.

If α_{Ps} is small (e.g. -0.1) the fuel tax effect is almost negligible. In this case a standard is clearly preferable with an empirical saving effect of about 90 % of the theoretically calculated 100 %. If, however, α_{vkm} is high, the tax is preferable. As mentioned previously α_{vkm} is in the range of -0.4 to -0.45. This leads to an ambiguous situation and it is likely that a combined introduction of standards and fuel taxes depending on the service price elasticity will lead to the most beneficial solution for society.

Also, a mix of different monetary and non-monetary measures can lead to the best results in promotion of electric vehicles, see Ajanovic, 2015. One good example is Norway where

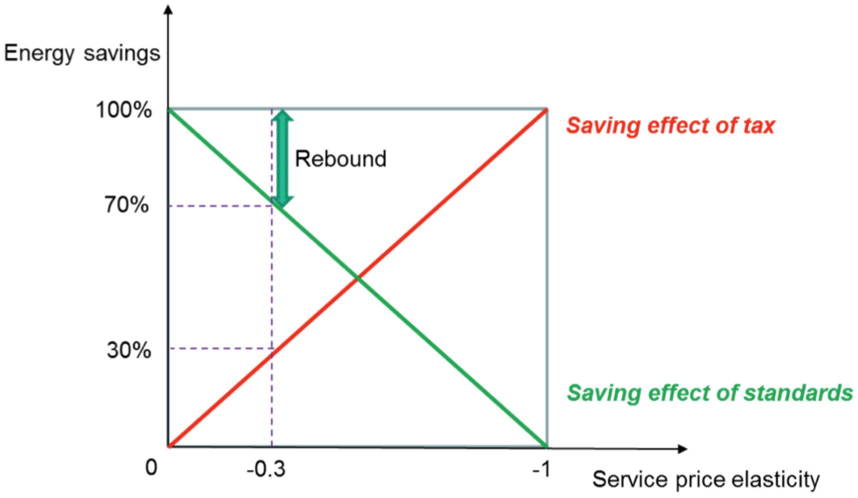

Figure 13. Effect of a tax versus standard depending on service price elasticity.

electric vehicles are exempted from registration tax, value add tax, annual car tax, road toll and congestion charges. Additionally, drivers of electric vehicles have access to bus lines and free parking spaces (Malvik et al., 2013). Moreover, a good public charging network is provided, with about 10,000 charging stations (LeSage, 2013).

Conclusions

The major conclusions from this analysis are:

1. Despite the fact that there are many parameters that constitute a formal framework to explain energy consumption and CO_2 emissions, there is only one key parameter which influences final CO_2 emissions and this is the service price elasticity. Our results for the service price elasticity of car driving in Europe are about -0.4 to -0.45.
2. The service price elasticity impacts fuel taxes, standards as well as registration taxes.
3. The major reason is that standards and fuel taxes are linked via the service price elasticity and are not independent. The magnitude of the service price elasticity defines which instrument is more effective – the tax or standard.
4. Another finding is that the introduction of a registration tax is in principle the same as the introduction of a standard and leads to the same rebound problems. The registration taxes may cover a specific part of the standards' component.
5. The intended introduction of standards as announced by the EU will not lead to the theoretically possible energy savings and CO_2-reduction. The major reason is that the rebound effect due to more km driven and larger cars will take back part of the theoretically calculated savings.
6. This result leads to the situation that a mix of policies is preferable. A combined tax-standard policy will lead to a win-win situation for the environment and car drivers. A simultaneously introduced fuel tax will compensate for the rebound effect without hurting car drivers due to service vkm driven remaining at the same service price. The fuel tax should compensate the standard to an extent so that finally the service price before and after policy introduction remains the same. Yet, because registration taxes work as standards, a fuel tax must also accompany an intended introduction of registration taxes.

References

ACEA. 2014. Tax Guide 2014. www.acea.be

Ajanovic A., Haas R. (2014a), The impact of fiscal policies and standards on passenger car CO_2 emissions in EU countries, Energy Production and Management in the 21st Century: The Quest for Sustainable Energy. ENERGY QUEST 2014. WIT press 2014, ISBN: 978-1-84564-816-9 (p. 609–624).

Ajanovic A., Haas R. (2014b), Evaluating the impact of standards and fiscal policies on CO_2 emissions of cars in Europe, 2014 IEPPEC Conference, 9–11 September 2014, Berlin, Germany.

Ajanovic A., L. Schipper, R. Haas. The impact of more efficient but larger new passenger cars on energy consumption in EU-15 countries. Energy 48 (2012), 346–355.

Ajanovic A. (2015). The future of electric vehicles: prospects and impediments WIREs Energy Environ 2015. doi: 10.1002/wene.160.

Ajanovic A, R. Haas. 2011." On the effectiveness of standards vs. taxes for reducing CO_2 emissions in passenger car transport Europe". Proceedings, Risø International Energy Conference (RIEC).

Ajanovic A., R. Haas. 2010. "The impact of fiscal policies on passenger car transport energy demand in OECD countries". Proceedings, 29th USAEE/IAEE Annual North American Conference in Calgary. Canada.

Ajanovic A., R. Haas. 2010a."On extracting the impact of consumer behaviour and the rebound effect in passenger car transport in selected EU countries". Proceedings, 8th BIEE Academic Conference, Oxford.

Ajanovic A., R. Haas, 2012. "The role of efficiency improvements vs. price effects for modeling passenger car transport demand and energy demand — Lessons from European countries". Energy Policy 41, 36–46.

Dahl C.A. 2012. "Measuring global gasoline and diesel price and income elasticities". Energy Policy 41.

Dargay, J.M., 1993. "Are price and income elasticities of demand constant? The UK Experience" EE16. Oxford Institute for Energy Studies.

EC. 2014. Directorate-General for Mobility and Transport (DG MOVE), http://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2014_en.htm accessed on 4.11.2014.

EC, 2009. European Commission. Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles. June 2009.

EEA, 2014. European Environment Agency Monitoring CO_2 emissions from passenger cars and vans in 2013. ISBN 978-92-9213-494-5, doi:10.2800/23352.

EEP. 2013. Europe's Energy Portal. http://www.energy.eu/ accessed on 1.10. 2013.

EU website on Climate action in the transport sector: http://ec.europa.eu/clima/policies/transport/vehicles/cars/faq_en.htm, accessed on 15.5.2014.

Goodwin, P.B., Dargay, J.M., Hanly, M., 2004. "Elasticities of road traffic and fuel consumption with respect to price and income: a review". Transport Reviews 24 (3), 292–375.

Haas, R., Nakicenovic, N., Ajanovic, A., Faber, T., Kranzl, L., Mueller, A., Resch, G., 2009. "Towards sustainability of energy systems: a primer on how to apply the concept of energy services to identify necessary trends and policies". Energy Policy 36, 4012–4021.

H.P.J. de Wilde, P. Kroon. Policy options to reduce passenger cars CO_2 emissions after 2020. ECN. ECN-E-13-005. February 2013.

IEA, 2013. Global EV Outlook, OECD/IEA, 2013.

Malvik H.V., Hannisdahl O.H., Wensaas G.B. The future is electric! The EV revolution in Norway – explanations and lessons learned. In: eceee, 2013.

LeSage J. Strong Incentives Help Norway Love Electric Vehicles after All these Years. Autoblog Green, 7

January 2012. Available at: http://green.autoblog.com/2013/01/07/strong-incentives-help-norway-love-electric-vehicles/. (Accessed November 17, 2013.)

ODYSSEE Database. http://www.odyssee-indicators.org/.

Shahan Z., Electric vehicle market share in 19 countries. http://www.abb-conversations.com/2014/03/electric-vehicle-market-share-in-19-countries/ (Accessed January 10, 2014).

WB, 2014. http://databank.worldbank.org/data/databases.aspx (Accessed January 10, 2014).

Walker, I.O., Wirl, F., 1993. "Irreversible price-induced efficiency improvements: theory and empirical application to road transportation". The Energy Journal 14 (4), 183–205.

Wirl F. 1992. "The impact of conservation, technology and the new registration tax on automobiles on energy consumption". Empirica – Austrian economic paper. Vol.19, No. 1.