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Policy options for a decarbonisation of passenger cars in the EU

Recommendations based on a literature review

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Abstract

In this policy paper we discuss policy instruments which can help to decarbonise passenger cars in the European Union. We elaborate to what extent these policy instruments are effective, technology-neutral, predictable, cost-effective and enforceable. Based on these criteria, we develop recommendations for the European Union and its Member States on (1) how to shape their policy frameworks in order to achieve existing climate change mitigation targets; (2) how to support car manufacturers in selling innovative and competitive products; and (3) how to encourage consumers in Europe to purchase appropriate vehicles.

We conclude that favourable policy instruments are used, but there is a strong need for adjustment and further development. The effectiveness of the current *EU emission standard* should be further increased by turning away from granting "super-credits" and introducing a size-based (instead of weight-based) credit system. Moreover, its overall ambition is questionable and the existing compliance mechanisms should be sharpened.

Fuel taxes are an effective means to push consumers to buy energy-efficient cars. However, a sharp increase may not have the desired effects. Instead, the Member States should harmonise their excise duties at the level of those Member States, which currently impose the highest taxes (Netherlands, Italy). This includes the abolition of any diesel tax bonus. An introduction and harmonisation of *vehicle taxes* (purchase and circulation) should be based on a vehicle's energy consumption. Additionally, reformation efforts should aim to change the taxation of company cars in a way that vehicle sizes are reduced over time.

Ambitious Member States may also want to introduce a *sales quota* for electric vehicles. Sales quotas are a very cost-effective policy instrument provided that the mandated technology will achieve a certain market share. This may be assumed for battery-electric vehicles. Further supportive instruments that should be considered are *eco-labelling*, *public procurement* and *purchase incentives*. However, the latter instrument's effectiveness is debatable and its implementation should therefore not be a Member State's priority.

Contents

1 Introduction

In this paper, we intend to convey an understanding of the policy instruments, which could be effective in supporting the development, marketing and sales of low- and zero- carbon passenger cars in the European Union (EU). We discuss,

- how to guide the (European) automotive industry in developing and producing passenger cars with low CO_2 emissions,
- how to support consumers and incentivise the purchase and use of such low carbon vehicles, and
- the characteristics of possible policies.

Based on this, we provide policy recommendations for the EU and its Member States. The discussion about an appropriate pathway to decarbonise passenger cars is based on a review and summary of academic and non-academic literature (studies, reports, news articles, figures from public authorities, trade associations, companies, etc.).[1] We consider this discussion highly relevant, because European policy makers, the European automotive industry and consumers are in a turmoil for three main reasons.

First, the EU and its Member States are committed to achieve the Paris Agreement, i.e. they are to pursue efforts to limit the global mean temperature increase to 1.5 °C above pre-industrial levels, requiring a transformation of the transport sector. But EU-28 transport final energy consumption and corresponding emissions of greenhouse gases (GHG) are roughly stagnating since 2000. Since 2013, there is even an increasing tendency (EEA 2016, see Figure 1-1). It is impossible to read a beginning transformation from these figures.

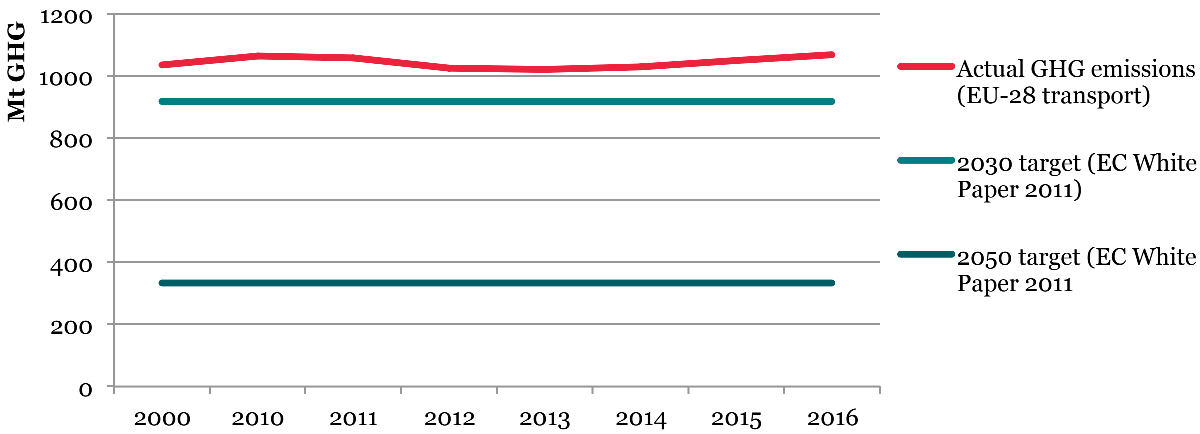


Fig. 1-1 EU-28 transport emissions of greenhouse gases. Source: EEA 2016

[1] This study solely addresses the issue of decarbonising new passenger cars in the EU. Thus, we do not consider the possible development of, and means of controlling, the total amount of CO_2 emissions that can be attributed to the use of passenger cars or to vehicle transport as such. Reducing the CO_2 emissions of (new) vehicles is by no means an indication that total CO_2 emissions caused by new cars or by the vehicle fleet as such decline. For instance, the decline in average values may be offset by increases in the total number of cars sold or greater distances travelled. By the same token it should be noted that the considerations do neither take into account the possible impacts of policies on average mileage nor driving behaviour. Such changes would have implications in terms of fuel tax revenue and lifetime of the cars.

What is more, road transport is responsible for about three quarters of transport-related GHG emissions in the EU. Of these emissions, 44% are caused by passenger cars (see Figure 1-2). This is because car passenger travel, with a share of around 70%, remains the dominant mode of transport with regard to the volume of passenger kilometres (EEA 2016).

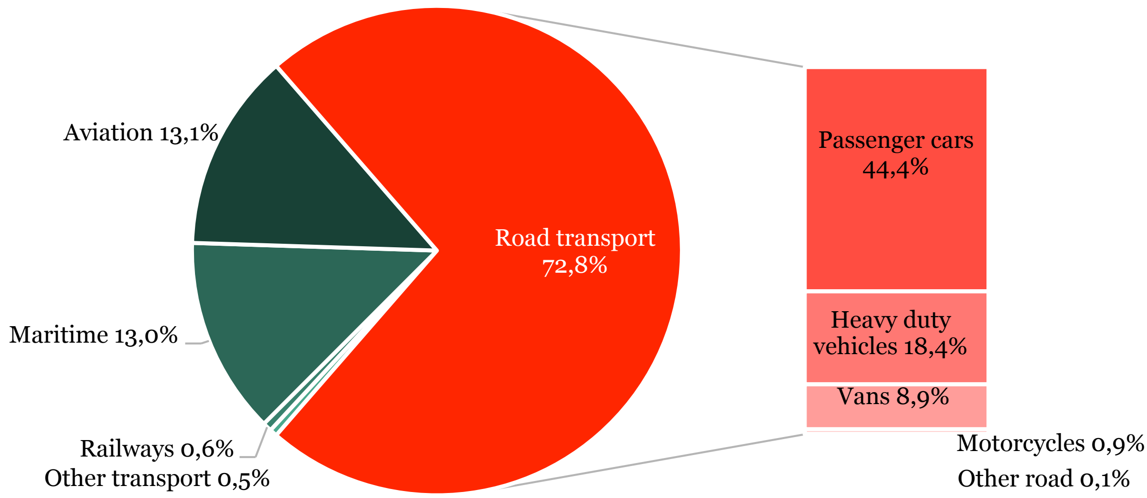


Fig. 1-2 Share of EU-28 transport GHG emissions by mode. Source: EEA 2016

Second, the automotive industry needs support to overcome path dependencies (e.g. Veugelers 2012). Although car makers have started to develop alternatives to the internal combustion engine (ICE), such as electric, hybrid, and fuel-cell vehicles, they face challenges concerning the introduction of such potentially disruptive technologies as mainstream into the market. European car makers must develop electric vehicles to remain competitive vis-à-vis new market players, but they are locked into the diesel technology (Skeete 2017). The share of electric vehicles in most European countries remains low. By 2016, the real share of electric vehicle sales in Europe was only half as high as the manufacturers' targeted share (Transport & Environment 2017a).

Figure 1-3 shows the new registrations of passenger cars in the European Union as indicated by the European Automobile Manufacturers' Association (ACEA). In general, the European car market is growing. The share of electric vehicles, however, has increased only moderately between 2016 and 2017. In 2017, 15.1 million new passenger cars were registered in the EU, while the vehicle stock amounted to about 250 million. This implies that roughly 6% of the vehicle fleet is replaced annually. Even if from now on all new registered cars were climate-friendly, it would take about 17 years to completely replace the car stock in the EU. This 'naïve fallacy' spells out the need for a radical transformation of the car market.

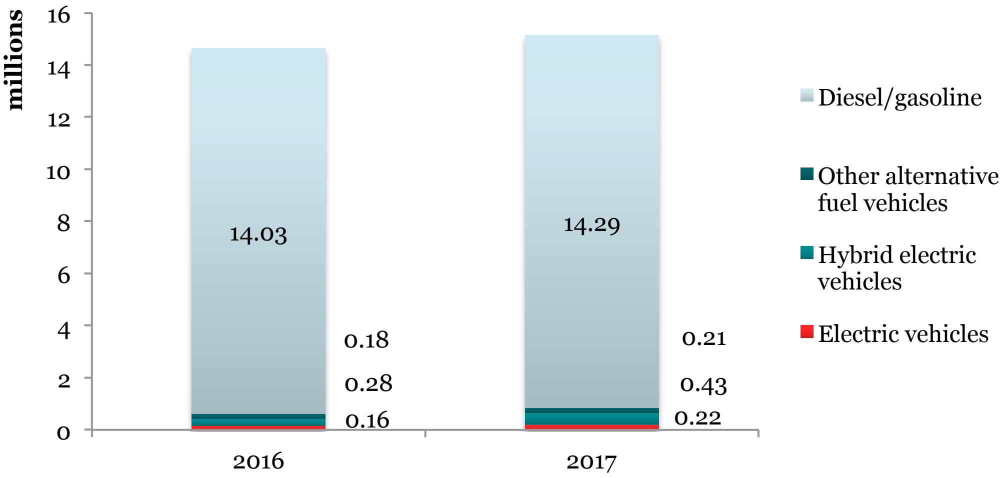


Fig. 1-3 Registrations of new passenger cars in the EU in 2016 and 2017. Source: Website ACEA

Third, European car drivers are discomfited from the emissions scandal and the suspicion of a cartel agreement of German original equipment manufacturers (OEMs). The emissions scandal had started in 2015 when it became public that Volkswagen had intentionally programmed diesel engines to activate an air pollutants control device during laboratory testing. In the following months and years, an intensive discussion aroused about how to improve the air quality in urban areas and especially nearby heavily congested roads. Cities all over Europe are considering the (temporary) ban of diesel cars in central areas. Moreover, consumers are seeking for both inexpensive and environmentally friendly cars.

This policy paper is structured as follows. We first provide a brief overview of the history of policy targets and corresponding instruments in the EU. Then, we present some theoretic concepts for policies to influence demand and supply of low-carbon passenger cars. Subsequently, we analyse the characteristics of policy options by using different criteria in order to highlight their advantages and disadvantages. On this basis, we finally provide recommendations to European policy makers for how adequate policies and measures should be shaped in the near future.

2 History of EU policy targets and achievements

In principle, the EU follows three legislative approaches to cut vehicle GHG emissions:

- Fostering technology improvements of the vehicles.
- Requiring qualities of the fuels used by these vehicles.
- Developing further the vehicles' infrastructures.

So far, the focus has mainly been on vehicle technology. In 1995, the European Commission (EC) communicated a strategy to reduce CO_2 emissions from new passenger cars (COM(95) 689). The strategy was based on three main pillars: (a) agreements with OEMs on fuel economy improvements, (b) fuel-economy labelling of new passenger cars, and (c) the promotion of car fuel efficiency by fiscal measures at the national (Member State) level.

The Commission tried to achieve the first pillar through a voluntary agreement with European car manufacturers, who promised to gradually improve the fuel efficiency of cars produced. The 1998 voluntary agreement between ACEA (the EU's Automobile Manufacturers Association) and the Commission included a commitment by the carmakers to achieve a target of 140 g/km by 2008. Although progress was made, average emissions fell only to 154 g/km in 2008 (see Figure 2-1). The failure of the automotive industry to live up to their commitment let to binding legislation.

In 2009, the EC enacted two laws. First, Directive 2009/30/EC ("Fuel Quality Directive") requires a reduction of the GHG intensity of the fuels used in vehicles by 6% by 2020. Second, and more importantly, the EC instituted Regulation EC 443/2009, which sets mandatory CO_2 emission standards for the sales-weighted average from new passenger cars. It established the goal of 95 g CO_2 per km by 2021 with an intermediate target of 130 g/km by 2015. The Regulation is accompanied by a car labelling scheme. A label near the point of sale showing fuel economy shall help drivers choose new cars with low fuel consumption (Directive 1999/94/EC).[2]

The European Environment Agency (EEA) monitors the CO_2 emissions performance of new passenger cars. This dataset is used by the European Commission to evaluate whether car manufacturers comply with their mandatory CO_2 targets. The EEA collects the data from the Member States on a yearly basis. The EEA data show that the 2015 target was met; the sales-weighted average CO_2 emissions from new passenger vehicles in the EU in 2016 were at 118 g CO_2 per km (see Figure 2-1).[3]

Importantly, however, the indicators currently used are unrepresentative and in consequence there is a divergence between officially reported fuel consumption of the new car fleet and real-world performance; and this divergence has been growing in the recent past. The International Council on Clean Transportation (ICCT) tracks this divergence in its „From Laboratory to Road" series. According to the ICCT, the mean gap of the officially reported fuel consumption and the real consumption amounted

[2] The actual implementation of this Directive is subject to strong criticism. For example, the label calculation takes into account the vehicle's weight. In consequence, cars with high fuel consumption may be labelled economical. A detailed reflection of the status of the CO_2 labelling of passenger cars in Europe can be found in Haq & Weiss (2016).

[3] These emissions convert into 5.1 l/100 km gasoline equivalent.

to approximately 9% in 2001 and to 42% in 2016 (Tietge et al. 2017, see also Figure 2-1). Obviously the car manufacturers increasingly exploited the legal options provided by the test procedure of the New European Driving Cycle (NEDC), which was applied in this period during the type approval, in order to minimise the officially reported fuel consumption and according CO_2 emissions.[4]

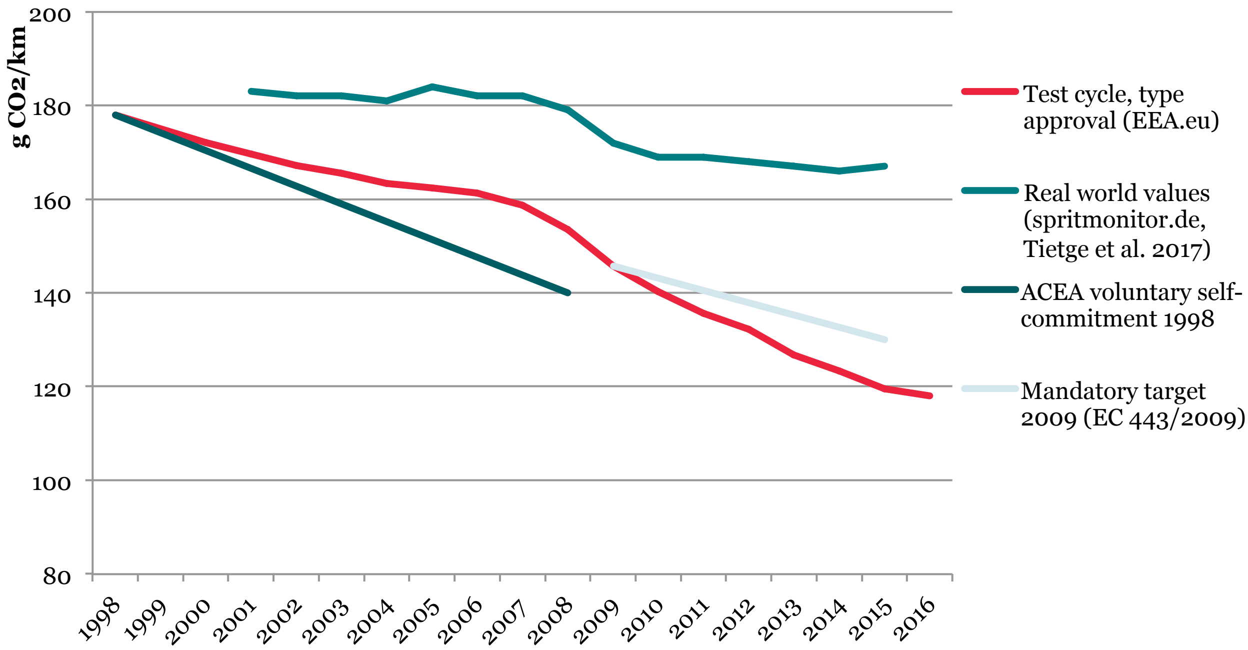


Fig. 2-1 **Development of average CO_2-emissions per km from new passenger cars in the EU. Source: as indicated**

As a consequence of the increasing discrepancies between tested and real CO_2 emissions, and also because of the scandals relating to the tested and real NO_X emissions from diesel engines, the EC now employs a new testing procedure, called the "Worldwide Harmonised Light Vehicle Test Procedure" (WLTP). WLTP officially applies to new passenger cars to be approved at any vehicle registration office in the EU since September 2017. It is supposed to provide a more realistic representation of conditions encountered in practice.[5]

[4] The official fuel consumption and according CO_2 emissions are reported based on test procedure measurements during the type approval. Until September 2017, the New European Driving Cycle (NEDC) was applied. This test offers a stylized driving speed pattern with low accelerations, constant speed cruises, and many idling events. However, the transient accelerations are much steeper and more dynamic in current practice. Moreover, measures to minimise aerodynamic resistance and vehicle weight may be applied.
The ICCT analyses the specific real world CO_2 emissions of cars as indicated in online consumer web services such as Spritmonitor.de (http://www.spritmonitor.de). Launched in Germany in 2001, spritmonitor.de aims to provide drivers with a simple tool to monitor their fuel consumption and makes real-world fuel consumption figures available to the public. Spritmonitor.de has more than 400,000 registered users, data on more than 600,000 vehicles, and is available in German, English and French. The ICCT acquired this dataset in April 2016 for their latest "From Laboratory to Road" analysis; the Spritmonitor.de time series illustrated in Figure 2-1 is based on this ICCT analysis (Tietge et al. 2017).

[5] The impact of the introduction of WLTP on the average fleet-wide CO_2 emissions is estimated to be in the order of 15-25% (Fontaras et al. 2017), increasing the average CO_2 emissions of new passenger cars between 18 and 30 g/km (although any calculation has a wide margin of uncertainty due to the fact that the new definitions in the protocol regarding vehicle classification, road load determination and type approval extension cannot be easily quantified).

However, the CO_2 targets that car manufacturers have to meet by 2021 are based on the old NEDC test. From the introduction of the new WLTP test, the WLTP values will be translated back to NEDC-equivalent values to monitor compliance against the CO_2 targets set by the EU.

There is more criticism on the EU emissions standard. Most importantly, improvements in vehicle fuel efficiency have up to now not been sufficient to neutralise the effect of increased distances covered in Eastern European countries and of ever increasing car size all over Europe. A large part of the early success of the EU's emission standard in increasing fleet-average fuel economy is due to vehicle dieselisation. This trend occurred in Europe due to the inherent efficiencies of diesel engines and higher energy content of diesel. However, it has been argued that dieselisation of the passenger vehicle fleet did not result in overall decrease in vehicular GHG emissions, particularly because the vehicles tend to be heavier, and they tend to be driven more than gasoline vehicles because of lower diesel prices (An et al. 2011).

The heavier a car is, the greater its fuel consumption and CO_2 emissions. Mass reduction is therefore an effective means to reduce car emissions. The current EU emissions standard under Regulation EC 443/2009 offers little incentive to reduce the mass of vehicles. The lighter a manufacturer's fleet, the lower its assigned CO_2 target. That is, if a manufacturer reduces the mean mass of its passenger cars, it must then also achieve a lower target (expressed in g CO_2/km). A weight-reduction advantage would be neutralised. According to an ICCT analysis, the weight of new passenger cars in the EU has grown by an average of one percent per year in the period 2002 to 2012 (Mock 2013).

There are currently no plans to extend the target under the Fuel Quality Directive beyond the year 2020. Instead, the EC proposed to address the decarbonisation of transport fuels after 2020 in the framework of the Renewable Energy Directive. The present proposal for a revision of this directive includes the target to achieve at least 27% renewables in the final energy consumption in the EU by 2030 (COM/2016/0767 final/2).

The recent EU proposal for a Clean Mobility Package contains new CO_2 standards beyond 2021. It calls for a reduction of 30 percent in average new car fleet CO_2 emissions by 2030 compared to 2021, with an interim goal of minus 15 percent by 2025. Accompanying measures are provisions for public procurement and an action plan to build infrastructure for alternative fuels. The German car industry association VDA said in a statement that the proposed emission targets were "extremely challenging", "ignoring technical reality" and would put carmakers at a disadvantage in global markets (Website VDA). By contrast, environmental organisations criticise this proposal to be falling short of the United Nations' climate change mitigation ambitions under the Paris Agreement. Ambitious supplementing policies and measures on the national levels were now necessary to meet the targets, most notably fiscal measures such as taxes and levies to increase fuel efficiency. An analysis of a German think tank (Agora Verkehrswende 2018) states that the recent EU proposal to update Directive 1999/94/EC is far from sufficient to reaching the German climate change mitigation goals.

3 Types of Policy Options

In general, policies that aim at promoting environmental technologies can be broken down into four major categories: market-based, command-and-control, information-based instruments and voluntary agreements (Crespi et al. 2015). Market-based and command-and-control regulations might be characterized as 'hard' instruments, as they introduce specific obligations for market actors, while the latter two instruments are rather 'soft' because of their reliance on the stimulation of discretionary activities (Crespi et al. 2015). In the context of this paper, we want to focus on hard policy options, while information-based measures are regarded as merely complimentary and supportive. We do not consider voluntary agreements, such as self-commitments of automobile manufacturers, since they have proven ineffective in the EU context in the past (as outlined in the previous chapter). In the following, the different categories of environmental policies and associated measures that can help to drive the development and adoption of less polluting passenger cars are explained in more detail. Table 3-1 provides a summary of policy options and exemplary measures.

Tab. 3-1 Types of policy instruments and examples. Source: own compilation

Instrument type	Examples
Market-based instruments	Fuel taxes
	Vehicle fees and taxes
	Purchase incentives
	Emission trading
	Public procurement
Command-and-control instruments	Fuel economy / emission standards
	Technology mandates / sales quota
	Privileges for low-emission vehicles
Information-based instruments	Fuel economy / emission labels
Voluntary agreements	Industry self-commitments

Market-based policies, which are often also termed economic or fiscal measures, try to correct for negative externalities by economically compensating market actors who decide to adopt environmental technologies and by punishing investments in polluting technologies. The underlying assumption is that the resulting changes in prices create economic (dis-)incentives and support environmental-friendly behaviour (Bergek & Berggren 2014, Crespi et al. 2015). With regard to the decarbonisation of passenger cars, there are a number of possible fiscal measures, including fuel and vehicle taxation, purchase incentives, emission trading schemes or public procurement.

Command-and-control measures, on the other hand, aim at promoting environmental technologies through standards, obligations or non-monetary incentives. In contrast to market-based instruments, the objective of command-and-control policies is therefore not the manipulation of market mechanisms through prices. Instead, market actors are expected to comply with regulations that govern maximum emission levels or the use of certain technologies (Bergek & Berggren 2014, Crespi et al. 2015). In the context of passenger cars, examples are fuel economy and emission standards, fuel and electricity standards, technology mandates and sales quota for low-emission vehicles.

The third category of policies, information-based measures, have the aim of raising awareness among consumers and increase transparency about the environmental footprints of products. Through product labels and certification, e.g. regarding fuel economy, consumers are able to compare different products and make informed purchase decisions (Crespi et al. 2015). Since information-based policy instruments per se do not create direct or indirect incentives for the adoption of more fuel-efficient vehicles, we regard them as a supportive element of other market-based and command-and-control measures.

4 Analysis of Instruments

This chapter discusses the different types of 'hard' policy options (as outlined in the previous chapter) and complimentary policies for a decarbonisation of new passenger cars in Europe. In so doing, we consider the following aspects[6]:

- ***Responsibility***
  ...refers to the main level of responsibility for policy implementation (EU vs. individual Member States).
- ***Scope***
  ...refers to the primary target of the policy, i.e. whether it aims at steering demand or supply.
- ***Effectiveness***
  ...refers to a policy's effectiveness in increasing demand for low-carbon vehicles and/or stimulating innovation.
- ***Selection***
  ...refers to the technological neutrality of a policy, i.e. whether it leads to a selection of particular technology or whether it is open to different technological trajectories.
- ***Cost-effectiveness***
  ...refers to a policy's effectiveness in achieving the set targets at lowest possible costs for society.
- ***Predictability***
  ...refers to the question whether the implementation of a policy leads to a foreseeable, credible and consistent setting in the long run. The degree of uncertainty associated with a policy is an important aspect for market actors, since it affects consumers' purchase and producer's investments decisions.
- ***Enforceability***
  ...refers to the difficulty of enforcing a certain policy.

4.1 Market-based policies

Market-based policies include fuel taxes, vehicles taxes, purchase incentives, emissions trading, and public procurement.

Fuel taxes

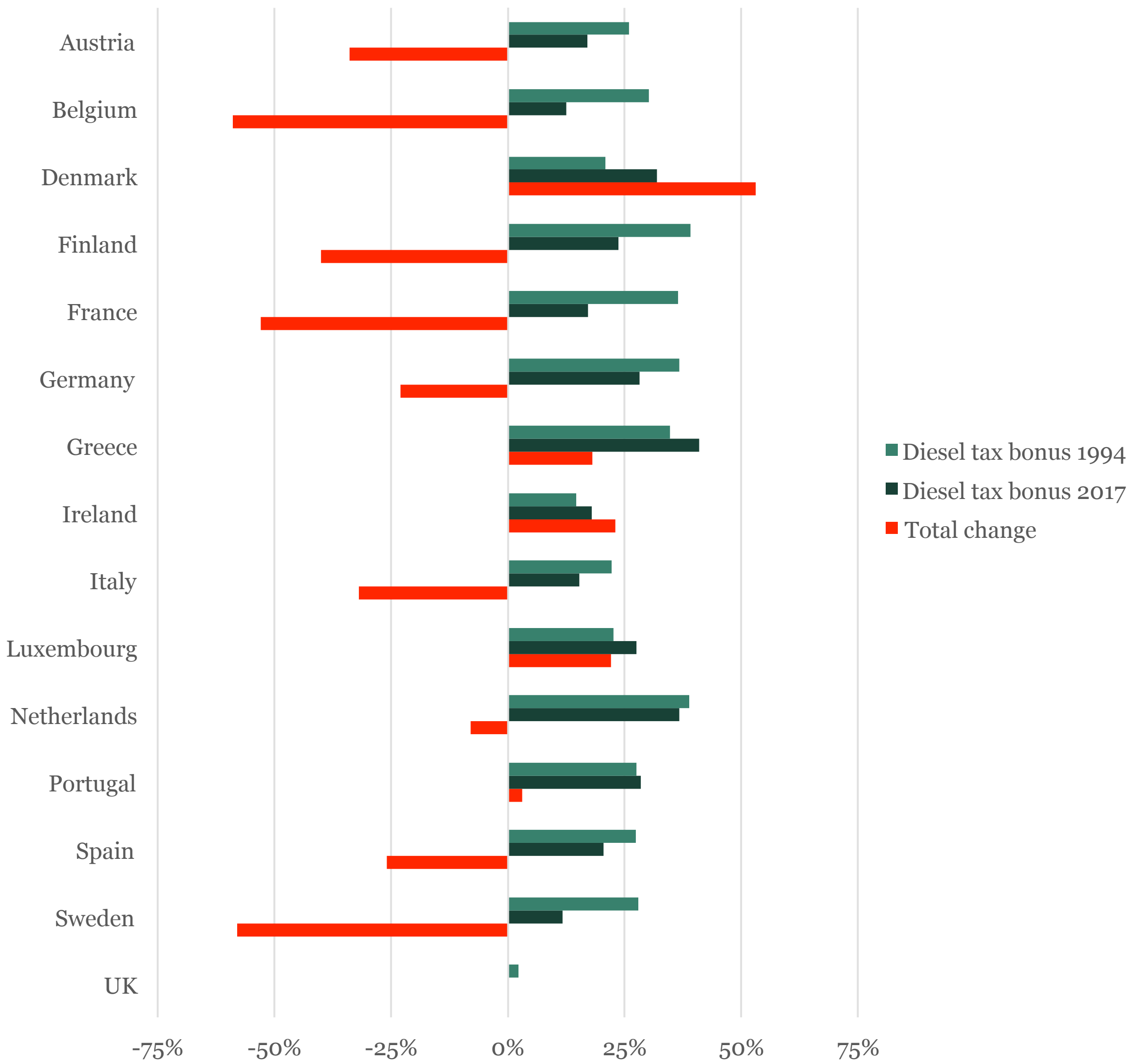
Taxes on fuels aim at promoting the production of more fuel-efficient vehicles through change of demand. It is assumed that increased taxation leads to higher prices of fuels and increasing operation costs and, in turn, reduces demand for vehicles with a comparatively low fuel economy. In the long run, this shift in demand is supposed to lead to an increased production of cars with improved fuel efficiency (Clerides & Zachariadis 2008, Ross Morrow et al. 2010).

Ideally, fuel taxes are determined either on energy content of a fuel, the amount of CO_2 that is emitted during its combustion or biofuel share (Roland Berger 2016,

[6] It should be noted that the review and discussion of literature in this discussion paper should not be regarded as exhaustive. The goal is to provide an overview of arguments for and against certain policy measures. Not all of the above-mentioned policy characteristics have been addressed by all authors.

Transport & Environment 2017b). Currently, most EU Member States privilege diesel over petrol in their taxation schemes (see Figure 4-1), which has incentivized the production of diesel-fuelled cars through a market-pull effect (Schipper 2011). Although a higher share of diesel cars in national fleets would be theoretically desirable because of the higher fuel efficiency of diesel engines, in reality the lower tax on diesel has led to the increased sale of larger and more powerful cars, such as sport utility vehicles (as outlined in chapter 2). These framework conditions have also indirectly contributed to the Dieselgate scandal, a widening gap between laboratory and real-world emissions, and the technological lock-in of European automakers (Skeete 2017). The under-taxation of diesel has been criticized by various EU regulators, but responsibility remains at the Member States level and harmonized EU-wide amendments are difficult to enforce (Skeete 2017).

Fig. 4-1 Diesel tax bonus[7] in EU Member States. Source: Transport & Environment 2017b



[7] Diesel tax bonus = 100 x (petrol tax per litre – diesel tax per litre) / petrol tax per litre

A reformed taxation should ideally be based on the energy and/or carbon content of fuels (Transport & Environment 2017b) but the consequences and effectiveness of such a reform are hard to predict, since the effectiveness of fuel taxes in driving down GHG emissions from passenger cars is debated. Some authors have shown that the average fuel consumption of cars in developed countries would be much higher without fuel taxation (Jiménez et al. 2016, Sprei & Karlsson 2013, van den Brink & van Wee 2001) and that higher fuel prices have triggered investments in R&D for clean technologies that led to incremental innovation, especially regarding ICE vehicles (Alam et al. 2017, Barbieri 2015, Bergek & Berggren 2014), which has ultimately driven improvements in fuel efficiency (Clerides & Zachariadis 2008, Jimenez et al. 2016, Schipper 2011). Having said that, the positive environmental effect of past and current fuel taxes is rather low and might primarily be caused by promoting energy efficient driving behaviour and shorter average distances travelled rather than technological improvements (EC 2002).

Thus, fuel taxes might not be as efficient in promoting fuel efficient vehicles as economic theory would suggest. This has several reasons. First, there is a tendency that car buyers behave myopically. Typically, consumers underestimate potential future cost savings that result from buying a car with better fuel economy, because systematic analyses of such savings are rarely undertaken (Clerides & Zachariadis 2008). Instead, the purchase price of a car often sends a stronger price signal to the potential buyer. Second, price elasticity of demand can be relatively low and varies by country. This implies that fuel taxes need to be raised to quite a high level to have a significant impact on the sale of more fuel-efficient cars (Bergek & Berggren 2014). Apart from that, it is difficult to assess the level of taxation that is sufficient to induce changes in consumer behaviour. Third, increases in fuel prices due to the taxation do not seem to influence consumer's purchase decisions in the short term, but are rather effective in changing car purchase patterns over longer time spans (Giblin & McNabola 2009, Lah 2015). These problems could be overcome by an adjustment of fuel taxes over time based on the availability of new information (Gallagher et al. 2007). To overcome existing path dependencies in the automotive industry, some authors have proposed to start with a high taxation and relax it as soon as soon as knowledge production and technological development shifts in a cleaner direction (Alam et al. 2017).

Although potentially being more cost-efficient than other policy instruments, such as fuel economy standards or incentive programs (Fox et al. 2017, Schipper 2011, Shiau et al. 2009), the high level of fuel taxation necessary to induce technological change can pose severe barriers to the implementation of effective taxation schemes and even render them politically infeasible (Bergek & Berggren 2014). Consumers in some countries might be suspicious of environmental taxes and consequently show little support for such measures (Clerides & Zachariadis 2008). In the EU, the end of the diesel tax privilege might result in a shift of consumer demand towards gasoline-powered cars and thus require other currently more expensive technologies, such as hybrid-electric vehicles, to close the resulting gap in GHG reductions (Roland Berger 2016), which could further impede consumer acceptability of fuel taxation. A revised tax scheme would, however, drastically increase state revenues and could compensate for revenue shortfalls caused by the expected increase in the uptake of zero emission vehicles (ECF 2017, UBA 2017). These tax revenues, in turn, could be used to promote R&D for low-carbon technologies and to achieve parity in terms of emission abatement costs (Ross Morrow et al. 2010).

If fuel taxes are determined based on energy or carbon content, they have the advantage of being relatively transparent and predictable. Yet, their objective is to steer demand through fuel prices, which themselves are very volatile and hard to predict. It is thus difficult to foresee the long-term policy signal that taxation of fossil fuels sends to consumers and producers. As is the case with other taxes, fuel taxes might also create distributional equity issues. Because the cost of driving would go up after the implementation of a fuel tax, the cost burden would be mainly on consumers. This could especially disadvantage lower-income households, if equivalent and affordable transportation options are not available and tax revenues are not redistributed through compensatory mechanisms (Gallagher et al. 2007).

It should also be noted that policies aiming at promoting cleaner cars through taxation of transportation fuels should not only focus on prices for fossil fuels but also for electricity. This is because a rise in electricity prices can lead to reduced demand of low-emission vehicles, such as electric cars, and therefore slow down innovation activities (Alam et al. 2017).

Vehicle taxes and purchase incentives

In contrast to taxes on fuels, taxes, fees and rebates on vehicles have the objective to steer demand for fuel efficient cars through influencing the cost of acquisition and ownership rather than usage. There are different options to achieve this goal. Governments can impose taxes on sales or the registration of new cars, on company-owned cars or introduce a circulation tax that is charged on an annual basis. In this regard, the purpose is to discourage the purchase of high-emitting vehicles through imposing progressive taxes or fees. On the other hand, the purchase of cars with low carbon emissions, such as electric vehicles, can also be directly incentivized by policy-makers through tax reductions or exemptions, and price subsidies (Pasaoglu et al. 2015, Greene & Ji 2016).

A special form of fiscal measures geared towards vehicle purchase is a feebate scheme. A feebate combines a purchase tax or fee with a rebate or subsidy to penalize the purchase of vehicles that are less fuel efficient than the average vehicle in a certain category and to simultaneously incentivize the purchase of comparatively fuel-efficient vehicles. The level of vehicle taxes, fees and rebates can be tied to engine size, power, weight, fuel type, fuel consumption or CO_2 emissions (Brand et al. 2013, Pasaoglu et al. 2015).

Empirical research suggests that feebates and registration taxes are particularly successful in stimulating demand for smaller and less emission-intensive passenger cars (Bishop et al. 2016, Brand et al. 2013, Cuenot 2009,) and the deployment of cleaner technologies (Greene et al. 2005). The introduction of a bonus-malus system in France in 2008, for example, led to an increased market share of vehicle classes that were subject to a rebate. At the same time, significant decreases in the average fuel economy of new cars sold were observed, even without the introduction of new technologies (Brand et al. 2013, Cuenot 2009, Lah 2015, van der Vooren & Brouillat 2015). Similar improvements in CO_2 emissions from new passenger cars due to a revised vehicle tax system have been observed in Ireland (Jiménez et al. 2016, Rogan et al. 2011), Denmark (Lah 2015) and the Netherlands (Kok 2011, Lah 2015). The effectiveness of monetary incentives for buying zero emission vehicles, in turn, is debated and heavily depends on the context. While Norway has successfully accelerated the uptake of electric vehicles through subsidies; in France, Germany, the Netherlands and UK, the relationship between financial incentives and their market share is less clear (Tietge et al. 2016). Similarly, the effects of scrappage premiums, as introduced in the past in countries like Germany, France, Italy and the UK, are questionable. Although such premiums can accelerate the sale of new and more fuel-efficient cars, car owners might decide to retire their old car sooner as initially planned, which would lead to reduced life cycle carbon savings (Brand et al. 2013, Jiménez et al. 2016). What is more, scrappage schemes have so far mainly been implemented to stimulate the car market rather than to achieve environmental benefits.

Transparency in vehicle taxation plays an important role as underlined by a study on new car purchases in Ireland (Giblin & McNabola 2009). It was found that if a registration tax is not explicitly stated in the purchase price, it might not be perceived as extra cost and thus hardly be effective in influencing buying behaviour. This is why the parallel existence of a circulation tax in Ireland probably had a greater impact on vehicle purchase, since the latter is charged annually and clearly shows the costs associated with carbon emissions (Giblin & McNabola 2009). However, whether vehicle taxes at the point of purchase (without rebates) or circulation taxes are superior in terms of promoting fuel efficiency is rather unclear. It seems to be more important that the respective tax is sufficiently differentiated and directly relates to a car's CO_2 emissions instead of a proxy such as weight or engine size (EC 2002, Lah 2015). Moreover, vehicle taxes should be strengthened over time to maintain their stringency and sustainably promote improvements in fuel economy.

With regard to company cars, the current taxation systems in most EU Member States favour more expensive and larger cars and have therefore hampered the diffusion of cars with better fuel economy (Berggren & Kageson 2017, Mandell 2009, PwC 2007, Wesseling et al. 2015). The inefficiency of current taxation stems from the fact that certain discounts are granted for company cars, so that taxes do not fully account for the benefits that result from using such cars for private purposes. The tax level should therefore ideally consider the full cost of leasing a car and create incentives for employees to choose cars with lower fuel or electricity consumption, e.g. through making employees pay for fuel or electricity directly and reimburse them based on distance driven later on (Berggren & Kageson 2017).

In general, it can be concluded that, if implemented correctly, taxes and rebates at the point of sale seem to send a strong price signal to consumers and favour cars with better fuel economy (Brand et al. 2013, Lah 2015). Such fiscal measures can hence help to overcome consumer myopia, as cost savings are already obtained at the point of purchase and not afterwards during vehicle usage. Nevertheless, especially rebates should also take into account the energy efficiency of electric vehicles and not only of vehicles equipped with an ICE. Although an increased uptake of electric vehicles is basically desirable, a misguided taxation, such as their exemption from vehicle taxation, can stimulate the sale of heavier and less energy efficient electric vehicles, which happened in the Netherlands (Berggren & Kageson 2017).

Cost-effectiveness is a potential issue of fiscal purchase (dis-)incentives (CE Delft 2012). If the focus is on subsidies or rebates, the consequence may be significant government spending and losses in state revenues, respectively, as experienced in France (Cuenot 2009) and Ireland (Brand et al. 2013, Giblin & McNabola 2009,). Manufacturers have been found to increase vehicle prices to capitalize on the introduction of rebates (Jiménez et al. 2016). Such behaviour would pose unnecessary burdens to consumers and undermine the policy's basic idea. Vehicle tax systems can lead to revenue losses for governments as well, as was experienced in the Netherlands, if they are not adapted to the improvements in fuel economy over time (Kok 2011). The lack of cost-effectiveness could undermine political feasibility of fiscal measures geared towards new vehicles. However, this shortcoming might be overcome by an adequate feebate system that compensates losses in state revenues induced by subsidies with income generated from the taxation of cars with relatively high specific carbon emissions (Brand et al. 2013, Giblin & McNabola 2009, Small 2012, van der Vooren & Broiullat 2015). Ideally, feebates are thus revenue-neutral. However, although being an important design feature, the optimal pivot point of a feebate scheme is difficult to determine. Apart from that, feebates and vehicle taxes need to be constantly reviewed and strengthened in order to constitute a technology driver also in the long run (Sprei & Karlsson 2013). Besides being potentially revenue-neutral, a feebate system can also be designed in a way that neither consumers nor manufactures are overburdened (Brand et al. 2013). Producers can increase their revenues through added-value induced by selling novel and more expensive fuel-saving technologies, while from a consumer perspective, associated increases in prices are offset by rebates and fuel savings (Green et al. 2005).

Having said that, the reliance on purchase incentives for promoting radical innovation should be reduced over time, if the goal is to create a self-sustaining market and to prevent unnecessary burdens for state budgets (Berggren & Kageson 2017). This is especially important when it comes to the increased penetration of electric vehicles. While subsidies may render this technology more attractive to consumers in the short term through combatting one major disadvantage, namely high acquisition costs, fiscal incentives should be reduced over time to promote innovation and a reduction of production costs. Besides that, taxes imposed at the time of vehicle purchase or registration may motivate car owners to keep their old cars longer and thus slow down the diffusion of new technologies (Lah 2015).

While in general, vehicle taxation and rebates may send strong price signals to consumers, they provide little investment security for car producers. The responsibility for taxes and fiscal incentives resides on a Member State level (PwC 2007). Although the EC repeatedly advocated tax reforms to harmonize taxation among Member States, EU wide harmonization of vehicle taxes is difficult to achieve and manufacturers may be exposed to conflicting and constantly changing policy regimes (Roland Berger 2016). Subsidies for radically new technologies, such as electric vehicles, might even differ among federal states or municipalities, creating further market uncertainties (Tietge et al. 2016). What is more, it is difficult to predict how consumer behaviour changes after the implementation or amendment of taxes and purchase incentives. Especially subsidies are often restricted to relatively short time periods and the development of buying behaviour after their discontinuance is hardly foreseeable.

Emission trading

In order to regulate emissions from new passenger cars, it has also been discussed to include the road transport sector in the EU emission trading scheme (ETS). An inclusion of road transport in the EU ETS would impose a cap on the amount of GHG that can be emitted by all participants. Permits would be auctioned, sold or allocated for free and could be traded subsequently, either on the demand side (e.g. among consumers) or on the supply side (e.g. among car manufacturers). Basically, three forms of integration of road transport into such a cap-and-trade system are conceivable: (1) consumer need to buy emission allowances based on their annual mileage; (2) car manufacturers need to buy allowances for cars sold based on average lifetime emissions per vehicle; or (3) fuel suppliers must buy allowances for the amount of fuel sold (Roland Berger 2016).

Since there is no past or currently existing example of such an inclusion of road transport in an ETS, little is known about its effectiveness in promoting technological advancements and changes in consumer behaviour. However, if ever implemented, obligating fuel suppliers seems to be the most feasible form of implementation. This is because an implementation on the part of car producers would require an assessment of the CO_2 emissions that each car emits during its life cycle. Such an assessment is regarded as complex and the exact amount of emissions could possibly not be accounted for. On the other hand, charging consumers based on the emission intensity of their vehicle and annual mileage would entail a huge administrative effort. It therefore seems most plausible that fuel suppliers need to purchase allowances based on the CO_2 intensity of their fuels and the amount sold (Roland Berger 2016).

It can be assumed that if fuel suppliers are charged for their GHG emissions, fuel prices would increase and likewise, also the operation costs of cars (Mock et al. 2014). In such a case, an integration of road transport into the EU ETS would be similar to imposing a fuel tax. Such an EU-wide harmonized price on CO_2 emissions from fuel use could overcome the disadvantages of the currently existing patchwork of national fuel taxation and transfer responsibility from individual Member States to the EU.

Having said that, in contrast to a fixed tax rate, prices of CO_2 emissions tend to be very volatile and hard to predict. Moreover, several authors have argued that current ETS prices would simply be too low to have any measurable steering effect on vehicle demand (Cambridge Econometrics 2014, Mock et al. 2014, Öko-Institut 2015). Based on simulations, it has been found that the price for emission allowances would need to be magnitudes of order higher than they currently are and this is not likely to happen in the near future (Cambridge Econometrics 2014, Mock et al. 2014). Yet, as with other policy measures that are geared towards the cost of driving, a certain price level needs to be reached in order to overcome consumer myopia and provide incentives for buying more fuel-efficient cars.

Apart from a questionable impact on the fuel economy of new cars, including road transport in the EU ETS could possibly have other negative side effects. The relatively high price level necessary to steer car demand can be regarded as politically infeasible, since it would place additional and heavy burdens on industries that are already included in the EU ETS, such as emission-intensive industries, but would also indirectly affect other industries and consumers (Cambridge Econometrics 2014). What is more, if emission reductions of road transport are below set targets, other sectors would possibly be exposed to additional pressure to reduce GHGs (Öko-Institut 2015). The inclusion of road transport in the existing ETS could also cannibalize the EU's long-term GHG reduction targets. Such a situation might be created if emission reductions in road transport would be significantly above targets. In this case, the pressure on other sectors in the EU ETS would decrease and could possibly lead to higher overall emissions compared to an ETS without the inclusion of road transport (Öko-Institut 2015).

Public procurement

Demand for low-carbon vehicles can also be stimulated through public procurement. Theoretically speaking, public procurement incentivizes the commercialization and public visibility of radically new technologies, such as electric vehicles (Bergek & Berggren, 2014). The European Commission states that "in many sectors such as [...] transport, [...] public authorities are the principal buyers. Transparent, fair and competitive public procurement across the EU's Single Market generates business opportunities, drives economic growth and creates jobs" (Website EC). The principles and legal framework of public procurement within the EU are mainly defined under Directives 2014/23-25/EU, which enhance the efficiency of public procurement systems in Europe, and foresee more intelligent norms and electronic procedures. One important novelty of public procurement in Europe envisaged by the EC is the intention to foster life cycle costs as award criterion rather than procedures which award only on the basis of the lowest price. This would put energy efficient vehicles in advantage. Research about public procurement found that this policy instrument may indeed play a significant role in fostering transport technology innovations (Bergek & Berggren 2014). The market pull effect of public procurement is, however, debatable, since the additional demand created is rather small when compared to the entire market for passenger cars. What is more, governments' procurement programs are often limited to relatively short time spans and are thus inadequate for sending predictable policy signals to car manufacturers in the long run.

4.2 Command and control policies

Command and control measures include emissions standards, privileges for zero/low emission vehicles and sales quotas. Further regulative measures are subsumed in the subsequent section about compliance measures.

Fuel economy and emission standards

Fuel economy and emission standards are legal requirements governing fuel consumption and GHG/CO_2 emissions released into the atmosphere. Emission standards set quantitative limits on the permissible amount per passenger car, typically as a weight-based average of a particular fleet (see also chapter 2).

The characteristics of passenger car fleets vary across regions. The vehicle specifications, including engine size, engine power, vehicle weight, and vehicle size, have an impact on fuel consumption and GHG emissions. For cars with similar characteristics, diesel cars are typically more efficient than gasoline cars because of the higher energy density of diesel fuel compared with gasoline, and because of the different combustion process.[8] Figure 4-2 and Table 4-2 provide an overview of emission standards worldwide, along with their target value, calculation basis and compliance mechanism.

It appears that fuel economy and emission standards are widely applied. They may include loopholes and caveats (Yang & Bandivadekar 2017, Transport & Environment 2012, see also chapter 2), however, they have proven to be effective tools for reducing fossil fuel consumption and CO_2 emissions globally (Atabani et al. 2011). Brown et al. (2010) conclude that a regulative framework based on standards ensures a transition to a market which includes transformative (low-emission) technologies.

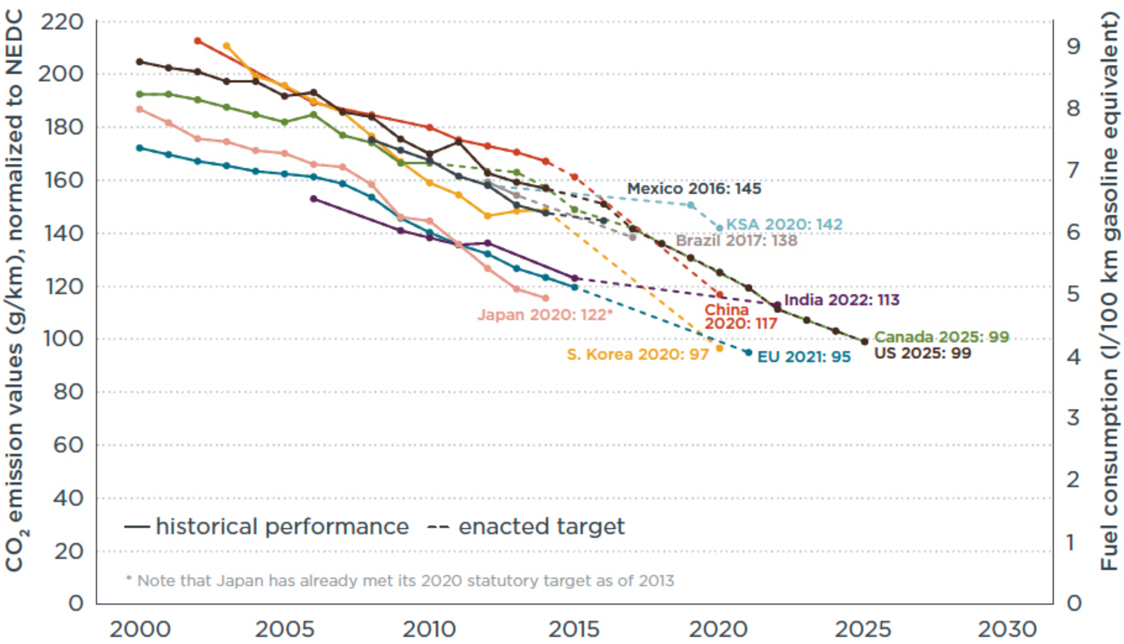


Fig. 4-2 **Historical fleet CO_2 emissions performance and current standards (g CO_2/km normalized to NEDC) for passenger cars. Source: ICCT 2017**

[8] However, diesel engines make more sense in bigger cars due to the higher engine weight. The diesel engine is therefore not suited for fuel savings through a fleet that consists of smaller cars. From this perspective, the diesel technology should not be regarded as a means to protect the climate.

Tab. 4-2 Fuel economy and GHG emission standards for vehicles around the world. Source: Yang & Bandivadekar 2017

Country/ region	Target year	Regulated metric	Unadjusted Fleet Target/Measure	Form of target curve	Test cycle
Brazil	2017	Energy consumption	1.82 MJ/km	Weight-based corporate average	US combined
Canada	2016 2025	GHG	217 gCO_2/mile	Footprint-based corporate average	US combined
China	2015 2020	Fuel consumption	6.9 l/100 km 5 l/100 km	Weight-class based corporate average	NEDC
EU	2015 2021	CO_2	130 g/km 95 g/km	Weight-based corporate average	NEDC
India	2017 2022	CO_2	130 g/km 113 g/km	Weight-based corporate average	NEDC
Japan	2015 2020	Fuel economy	16.8 km/l 20.3 km/l	Weight-class based corporate average	JC08
Mexico	2016	Fuel economy/GHG	39.3 mpg or 140 g/km	Footprint-based corporate average	US combined
Saudi Arabia	2020	Fuel economy	17 km/l	Footprint-based corporate average	US combined
South Korea	2015 2020	Fuel economy/GHG	17 km/L or 140 gCO_2 /km 24 km/L or 97 gCO_2 /km	Weight-based corporate average	US combined
USA	2016 2025	Fuel economy/GHG	36.2 mpg & 225 gCO_2/mile 55.2 mpg & 147 gCO_2/mile	Footprint-based corporate average	US combined

Emission standards are cost-effective instruments but must be ambitious. According to van der Vooren & Brouillat (2015), only high standards generate additional CO_2 reduction against a "no policy" scenario. In their agent based modelling of different policy mixes, they find that the observed reduction in CO_2 emissions can be explained by increased pressure on the market to improve existing technologies. At the same time, standards do not have a substantial impact on public finance.

Siskos et al. (2015) underpin that CO_2 standards support the transition to a sustainable low carbon transport system, provided that considerable future reductions of battery and fuel cell costs take place together with coordinated development of recharging and refuelling infrastructure. They also find that CO_2 standards imply a significant change of the structure of costs as currently faced by final consumers. Consumers would have to undertake considerably higher upfront expenditures for purchasing transport equipment and they would benefit from significantly lower vehicle running costs. According to Yang et al. (2017), the EU emission standard incurs a gasoline fuel cost saving for a Ford Focus model meeting 2016 vehicle CO_2 emission standards, compared with a 2006 baseline Focus model (net fuel price, excluding fuel tax) of up to 700 Euro (depending on the Member State) for the first four years of ownership with 15,000 km of driving annually.

However, from a consumer perspective, emission standards are not necessarily cost-effective. Cost-effectiveness depends strongly on how consumers value vehicles' amenities, because these may be reduced in fuel efficient cars. Thus, depending on preferences, the fuel cost savings induced by emission standards may be offset by costs for amenities (Small 2012).

Emission standards are predictable, which is a prerequisite for ambitious climate change mitigation. The fulfilment of the Paris Agreement demands an early decarbonisation of the European transport sector. As it may take about 17 years for the full vehicle stock to get replaced (see chapter 1), an according transition period has to be ensured.[9] An emission standard allows for this lead-time. Moreover, it can set future target values well in advance and allows manufacturers to develop and deploy the technologies needed to meet the respective target level (Franckx 2015). Yet, allowing a weight-based target curve flaws absolute emission targets, which are a prerequisite to achieve climate change mitigation goals. Similarily, emission standards are less predictable if they do not account for the vehicles' real fuel consumption but rely on emissions measured during a test cycle under laboratory conditions.

Fuel economy and emission standards are relatively easy to enforce, as they aim to limit the fuel consumption throughout the regulated vehicle fleet. A key benefit for policy makers is therefore the need to deal with only a relatively small number of car manufacturers, whereas other policies such as fiscal measures usually target a large number of consumers or their respective vehicle (Lah 2015).

Sales quota

A broad introduction of electric vehicles is often mentioned as necessary for reducing carbon emissions from road transport, and a major shift away from the internal combustion engine will simultaneously cut air pollution and urban noise substantially (e.g. Lah 2017). Sales quotas are an option to phase out fossil fuel based propulsion technologies and phase in electric vehicles through technology mandates Such a market transformation could be achieved by either mandating minimum sales numbers for low-carbon vehicles or limiting the number of sales of cars with ICEs. Ideally, such quotas should be constantly increased and decreased, respectively, to promote long-term incentives for innovation (Berggren & Kageson 2017).

The most prominent example for a sales quota for electric vehicles is China. The Chinese Ministry of Industry and Information Technology announced in 2017 that car producers must obtain credit points linked to the production of various types of electric vehicles (Website Bloomberg). Berggren & Kageson (2017) argue in favour of a sales quota because of its predictability: "A Zero Emission Vehicle (ZEV) target in 2025 would be the best way of sending a clear signal to the automotive industry and investors in battery development and manufacturing that the EU is serious about a rapid shift to electric vehicles. Providing planning security, the target would require automakers to gradually increase the share of EVs [electric vehicles] among new sales". A technology mandate in favour of electric vehicles would also increase securi-

[9] Assuming a policy mix of ambitious market-based (demand-pull) measures, this period may likely be shorter.

ty for investments in charging infrastructure and overcome the currently persisting 'chicken and egg' dilemma (Transport & Environment 2017a). The quota could also allow for flexibility, if manufactures received certificates for each car sold which is equipped with the demanded technology and if they could trade these to reach their assigned target. Penalty payments for falling short of the given sales target would ensure enough incentive to comply with it.

However, sales quotas might be more difficult to enforce than fuel economy and emissions standards, since they drastically limit the choice of technological trajectories for OEMs. It can be expected that especially manufacturers that have so far heavily relied on ICE-related innovations to achieve their emission targets, will oppose such regulation.

The key question policy makers have to answer when they consider a sales quota, is if they prefer a technology-specific or a technology-neutral approach (as is the case with emission standards). In their analysis of policies' cost-effectiveness, Fox et al. (2017) find that technology-specific vehicle standards requiring sales of just one technology are more cost-effective than vehicle standards allowing competition among technologies *in case* policy makers decide for the technology that the market would finally prefer under a no policy scenario.[10]

A recent scenario analysis for the German transport sector assumes, amongst others, command and control measures to decarbonise passenger cars (Rudolph et al. 2017). It thereby points to advantages and shortcomings of both technology-specific and technology-neutral approaches: battery-electric vehicles provide the opportunity of direct electrification including maximum efficiency, a prerequisite to decarbonise the German *passenger* transport sector. A (technology-specific) sales quota would accomplish meeting the target. However, decarbonisation of *freight* transport demands other technology options than battery-electric vehicles, e.g. synthetic fuels in combustion engines. But a scenario assuming heavy duty vehicles equipped with internal combustion engines would make a passenger car market without ICE rather unlikely, because of the existing infrastructure and the option to import cars equipped with ICE to Germany. This, in turn, would countermine the quota's cost-effectiveness.

Privileges for zero and low emission vehicles

Privileges for zero or low emission vehicles may be dedicated lanes or parking lots in city centres. Municipalities may also introduce temporal and spatial access restrictions for dedicated areas depending on a cars specific emissions.

Free charging at car parks, as well as exemptions from (congestion) charges and (parking) fees in some cities, "relieve owners of electric cars of most of the variable costs of driving. Such incentives may be worth considering in the first phase in order to encourage people to become early adopters, but they clearly turn negative from an overall environmental perspective if used for many years and extended to a large fleet" (Berggren & Kageson 2017).

[10] Policy costs of a (technology-neutral) carbon tax were twice as cost-effective as the best vehicle standard (Fox et al. 2017).

The effect of such measures to increase demand for low emission vehicles is unknown. Cities mainly introduce access restrictions to foster modal shifts towards public and active transport, as well as to reduce overall traffic levels. In this respect, this kind of measure has proven to be successful (Cairns & Goodwin 1998).

4.3 Complementary policies

There are some policy instruments which can be regarded as supporting both market-based and command and control measures, such as information-based measures, financial support for R&D and infrastructure development or fuel and electricity standards. Such policies do not directly stimulate demand or supply of low-carbon passenger cars but can be considered as establishing appropriate framework conditions for such a transformation.

Information-based measures

There are different ways of increasing environmental awareness of consumers and promoting pro-environmental behaviour. While hard policy measures might be the most effective way in achieving a transformation of the car market, policy-makers should not underestimate the role of the feeling of personal responsibility. Although a steady shift of social norms has occurred in recent years, in that owning an environmental-friendly car is now often seen as progressive rather than extreme, environmental concerns still play a minor role for purchase decisions. What is more, in their advertising, car companies mainly emphasize characteristics that counteract environmental efforts, such as engine power, performance or certain amenities (Sprei & Wickelgren 2011). The challenge is therefore to make the purchase and possession or low-carbon vehicles socially esteemed and desirable. Manufacturers should consequently think of novel ways of marketing their products. In a similar vein, governments might want to better inform the public of the importance of reducing GHG emissions from road transport and showcase already existing technological solutions, such as electric vehicles, to increase awareness (Tietge et al. 2016).

To support transparency and help consumer to make informed buying decisions, some authors have advocated a reform of the currently existing environmental labelling scheme for passenger cars. Haq et al. (2016) argue that the EU car labelling would be more effective, if data and classification metrics accurately reflected the fuel consumption and CO_2 emissions observed by consumers. Governments might also want to introduce labels that indicate the total cost of ownership of a particular vehicle to highlight the financial advantages of driving a fuel-efficient car and to overcome consumer myopia Eco labelling schemes for cars are typical measures supporting the effectiveness of other measures, which is an important reason why it is difficult to evaluate their impact (Anable et al. 2006). Lundquist Noblet et al. (2006) report the results of a vehicle choice experiment. They find that consumers consider the vehicle's emissions in their purchase decision-making process in case there are provided the information.

Another option is to extend the current labelling system of passenger cars to fuels and electricity. With regard to conventional cars, more transparency about a fuel type's CO_2 footprint and the charged fuel tax at the point of sale (e.g. at gas stations) could be established through introducing appropriate labelling (Roland Berger 2016). Moreover, in order to improve the life cycle emissions of electric vehicles, consumers should also be educated about the origin of the electricity used at public charging points. This could be done by e.g. indicating the amount of renewable energy sourced (Kampman et al. 2010).

R&D subsidies and infrastructure development

Governments often subsidize R&D in specific technologies to promote their advancement and diffusion. Concerning vehicle technologies, especially electromobility research is financially supported by the EU and its Member States. The overall aim is to accelerate the market uptake of all kinds of electric vehicles, but most notably battery electric and plug-in hybrid electric vehicles, while fuel cell vehicles might also play a role in the future. Government support for electric vehicles is viewed as being crucial, since most currently available models suffer from a low driving range and high purchase prices when compared to conventional cars (Tietge et al. 2016). Fiscal R&D support can help to promote the development of less costly and more efficient battery technologies, which would both lead to lower purchase prices and higher range and consequently increase consumer attractiveness. Supply side R&D policies can also be a substitute or supplement for financial purchase incentives for electric vehicles. However, in contract to purchase incentives, the effectiveness of R&D subsidies is hardly predictable and verifiable, since there is no guarantee that certain technologies ever achieve their breakthrough. Moreover, focusing on a particular propulsion technology might hamper innovation in other areas and as such, financial support for electro-mobility research can create a technological bias.

Another reason to combat the slow uptake of electric vehicles is the lack of charging infrastructure. The importance of a dense charging network is emphasized by the fact that although the UK, France and Netherlands have all introduced financial purchase incentives, the electric vehicles market share differs significantly between the countries. This is probably due to a varying density of public charging infrastructure (Tietge et al. 2016). The EU and national governments should thus also consider to financially support the extension of the charging network across Europe to promote the adoption of electric vehicles.

Fuel and electricity standards

A fuel or electricity standard is a regulation to ensure that the fuel or electricity consumed by vehicles comes from renewable energy sources. This is especially important in the light of an increased diffusion of electric vehicles. Kampman et al. (2010) conclude that „if policy aims are to both stimulate electric vehicles and ensure that the additional electricity consumption is 100% green, [...] the best policy options are macro-policy regulations targeted at 100% additional green electricity production for all electricity that is consumed by electric vehicles“. A national government (or the EU) could adopt a target for renewable electricity in the form of a mandatory percentage of renewable electricity production which increases according to the increase of electricity consumption arising from electric vehicle usage. This would ensure that life-cycle emissions from electric vehicles would decrease over time.

4.4 Summary

Table 4-3 summarizes the scope, level of responsibility and main advantages and disadvantages of the market-based and command-and-control policy instruments discussed in this chapter.

Tab. 4-3 Assessment of policies. Source: own compilation

Policy instrument	Responsibility	Scope	Advantages	Disadvantages
Market-based measures				
Fuel taxes	Member State	Demand side (consumers)	• ambitious taxation increases operation costs and stimulates demand for fuel-efficient cars	• fuel price volatility makes effectiveness hardly predictable • high fuel taxes can be politically infeasible • currently favours diesel cars
Vehicle taxes	Member State	Demand side (consumers)	• sends strong price signal to consumers	• currently too many exemptions and often favours diesel and larger cars
Purchase incentives	Member State	Demand side (consumers)	• sends strong price signal to consumers	• heavy burden on government budget • long-term predictability is low
Feebates	Member State	Demand side (consumers)	• sends strong price signal to consumers • potentially revenue neutral	• long-term predictability is low • optimal pivot point hard to predict
Road transport in EU ETS	EU	Demand or supply side (consumers, fuel suppliers, manufacturers)	• interaction with other sectors and thereby cost-effective	• requires immense increases in prices for emission allowances to be effective • may have negative side effects for other industries
Public Procurement	Member State	Demand side (public sector)	• triggers innovation and thereby supports the uptake of new technologies	• market pull effect is limited
Command-and-control measures				
Fuel economy/ emissions standards	EU	Supply side (manufacturers)	• cost-effective • effective in promoting innovation • technology-neutral	• needs adequate compliance measures and enforcement
Privileges for low emission vehicles	Member State	Demand side (consumers)	• easy to enforce	• effectiveness questionable
Sales quota	Member State	Supply side (manufacturers)	• cost-effective if 'winning' technology is selected	• technology specific • high political cost

5 Recommendations

In theory, an optimal mix of policies should be effective in increasing the demand and supply of low-carbon vehicles, be technology-neutral, predictable to all market actors, easily enforceable by policy-makers and achieve all of these criteria with the least costs for society. Under realistic assumptions, such a situation is unlikely, because of the inherent advantages and disadvantages of possible policy instruments (as outlined in the previous chapter). Policy-makers should strive to select a portfolio of policies that as a whole comes closest to meeting these criteria.

The EU and its Member States already employ the most relevant instruments in this respect. The EU enacts an emission standard, whereas the responsibility for market-based measures (i.e. fuel and vehicle taxes) resides mostly on a Member State level. In the following, we provide recommendations to the EU and its Member States on how they could combine different policy measures in order to achieve their targets while fine-tuning the above-mentioned criteria as far as possible.

The European Union

Most of the reviewed literature emphasizes the importance of emission standards for decarbonizing passenger cars in the EU. Many authors regard such regulation as a central element of an appropriate policy mix. Standards are predictable for manufacturers and do not mandate a specific technological trajectory. Therefore, they provide sufficient lead time for compliance as well as flexibility with regard to innovation activities. Nevertheless, the effectiveness and predictability of current regulation on standards could be further increased by turning away from granting “supercredits” and introducing a size-based (instead of weight-based) credit system (Mock 2013). At present, the sale of zero-emission vehicles weakens the emission targets for some manufacturers, enabling them to sell a greater number of larger and fuel inefficient cars (Transport & Environment 2012).

Moreover, the current EC proposal for a Clean Mobility Package appears to be too unambitious to reach the climate mitigation goals of the Paris Agreement, the EU and any EU Member State, bearing in mind that the reduction targets are based on the NEDC, which does not represent the vehicles’ real CO_2 emissions.

EU Member States

Based on the review of literature, fuel taxation might be an effective instrument for a decarbonization of passenger cars. Having said that, fuel taxes are already relatively high in some Member States and further increases may be difficult to justify (Clerides & Zachariadis 2008). But there is a need for harmonisation between countries to strengthen policy makers’ position and increase the pressure on manufacturers to transform their fleets. Fuel taxation, however, also has some disadvantages. For one, fuel taxes appear to only partially overcome consumer myopia. Apart from that, fuel prices are subject to high volatility and as such, incapable of sending predictable policy signals in the long run. In consequence, a reformation of current taxation should primarily focus on the removal of the diesel privilege in order to counteract the ever-increasing size of new passenger cars and free manufacturers from their technological lock-in.

To generate a significant technology pull effect, vehicle taxes and purchase incentives appear to be more appropriate than fuel taxation (Mock et al. 2014). Especially measures that influence the acquisition costs of a car might be effective in changing demand (Öko-Institut 2015). They are promising for promoting early stages of technology deployment, but should be taken to a limited extent after technology diffusion has gained momentum in order to create a self-sustaining market (Pasaoglu et al. 2012). Member States, however, might refrain from solely subsidizing purchase prices or granting tax discounts; and rather implement a bonus-malus system instead, also known as feebates. This is due to the fact that, if designed correctly, a feebate scheme for vehicle purchase and registration is revenue neutral and thus the most cost effective purchase incentive. It should be based on a vehicle's energy consumption to decrease the vehicles' size (Rudolph et al. 2017).

Besides that, the taxation of company cars should be reformed, if it gives advantage to large cars, which is still the case in most EU Member States. All in all, feebates and vehicle taxation are important demand-side policy measures. They can help to ensure that the technology push induced by the EU emission standard supported by sufficient demand.

If Member States realise that the specific CO_2 emission reductions of their country's fleet only advance weakly, they can introduce a sales quota for electric vehicles, which is an already mature technology for certain mobility patterns, yet with low market share. Technology mandates can be an effective instrument to force the sale of radically new low-carbon technologies, such as electric vehicles. Yet, policy-makers should be careful in selecting a 'winning' technology upfront. The risk of picking the wrong technology should be carefully assessed and based on reliable information or estimates about future technological developments, learning curves and consumer acceptance (Fontaras et al. 2017, Fox et al. 2017).

Technology-specific sales quota should thus at least provide manufacturers with a certain amount of flexibility, e.g. through the possibility of trading certificates. Moreover, quotas should ideally be tailored to the market realities in each Member State to ensure their feasibility (trip distances, alternative modes of transport, purchasing power, and infrastructure).

That being said, technology mandates might impede the effectiveness of the EU emission standard. A greater the share of low-carbon cars sold per manufacturer would lower the efforts necessary for improving the fuel efficiency of conventional cars. This is because the current's emission standards reliance on sales weighted average emissions per car. In consequence, regulation on emission standards would need to be tightened accordingly.

Municipalities

Like purchase incentives, privileges for zero- and low-carbon vehicles (e.g. dedicated lanes, parking lots or free charging) can be an effective measure to promote the uptake of such technologies in their early phases. However, with a growing share of such vehicles in the passenger car fleet, the maintenance of privileges becomes less feasible. Local policy makers should constantly monitor their measures and adjust if necessary. Instead of providing privileges for zero- and low-carbon vehicles, cities and rural municipalities may also introduce measures that increase the local transport system efficiency, i.e. increase the vehicles' occupancy and foster modal shifts towards public and active transport.

Member States, regional governments and municipalities might also want to make a coordinated effort regarding privileges to create consistent framework conditions for car owners.

Further recommendations

The discussed fiscal measures and command-and-control should be accompanied by policies that establish the necessary framework conditions for a diffusion of low-carbon technologies. The public sector, in cooperation with automobile manufactures, might want to increase environmental awareness of consumers through education campaigns. The EU and Member States should also consider a revision of the environmental labelling scheme for passenger cars to help consumers in making informed purchase decisions. In so doing, more meaningful indicators, e.g. based on the vehicle's energy consumption instead of its weight, should be introduced to increase transparency and reliability. Public procurement should focus on a vehicles' life cycle cost rather than employing the lowest purchase price criterion.

Finally, the European Union and its Member States should ensure that their policy framework is complied with. The application of the NEDC test legally enhanced the passenger cars' stated fuel economy. The defeat devices to reduce NO_x test emissions were illegal but without strict consequences (Luhmann 2017). The WLTP driving cycle test may need further adjustment, national approval authorities should be obliged to monitor and enforce compliance.

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