# Reducing $CO_2$ from Cars in the European Union: Emission Standards or Emission Trading?[1]

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## Abstract

*$CO_2$ emissions mandates for new light-duty passenger vehicles have recently been adopted in the European Union (EU), which require steady reductions to 95 g $CO_2$/km in 2021. Using a computable general equilibrium (CGE) model, we analyze the impact of the mandates on oil demand, $CO_2$ emissions, and economic welfare, and compare the results to an emission trading scenario that achieves identical emissions reductions. We find that vehicle emission standards reduce $CO_2$ emissions from transportation by about 50 Mt$CO_2$ and lower the oil expenditures by about €6 billion, but at a net added cost of €12 billion in 2020. Tightening $CO_2$ standards further after 2021 would cost the EU economy an additional €24-63 billion in 2025 compared with an emission trading system achieving the same economy-wide $CO_2$ reduction. We offer a discussion of the design features for incorporating transport into the emission trading system.*

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## 1. Introduction

European Union legislation sets mandatory $CO_2$ emissions reduction targets for new cars (EC, 2009). The legislation is based on the EU strategy for passenger cars and light commercial vehicles that is at once aimed at fighting climate change, reducing the EU reliance on imported fuels, and improving air quality (EC, 2007). It sets a new vehicle fleet average for passenger cars of 130 grams of $CO_2$ per kilometer (g/km) for 2015 (phased in from 2012), falling to 95 g/km by 2021. The 2007 new car fleet average was about 159 g/km (EC, 2014a). The goal of this paper is to assess the resulting $CO_2$ emissions, energy, and economic impacts of the EU $CO_2$ mandates, and compare them to an alternative scenario where vehicle emissions are part of an emission trading system designed to meet Europe's announced economy-wide targets. Most analyses to date have been based on simplified benefit-cost calculations that estimate fuel savings and additional costs of introducing new technology deployment driven by the targets (e.g., TNO, 2011; Ricardo-AEA, 2014; ICCT, 2014a). We argue that assessment of the performance of the EU targets and alternatives should account for interactions of the transport sector with other energy sectors and with other parts of the economy. For this purpose we apply a global, economy-wide model of energy and emissions. The MIT Economic Projection and Policy Analysis (EPPA) model (Paltsev et al., 2005), in the version applied here, includes a technology-rich representation of the passenger vehicle transport sector and its substitution with purchased modes, as documented in Karplus et al. (2013a).

The paper is organized as follows. In Section 2 we discuss some fuel economy standard basics and describe in more detail the European standards. In Section 3 we describe the model used for the analysis. In Section 4 we implement a scenario analysis to study the effects of the EU $CO_2$ standards for passenger cars. Section 5 provides a discussion of practical steps for bringing vehicles into emission trading system and briefly discusses additional policy measures to stimulate innovation and technology deployment. Section 6 summarizes the results and conclusions.

## 2. Fuel Standards Basics and the European Requirements

Tailpipe $CO_2$ emissions standards, as adopted in Europe, are similar to fuel economy standards, such as the US Corporate Average Fuel Economy (CAFE) standards, which date to the Energy Policy and Conservation Act of 1975 (US EPCA, 1975). Fuel use per mile or kilometer, the target in fuel economy standards, translates directly to $CO_2$ emissions given the carbon content of the fuel. For example, 95 g/km is equivalent to 4.1 liters of gasoline per 100 kilometers (l/km) or 57.4 miles per gallon (mpg) of gasoline. In general, however, there is a gap between test standards and actual on-road performance of vehicles. A direct translation of targets between countries is further complicated as it also should reflect the mix of gasoline and diesel cars in each country because they have different fuel efficiencies. The ICCT (2014a) estimates that the 95 g/km target for the EU is equivalent to 3.8 l/km (considering a mix of gasoline and diesel cars) and to about 62 mpg in the US specification (considering the differences between the EU and US test standards).

### *2.1 Fuel economy standard basics*

Emissions and fuel economy standards have become a popular regulatory mechanism with many countries setting such targets despite economists questioning of their effectiveness (ICCT, 2014a; Karplus, et al, 2015). An initial issue is the translation of targets defined by a specific test cycle to actual fuel use or emissions reductions. Test cycle settings differ among jurisdictions (e.g., Europe and the US) and differ from actual driving habits. The conditions under which the tests are conducted can also differ from actual road and environmental conditions. Currently, actual on-road fuel consumption exceeds the test results by about 20% in the U.S. (EPA, 2014) and about 30% in the EU (ICCT, 2014b).

Standards also often include other credits that relax the actual target, or manufacturers may find it less costly to simply pay noncompliance penalties. In the U.S. and EU, credits are available for reductions of hydrofluorocarbons (HFCs) used as refrigerants in air conditioning. Anderson and Sallee (2010) also point to the extensive use of credits for flex-fuel vehicles, an exception in recent US CAFE standards. The spread of flex fuel vehicles was an objective of the legislation, anticipating a growing supply of ethanol, which would reduce oil imports and $CO_2$ emissions. As it turned out, however, very little of the E85 fuel (an 85% ethanol blend) was available and so most of these flex vehicles continued to use petroleum-based fuels with no benefit to fuel imports or $CO_2$ emissions. While exceptions in legislation may or may not achieve the expected objective, they relax the actual fuel standard and can substantially reduce the estimated compliance costs (Anderson and Sallee, 2010).

While adjustments can be made to the stated standard to better estimate their effectiveness, economists’ concern is that the standards can actually affect consumer behavior, reducing fuel or emissions savings. To the extent the vehicles are more costly, the sales of efficient new vehicle sales may be reduced and old vehicles retained in the fleet longer. New cars that are purchased have lower fuel costs per distance traveled and that may lead to an increase in annual distance traveled, widely known as a “rebound” effect (Small and Van Dender, 2007). Moreover, the standards apply only to new vehicles, whereas a fuel or emissions tax creates opportunities to reduce fuel use in the existing fleet—for instance, through changes in driving habits, improved vehicle maintenance, earlier retirement of old vehicles, or in the case of emissions, substitution of low carbon energy sources. Higher fuel prices have been shown to incentivize consumer purchases of more efficient vehicles, although consumer responses have been shown to vary across regions (Klier and Linn, 2011). Because of these various inefficiencies taxes are widely considered to be the most cost-effective option for displacing petroleum-based fuel use. Despite the advantages, fuel taxes have failed to gain political traction in the United States (Knittel, 2012). Europe, on the other hand, already has among the highest fuel taxes in the world, and opposition to increasing the gasoline tax has been strong, particularly given the recent economic slowdown (Sterner, 2012).

Regulatory processes that assess the energy, emissions, and economic impacts of these fuel economy programs typically rely on vehicle fleet and technology models that do not capture behavioral impacts, or broader macroeconomic effects. Regulatory impact assessments in the United States (EPA, 2012a, 2012b) have focused on the new vehicle fleet and have not assessed impacts on fleet turnover, on non-transport sectors, or on global oil price and quantity demanded. In the European Union, EUCLIMIT, an economy-wide model for Europe has been used with broad sectoral coverage and fleet dynamics, however, international variables are still assumed to be exogenous (Eur-Lex, 2012).

A reason frequently given for implementing or tightening new vehicle fuel economy standards is that consumers underestimate the value of fuel savings over the life of the car, and therefore are unwilling to pay extra for efficiency at the time of vehicle purchase, requiring correction through policy (Greene et al., 2005). Recent work has tested this hypothesis. One study suggests that consumers that are indifferent between one dollar in fuel costs and 76 cents in vehicle purchase price (Allcott and Wozny, 2014), suggesting mild undervaluation, while other empirical work finds scant evidence of consumer myopia (Goldberg, 1998; Knittel et al., 2013).

Their work suggests that consumers respond rationally to price mechanisms like carbon taxes or gasoline taxes, leaving little need for additional policy intervention as prices influence both what cars people buy and how much people drive.

Comparison of cap and trade and fuel economy standards include that of Rausch and Karplus (2014), who use a model of the USA and find that cap-and-trade system is more efficient than fuel standards, and combination of cap-and-trade and fuel stands reduces inefficiencies but this combination is still less cost-effective in comparison to an economy-wide emission trading. Paltsev et al. (2014) considered a sequential policy design, where global emissions were first regulated in electricity and private transportation, but then later they were combined with economy-wide emissions trading and it reduces the cost of mitigation.

Ellerman et al. (2006) examined possible links between CAFE standards in the US with a proposed cap and trade system. They concluded that in the presence of an overall carbon cap, the CAFE standards are a poor regulatory policy for dealing with carbon emissions, whether or not it is integrated with the cap-and-trade system. A useful aspect of their study is discussion of the practical steps needed to bring transportation under emissions trading in a cost-effective manner that engages both upstream (level of fuel provider) and downstream (level of car owner) actors.

### *2.2 Europe vehicle standards*

The European Union has only recently pursued standards, having instead previously relied on fuel taxes. The new standards began with a voluntary agreement with car manufacturers to achieve 140 g/km for new vehicles sold in 2008-2009. The standard became mandatory when legislation required a fleet average for all new passenger cars registered in the EU of 130 g/km for the year 2015 (EC, 2009). The legislation included a so-called “limit value curve” to allow heavier cars to have higher emissions than lighter cars while preserving the overall fleet average. A target of 95 g/km was specified for the year 2020, with full implementation later delayed to 2021. In 2013 the European Parliament's Environmental Committee issued a report calling for a 2025 target in the range of 68 to 78 g/km (EPRS, 2014).

A summary of historic, enacted and proposed $CO_2$ emission reductions through 2025 for new cars in the EU is shown in Figure 1, with the US standards shown for comparison. Historically, the average EU cars are more fuel-efficient (and produce less tailpipe $CO_2$ emissions per kilometer) than US cars, which economists would likely attribute to higher fuel taxes in the EU. Differential fuel taxes for diesel and gasoline, have also contributed to a much larger penetration of diesel cars, which have higher fuel efficiency in liters per kilometer. The U.S. standards are specified through 2025, but they are enacted only up through the 2021 model year, with a mid-term review of the standards scheduled to take place in 2017.

As mentioned previously, the EU currently sets two targets for new cars: for 2015 at 130 g/km and for 2021 at 95 g/km. A gradual phase-in of the targets is achieved by increasing the percentage of the new vehicle fleet to which they apply. By 2020, 95% of new cars have to comply with the 95 g/km target, which, according to ICCT (2014a), makes it effectively a 98 g/km target for 2020. Full compliance must be achieved by 2021. In Figure 1 the requirements are drawn as a simple linear approximation between the 2015 and 2020 targets, with the range under discussion for 2025 also shown.

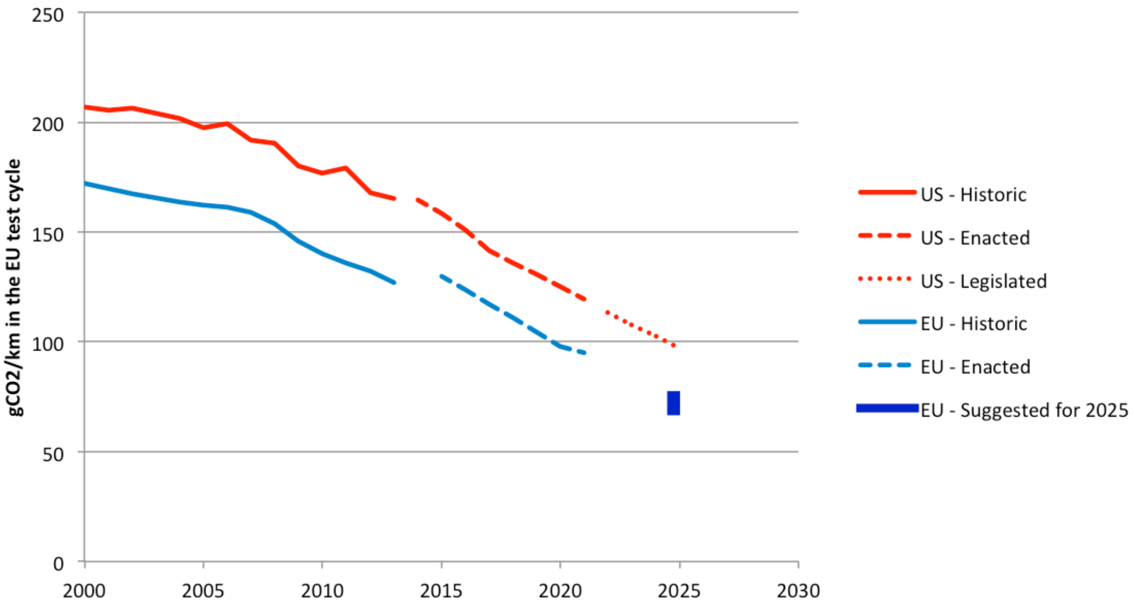

**Figure 1.** $CO_2$ regulations for cars in USA and EU normalized to the EU NEDC test cycle. Data source: ICCT (2014a), EPRS (2014).

Based on data of the European Environment Agency (EEA, 2014), in 2013 the fleet average for new cars was 127 g/km, falling below the 2015 standard, even though the phase-in schedule required that only 75% of newly-registered cars in 2013 meet the 130 g/km target. While seemingly good news, the EU system of testing cars to measure fuel economy and $CO_2$ emissions shows a growing gap between the test results and on-road performance of cars. The ICCT (2014b) estimates the divergence has grown from 8% in 2001 to 31% in 2013. Transport & Environment (2014) estimates that without action the divergence is likely to grow to over 50% by 2020. Applying the 31% difference to the 2013 test results leads to about 166 g/km for the actual performance of new cars. The growing difference between test results and on-road performance is a concern both in the EU and USA, and changes have been proposed for the testing and labelling of cars to better represent the fuel economy drivers are likely to experience

(EPA, 2014). Efforts such as ours, to estimate cost and effectiveness of such measures, must reflect as best they can the relationship between test standards and the likely actual on-road performance of vehicles. If the standards are taken at face value, costs of compliance and effectiveness will be overestimated. On the other hand, if test standards are changed to better reflect actual performance, the cost and effectiveness of the standards will be underestimated.

## 3. Model and Scenarios

We approach analysis of the European standards using a global energy-economic model, with detail on vehicle options for fuel saving and their costs, capable of capturing rebound and leakage effects, while estimating fuel savings, emissions reductions, and economic costs of the regulations. We capture leakage that occurs across sectors within economies, across regions, and between new and used passenger vehicles. The rebound effect is also captured, and based on parameterization of the costs associated with vehicle efficiency improvements, the contribution of resulting fuel savings given diverse taxation regimes for motor vehicle fuel, and heterogeneity in vehicle ownership and travel demand patterns. The model further captures how these two effects interact with each other.

### *3.1 Model Description*

We use the MIT Economic Projection and Policy Analysis (EPPA) model (Paltsev et al., 2005; Karplus et al., 2013a) for the analysis. It provides a multi-region, multi-sector recursive dynamic representation of the global economy. Data on production, consumption, intermediate inputs, international trade, energy and taxes for the base year of 2004 are from the Global Trade Analysis Project (GTAP) dataset (Narayanan and Walmsley, 2008). The GTAP dataset is aggregated into 16 regions (Table 1) and 24 sectors, including several advanced technology sectors parameterized with supplementary engineering cost data. The model includes representation of $CO_2$ and non-$CO_2$ (methane, $CH_4$; nitrous oxide, $N_2O$; hydrofluorocarbons, HFCs; perfluorocarbons, PFCs; and sulphur hexafluoride, $SF_6$) greenhouse gas emissions abatement, and calculates reductions from gas-specific control measures as well as those occurring as a byproduct of actions directed at $CO_2$. The model also tracks major air pollutants (sulfates SOx, nitrogen oxides NOx, black carbon BC, organic carbon OC, carbon monoxide CO, ammonia NH3, and non-methane volatile organic compounds VOCs). The data on GHG and air pollutants are documented in Waugh et al (2011).

From 2005 the model solves at 5-year intervals, with economic growth and energy use for 2005-2015 calibrated to data and short-term projections from the International Monetary Fund (IMF, 2014) and the International Energy Agency (IEA, 2014). The model includes a technology-rich representation of the passenger vehicle transport sector and its substitution with purchased modes, including aviation, rail, and marine transport (Paltsev et al., 2004). Several features were incorporated into the EPPA model to explicitly represent passenger vehicle transport sector detail (Karplus et al., 2013a). These features include an empirically-based parameterization of the relationship between income growth and demand for vehicle miles traveled (VMT), a representation of fleet turnover, and opportunities for fuel use and emissions abatement, including representation of electric vehicles. The opportunities for fuel efficiency improvement are parameterized based on data from the U.S Environmental Protection Agency (EPA, 2010; EPA, 2012b) as described in Karplus (2011), Karplus and Paltsev (2012), and Karplus et al (2013a).

**Table 1.** Sectors and regions in the EPPA model.

| ***Sectors*** | ***Regions*** |
|---|---|
| ***Non-Energy*** | Europe (EUR) |
| Agriculture | United States (USA) |
| Forestry | Canada (CAN) |
| Energy-Intensive Products | Japan (JPN) |
| Other Industries Products | Mexico (MEX) |
| Industrial Transportation | Australia & Oceania (ANZ) |
| Household Transportation | Russia (RUS) |
| Food | China (CHN) |
| Services | India (IND) |
| ***Energy*** | Brazil (BRA) |
| Coal | Rest of Latin America (LAM) |
| Crude Oil | Higher-Income Asia (ASI) |
| Refined Oil | Rest of East Asia (REA) |
| Natural Gas | Middle East (MES) |
| Electricity Generation Technologies | Africa (AFR) |
| Fossil | Rest of Europe and Central Asia (ROE) |
| Hydro | |
| Nuclear | |
| Solar and Wind | |
| Biomass | |
| Natural Gas Combined Cycle | |
| Natural Gas with $CO_2$ Capture and Storage (CCS) | |
| Advanced Coal with CCS | |
| Synthetic Gas from Coal | |
| Hydrogen from Coal | |
| Hydrogen from Gas | |
| Oil from Shale | |
| Liquid Fuel from Biomass | |

Note: Detail on aggregation of GTAP sectors and the addition of advanced technologies are provided in Paltsev *et al.* (2005). Details on the disaggregation of industrial and household transportation sectors are documented in Paltsev *et al.* (2004).

Given that the $CO_2$ standards apply only to new model-year vehicles, differentiation between the new and used vehicle fleets is essential. We also include a parameterization of the total miles traveled in both new (0 to 5-year-old) and used (6 years and older) vehicles and track changes in travel demand in response to changes in income as well as cost-per-kilometer. We represent the ability to substitute between new and used vehicles, an additional way in which consumers respond to changes in relative prices of vehicles and fuels as affected by the introduction of vehicle standards, fuel prices, or carbon prices as they are reflected in fuel prices. Details are provided in Karplus et al. (2015).

As noted, our representation of vehicle efficiency options is based on studies in the US. No comparable study has been done for the EU but the cost and fuel savings associated with different options is, first and foremost, a matter of technology possibilities that face automakers worldwide. Studies in Europe include an evaluation done by TNO (2011), which relied primarily on the existing literature and in-house expertise. In the US study, the US EPA included extensive communication with car manufacturers. The budget of the EPA studies was around an order of magnitude higher than that of the TNO work for the EU, and the lower budget obviously limited what the TNO could undertake (TNO, 2011). While a detailed study of costs of efficiency improvements in Europe would be ideal, we believe the US study offers a reasonable estimate of the technical options available to manufacturers.

If the marginal cost of improving vehicle efficiency is rising one might argue we underestimate costs using the EPA US-based assessment because the EU fleet is already more efficient than the US fleet. The fuel economy standards are implemented in the EPPA model as constraints on the fuel used per kilometer of household travel. They are converted to $CO_2$ standards based on characteristics of the fleet (composition of diesel and gasoline vehicles). The standards are imposed at their values based on *ex ante* usage assumptions (i.e., before any change in miles traveled due to the higher efficiency). This approach forces the model to simulate adoption of vehicle technologies that achieve the imposed standard at least cost. The production function specification for vehicles creates a Constant Elasticity of Substitution (CES) nest where the elasticity of substitution between fuel and powertrain capital captures the increasing cost of marginal improvements in vehicle efficiency, holding other characteristics of the vehicle fixed

(Karplus et al., 2013a). When simulated, tradeoffs between the power train and other characteristics of the vehicle, and the response of total vehicles-miles traveled due to lower energy costs per km are captured. The form of the utility function, the input shares, and the substitution elasticity between vehicle and powertrain capital determines how much the cost of travel changes in response to changes in the underlying $CO_2$ requirements and vehicle characteristics, which in turn determines the magnitude of the rebound effect. Demand for new vehicles is also affected by their cost. The model assumes consumers consider fuel savings over the life of the vehicle, but because of the recursive dynamic solution of the model they value savings given fuel prices in the year the vehicle is purchased. With rising fuel prices, this implies that some undervaluation of future fuel savings can exist, with potential room for fuel standards to improve on these myopic decisions.

### *3.2 Scenarios*

We consider several scenarios regarding the EU $CO_2$ emissions targets. Our "*No Policy*" scenario considers no economy-wide GHG reduction targets and no mandatory $CO_2$ emissions reduction targets for new cars. It provides the basis against which we compare the outcomes of the other scenarios. We then consider the EU GHG reduction targets (20% reduction by 2020 and 40% reduction by 2030 relative to 1990 levels) achieved by an economy-wide emission trading system (denoted as "*Emission Trading*"). In the *Emission Trading* scenario, permit trading is allowed across all sectors within the EU. We then create the "*Current ES*" scenario, where we add to *Emission Trading* the current emissions standards for vehicles of 130 g/km in 2015 improving to 98 g/km by 2020, and holding the requirement in 2025 at the 2021 target of 95 g/km. While the *Current ES* scenario is imposed on top of a system that allows trading with vehicle emissions, because the standards are binding on fuel economy this is equivalent to removing vehicles from the trading system, and adjusting the trading system to assure that Europe met its international commitment of 20% by 2020 and 40% by 2030, regardless of the vehicle emission standard requirements. We then add two scenarios that tighten targets further in 2025: to 78 g/km ("*ES78*") and to 68 g/km ("*ES68*"). We assume that the difference between the test values and on-road performance of new cars remains at 2013 levels of 30%. Table 2 summarizes the scenarios, which we run from 2010 to 2025, at five-year time steps of the model.

**Table 2.** List of Scenarios.

| Name | Description |
|---|---|
| *No Policy* | No GHG reductions and no mandatory $CO_2$ reduction targets for new cars. |
| *Emission Trading* | Economy-wide emission trading to achieve the EU goals (20% reduction in 2020, 40% reduction in 2030 relative to 1990 levels). |
| *Current ES* | Current policy for Emission Standards (ES) in cars: 130 g/km in 2015, 98 g/km in 2020, 95 g/km in 2025. The standards are imposed on top of the *Emission Trading.* |
| *ES78* | Same as *Current ES* for 2015-2020, 78 g/km in 2025. |
| *ES68* | Same as *Current ES* for 2015-2020, 68 g/km in 2025. |

For simplicity, we omit some features of the vehicle emission standard regulations that could loosen stringency in practice, for example, super-credits for extremely low emission vehicles and eco-innovations. We also assume that car manufacturers meet the standards rather than paying a penalty for excess emissions (set at €95 per g/km of exceedance per car sold).

## 4. Results

We first describe the trends in new vehicles and the total fleet in terms of fuel economy and $CO_2$ emissions per kilometer under each of the scenarios. We then describe the energy and total vehicle emissions implications of the each scenario. Lastly we evaluate the policy costs.

### *4.1. Impact of the current policies on new cars and total fleet*

To illustrate how the $CO_2$ mandate affects the efficiency of fuel use, we show projected on-road fuel consumption in liters per 100 km traveled of an average on-road vehicle in the new fleet and total vehicle fleet (Figure 2). As anticipated, we observe a declining trend in fuel efficiency through 2025, with declines in the total fleet lagging the new fleet as newer vintages of vehicles gradually replace the old vehicle stock. The model solves in 5-year time steps and so intervening years are linear interpolations. In 2025 the new fleet is projected to have on-road fuel consumption of 4.9 l/km in the *Current ES* scenario, 4.1 l/km in the *ES78* scenario, and 3.5 l/km in the *ES68* scenario. The corresponding numbers for the total fleet in 2025 are 6.1 l/km in the *Current ES* scenario, 5.5 l/km in the *ES78* scenario, and 5.1 l/km in the *ES68* scenario.

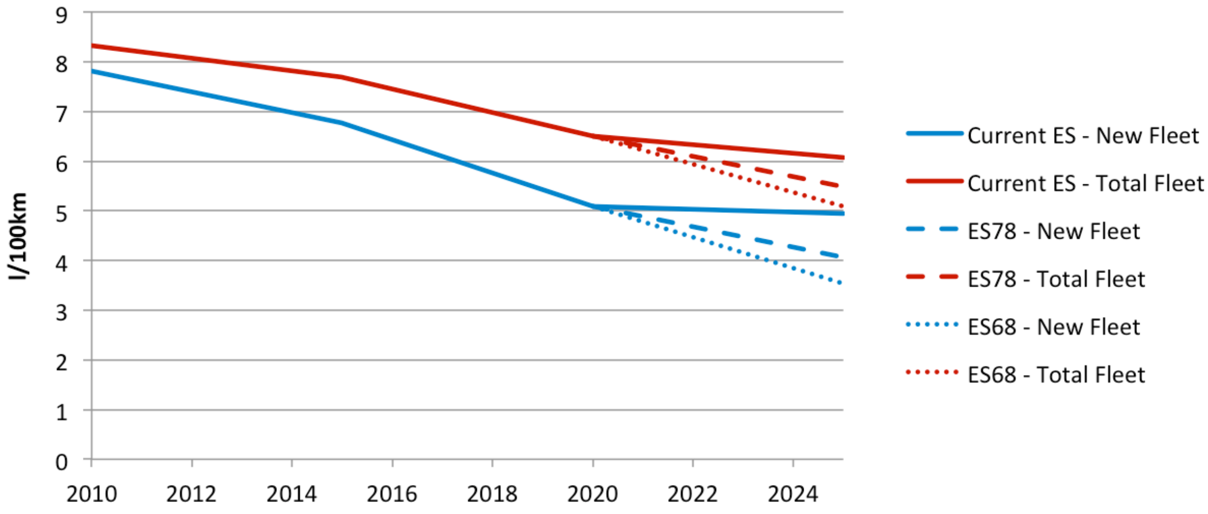

**Figure 2.** On-road fuel consumption for an average new car and total fleet.

On-road $CO_2$ emissions per kilometer for new cars and the total fleet in the *Current ES* scenario are presented in Figure 3, along with the actual test cycle requirements. Emissions per kilometer follow the fuel consumption trajectory. The curves for test cycle requirements are lower (i.e., less emissions per km) than the new vehicles $CO_2$ emissions per kilometer reflecting our assumption that the on-road performance of vehicles is 30% lower (i.e., more emissions per km) than the test cycle. In the *Current ES* Scenario, the mandates for new cars are set to be tightened from 130 g/km in 2015 to 95 g/km in 2025, while on road the new cars achieve 169 g/km in 2015 and 123 g/km in 2025 and the total fleet performance improves from 192 g/km in 2015 to 152 g/km in 2025. In the *ES78* and *ES68* scenarios, new cars in 2025 achieve 101 g/km and 88 g/km, respectively. The total fleet performances in 2025 in these scenarios are 137 g/km and 127 g/km, correspondingly.

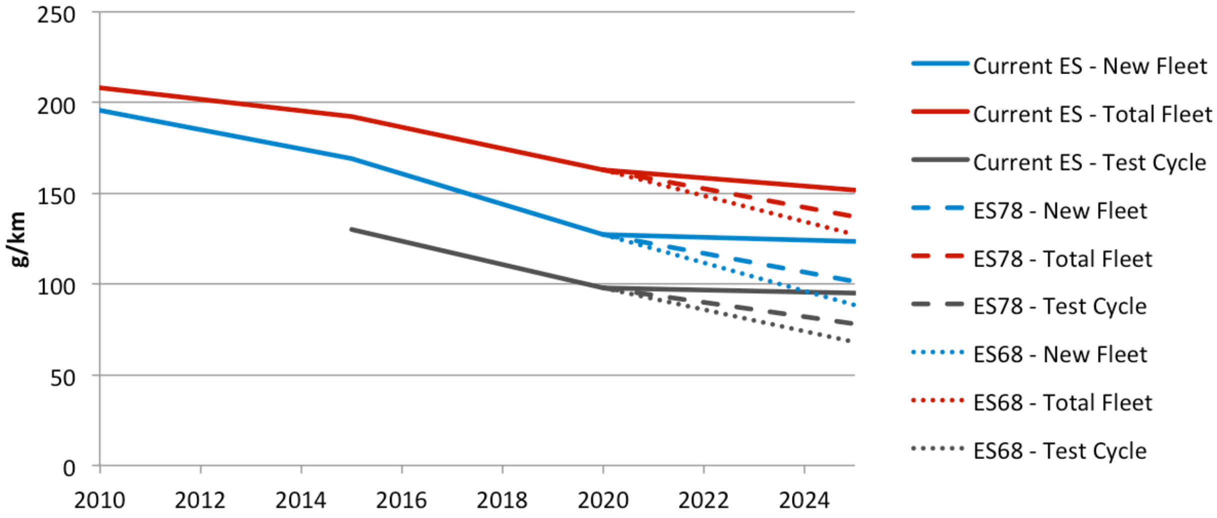

**Figure 3.** $CO_2$ mandates for new cars based on the test cycle ("test cycle") and on-road $CO_2$ emissions for an average new car ("new fleet") and total fleet ("total fleet")

### *4.2. Energy and environmental impacts of the current policies*

We now consider the net effect of the current EU $CO_2$ emission mandates on energy and environmental outcomes. We first focus on the change in the EU total oil consumption shown in Table 3. The *No Policy* scenario shows a slight decrease in oil use over the 2010-2025 period. The *Emission Trading* scenario further reduces the total EU year-on-year oil use by around 23 million tonnes of oil (mtoe) in 2020 and by around 55 mtoe in 2025, about 4% and 10% reductions relative to the *No Policy* scenario in 2020 and 2025, respectively. The *Current ES* scenario creates an additional reduction in the EU oil consumption of 12 mtoe/year in 2020 and 14 mtoe/year in 2025. With the steeper 2025 targets, the corresponding declines in the *ES78* and *ES68* scenarios are 18 and 20 mtoe/year in 2025.

Based on the projected oil price of around $75/barrel in 2020 and $80/barrel in 2025, we can estimate fuel expenditure savings in the *Current ES* scenario, which we find to be about €5.9 billion ($6.7 billion at the current exchange rates) in 2020 and about €7.1 billion ($8.2 billion) in 2025. Higher emission targets in 2025 would save more in reduced oil payments (€9.1 billion Euro in *ES78* and €10.4 billion Euro in *ES68*), but as we show later, they would also cost more.

**Table 3.** Oil use (mtoe) in the *No Policy* and reduction in oil use (mtoe) with alternative policy instruments.

| | No Policy, Oil Use, mtoe | Emission Trading, Oil Use Reduction, mtoe | Emission Standards, Oil Use Reduction, mtoe |
|---|---|---|---|
| 2015 | 562 | 17.2 | 20.8 |
| 2020 | 547 | 22.7 | 34.9 |
| 2025 | 552 | 55.1 | *see below* |
| *Current ES* | | | *69.1* |
| *ES78* | | | *73.0* |
| *ES68* | | | *75.4* |

Turning to $CO_2$ emissions in the policy scenarios, our simulation approach assures that a consistent EU-wide emissions target is achieved in both the *Emission Trading* and *Current ES* scenarios, however, private vehicle emission differ. In the *Emission Trading* scenario vehicle emissions are reduced by 18 million tonnes of $CO_2$ ($MtCO_2$) in 2020 and 28 $MtCO_2$ in 2025 (Table 4). The *Current ES* scenario in 2020 forces an additional 47 $MtCO_2$, for a total reduction from vehicles nearly 4 times that in the *Emission Trading* scenario. However, that is indicative of the fact that there are lower cost reductions elsewhere that are exploited in the *Emission Trading* scenario. We also observe that emission reductions from private cars are relatively modest compared to the total EU $CO_2$ emissions of about 3,100-3,400 $MtCO_2$ in 2020-2025. The total reduction from vehicles in the *Current ES* compared with the No Policy is only about 2% of economy-wide emissions. Emission reductions by sector are different in the *Current ES* and *Emission Trading* scenarios. As reported in Table 4, vehicle emissions abatement is lower in the *Emission Trading* scenario, which is compensated by an increased reduction in all other sectors of the economy with most additional abatement in electricity and energy-intensive sectors.

Potential emission reductions due to the displacement of petroleum-based fuels are partially offset by increases in vehicle travel due to the reduced cost per mile (a result of both higher vehicle efficiency and reduced fuel cost). In short, total $CO_2$ emissions suggest that when viewed in the EU-wide perspective, the net effect of current mandates on total EU $CO_2$ emissions is fairly modest. We consider the cost effectiveness of achieving these reductions relative to an efficient instrument targeting $CO_2$ in the next section.

**Table 4.** Economy-wide and vehicle $CO_2$ emissions reductions under alternative policies.

| | Economy-wide emissions, MtCO2 | | Reduction in Vehicle Emissions from No Policy, MtCO2 | |
|---|---|---|---|---|
| | No Policy | With Policy | Emission Trading | Emission Standards |
| 2015 | 3679 | 3525 | 15 | 30 |
| 2020 | 3605 | 3385 | 18 | 65 |
| 2025 | 3638 | 3123 | 28 | *see below* |
| *Current ES* | | | | *86* |
| *ES78* | | | | *102* |
| *ES68* | | | | *112* |

### *4.3. Economic impacts*

We report economic impacts in terms of changes in macroeconomic consumption where it is the same concept as in the well-recognized definition of GDP:

GDP = C (consumption) + I (investment) + G (government) +X (exports) –M (imports).

As evaluated within the model, an annual consumption change is equal to the annual welfare change, measured as equivalent variation. For a discussion of the relationship among these different cost concepts see Paltsev and Capros, (2013). Macroeconomic consumption changes are the net effect of the policy, accounting for the increase in vehicle manufacturing costs less any fuel savings, as well as effects of broader changes in allocative efficiency caused by the policy. The broader changes include such things as changes in other prices in the economy, investment, terms of trade effects, and reduction in fuel tax revenue. For example, more expensive vehicles require more saving going toward purchase of the vehicle thus squeezing out other investment, adding to the cost of the policy. Another example is that reduced demand for oil leads to a reduction in the world oil price, and since Europe is a net oil importer it benefits from the lower price. These international changes in price are more broadly referred to as changes in the terms of trade. Given the interdependencies of these effects it is impossible to completely separate them. Paltsev et al. (2007) offer a more detailed discussion of direct and indirect costs of climate policy.

We find on balance net consumption costs for both the *Emission Trading* and *Current ES* when compared with the *No Policy scenario* (Table 5). *Emission Trading* has a net cost of €2 billion in 2015, rising to €4.9 billion in 2020, and to about €8 billion in 2025. Adding the vehicle mandates in *Current ES* increases the costs by €0.7 billion in 2015 (to €2.7 billion), and €12.3 billion in 2020 (to €17.2 billion). By 2025 the additional consumption losses about double to €24.1 billion from the 2020 level of losses in *Current ES* even though the emissions target only falls from 98 g/km in 2020 to 95 g/km. Among factors leading to this strong jump in costs is continuing growth in the economy, and the crowding out of investment along the entire scenario that gradually slows economic growth, an effect that accumulates over time. With projected new car sales in the EU at about 13 million per year, the €12 billion added cost in 2020 in *Current ES* means the standards amount to an additional cost of about €925 per new car sold. This is a consumption loss divided by number of vehicles sold, and is hence net of fuel savings and includes other indirect economic costs (and benefits such as from terms of trade changes).

While economy-wide emissions are identical in both *Current ES* and *Emission Trading,* it is instructive to divide the total cost by the total emissions reduction to get an average cost per ton of emissions reduction. Combining information from Table 4 on the total economy-wide emission reduction of 220 $MtCO_2$ and reported in Table 5 costs of €4.9 billion and €17.2 billion, we can compare the average economy-wide costs of €22 per tonne of $CO_2$ in the *Emission Trading* scenario and €78 per tonne of $CO_2$ in the *Current ES* scenario, which makes the standards on average about 3.5 times more costly as an instrument to reduce emissions. Even more informative is an average cost of *additional* emission reductions in vehicles. For 2020 the additional vehicle emissions reductions are 47 $MtCO_2$ (18 $MtCO_2$ in the *Emission Trading* scenario vs 65 $MtCO_2$ in the *Current ES* scenario) at an added cost of €12.3 billion, making the average cost of this reduction about €260 per tonne of $CO_2$. Comparing these gives another sense of the economic inefficiency of the mandates.

As noted earlier, current mandates for vehicles are specified only to 2021. In the *Current ES* scenario we assumed this standard remained unchanged in 2025. Scenarios *ES78* and *ES68* allow us to estimate the costs of the tighter targets under discussion for 2025 (EPRS, 2014). As shown in Table 4 the costs are significant at €50.7 billion (€42.5 billion more than *Emission*

*Trading)* in *ES78* and €70.9 billion (€62.7 billion more) in *ES68*. These tighter standards come at ever-higher costs per ton of emissions reduction. The average cost of the 16 $MtCO_2$ of *additional* reduction in *ES78* (beyond *Current ES* in 2025) is €1,125 per tonne of $CO_2$; the average cost of the 10 billion tons of *additional* reduction in *ES68* (beyond *ES78*) is €2,020 per tonne of $CO_2$. Compared with the average cost per ton reduced with emissions trading, this calculation helps to indicate the degree of inefficiency created by the vehicle emissions mandates.

**Table 5.** Policy costs (in billion Euro/year) of reaching the same $CO_2$ targets with alternative policy instruments.

| | Emission Trading, billion Euro/year | Emission Standards, billion Euro/year |
|---|---|---|
| 2015 | 2.0 | 2.7 |
| 2020 | 4.9 | 17.2 |
| 2025 | 8.2 | *see below* |
| *Current ES* | | *32.2* |
| *ES78* | | *50.7* |
| *ES68* | | *70.9* |

Government tax revenues are reduced in the policy scenarios because the policies reduce overall economic activity and fuel use, which is a significant source of government revenue in Europe. An argument can be made that tax revenue-neutrality should be enforced to estimate the full policy cost. This could be accomplished by raising tax rates to compensate for revenue lost due to the declining tax base. Higher tax rates will generally lead to higher welfare costs, but the total additional cost will depend on which taxes are raised (Rausch et al., 2010). On the other hand, Gitiaux et al., (2012) showed that tax reform that reduced the very high fuel taxes in Europe and replaced the revenue with other taxes could actually improve welfare.

## 5. Including Road Transport into the EU Emission Trading Scheme

According to our analysis, reducing emissions in transport using standards is significantly more costly than using an emission trading scheme (ETS). A logical consequence is to call for a different policy approach in the EU, which uses the EU ETS to address transport emissions. Although the current EU legislation states that emissions standards will be in place at least until the 2020s (EU, 2014), the EU Council remains committed to the EU ETS as the main instrument for achieving the climate objective of the EU and has made clear that including transport in the EU ETS is still an option (EU, 2008). Moreover, the EU Council recently called upon the EU Commission "to further examine instruments and measures for a comprehensive and technology neutral approach for the promotion of emissions reduction and energy efficiency in transport, for electric transportation and for renewable energy sources in transport also after 2020" and recalls that "under existing legislation a Member State can opt to include the transport sector within the framework of the ETS" (EC, 2014b; Paragraph 2.13). Below we briefly discuss the practical aspects and implications of bringing private transportation into the EU ETS will be discussed in the following section (for an extended discussion, see also Achtnicht et al., 2015).

### *Regulated entity*

In its current form, the EU ETS obliges the actual emitters to hold emission allowances and thereby implements a rather direct polluter pays approach. However, in a situation with millions of car owners as mobile emitters, one of the first issue to address is the choice of the regulated entity, i.e., who in the transport sector should be required to hold allowances corresponding to the emissions caused by transport activities. In principle, any point along the fuel chain from upstream regulation of fuel providers (refineries, etc.) via the so-called midstream regulation of car manufacturers to downstream regulation of the actual car users could be chosen as a regulated entity. The point of regulation should be chosen such that the extended ETS incentivizes all abatement options along the fuel chain, ensures that all emissions are covered, and transaction costs are fully taken into account (Flachsland et al., 2011).

If car manufacturers were chosen as the regulated entity, it would require estimating lifetime emissions of vehicles (Desbarats, 2009). Just as with standards, influence from the regulation on the vehicle use after purchase would be limited. The high number of downstream users is likely to make the choice of consumers as the regulated entity extremely costly (Raux and Marlot, 2005) and barely practicable.

Regulating fuel providers seems the most encouraging option. Firstly, refineries are already covered by the EU ETS for production-related emissions and hence have experience with the EU ETS system. Secondly, the number of refineries is much lower than the number of potential downstream users, i.e. 243 million passenger cars and more than 512 million potential car users in the EU (NFF, 2014). Monitoring emissions at the level of fuel providers would be relatively easy as fuel sales are already monitored in all EU countries for fuel tax purposes. Furthermore, the cost of emission allowances is likely to be passed onto consumers through higher fuel prices incentivizing the implementation of a wide range of abatement options ranging from adjusting behavior to technological options.

### *Relation to existing EU ETS*

A cost effective way to include road transport would be to integrate the sector fully in the existing EU ETS. However, it is also conceivable to create a (linked) separate ETS for road transport alone, similarly to what has been done for aviation (EU, 2008). A separate ETS for road transport would make it possible to insulate the sectors in the existing EU ETS from effects on the allowance price from an inclusion of road transport. It would also allow differentiating the stringency of the respective reduction target in the separated systems. However, for exactly that reason, the system would be less cost effective.

Potentially cheaper reduction measures in the ETS sectors would not be utilized before more expensive measures in the transportation sector (and vice versa). The externality generated by CO2 emissions does not depend on the source of the emissions and the most cost effective regulation requires that abatement costs are equalized across sectors. In the analysis considered here, when transport is included in the emission trading system, production and exports of the electricity and energy-intensive sectors are not substantially affected, which is an argument for a full integration of transports into the EU ETS.

The results of our analysis discussed above confirm the findings from other studies that concluded that the marginal abatement cost curve for the road transport sector is steeper than for the remaining EU ETS.[3] Compared to a situation with standards, emission reductions are shifted to other ETS sectors (mostly to electricity and energy-intensive industries) once road transport is included in the ETS. As a consequence, the full inclusion of road transport into the EU ETS with a single common cap achieves efficiency gains, but also redistributes resources between sectors: compliance costs for the road sector are reduced while compliance costs for other sectors are increased. This results in distributional issues between sectors and highlights carbon leakage problems for energy-intensive trade-exposed sectors, which might see their international competitiveness negatively affected. However, the impact of the inclusion of road transport into the EU ETS on the allowance price depends on the exact setting of the cap as well as the

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[3] See for example Blom et al. (2007), Cambridge Econometrics (2014) and Heinrichs et al. (2014).

marginal abatement cost curve for the enlarged EU ETS. Our analysis suggests rather moderate allowance price increases. For example, in 2025 an economy-wide carbon price increases from about €17/t$CO_2$ in the *Current ES* scenario to about €21/t$CO_2$ in the *Emission Trading* scenario.

*Additional market failures*

Concerns about the dynamic efficiency of the ETS are sometimes raised. Will the necessary technological developments in the transport sector occur without standards given that our results show that emission reductions will at first take place predominantly in other ETS sectors and only later as allowance prices rise in the transport sector? The existing literature has generally supported the notion that market-based regulation such as emissions trading or taxing carbon provides the most effective long-term incentives for innovation as long as reduction targets are set appropriately (Jaffe and Stavins, 1995). Recent research also shows that the EU ETS has already contributed significantly to innovation in the field of low-carbon technologies and thus to long-term emission reductions (Martin et al., 2012; Calel and Dechezleprêtre, forthcoming).

Additional regulation is nevertheless reasonable as innovation and adoption of new technologies is associated with additional market failures beyond the $CO_2$ externality. These knowledge spillovers imply too little technology innovation and diffusion compared to the social optimum in the absence of additional regulation. There are also path dependencies, which act as barriers to the adoption and diffusion of new technologies (Arthur, 1989). Alternative fuel vehicles (e.g., electric, fuel cell, etc) require the existence of a network where these vehicles can refuel or recharge. The need for a network of suited refueling stations can then slow down or stop the uptake of a new propulsion technology. This is a coordination problem as a low uptake also implies that there is little incentive to expand the available network. The problem is further exacerbated with learning by doing externalities such that improvements in the efficiency of a technology also increase with use. Hence, there is no guarantee that the most efficient technology would emerge naturally as the long run market leader.

Acemoglu et al. (2012) find evidence of path dependencies in clean versus dirty innovation, which imply that sunk costs (investment into dirty technologies) will arise if a firm switches to cleaner technologies. Aghion et al. (2014) show path dependencies in "dirty" patents (internal combustion engine). They further show that firms innovate relatively more in clean technologies (e.g. electric and hybrid) when they face higher fuel prices. Given the additional externalities and path dependencies, Acemoglu et al (2012) along with many others have advocated for a policy mix where market based mechanisms like the EU ETS punish current emissions and innovation as well as diffusion are supported by subsidies and research support programs. Emission standards as they exist in the EU are a poor instrument for overcoming the prevailing market failures, as they do not internalize the positive externalities of innovation and supply networks.

## 6. Conclusions

Although $CO_2$ mandates are implemented at the sectoral level, this analysis illustrates the importance of an economy-wide analysis. Capturing both the rebound and the leakage effects, our model results suggest that at the EU level a $CO_2$ mandate serves energy policy goals (i.e., a reduction in oil use) far better than long-term global climate change mitigation objectives. Reductions in demand for petroleum as well as other fuels are further facilitated by the costs that a $CO_2$ mandate places on the economy, as capital costs rise to achieve vehicle efficiency improvements or accommodate the production of alternative fuel vehicles.

We find that in comparison to emission trading the vehicle mandates in 2020 reduce the $CO_2$ emissions from transportation by about 50 $MtCO_2$ and lower oil expenditures by about €6 billion, but the mandates cost additional €12 billion in 2020. Keeping the 2021 mandates unchanged for 2025 leads to the EU consumption loss of about €24 billion in 2025. Increasing the emission targets further to 78-68g/km leads to an annual consumption loss of €40-63 billion in 2025. $CO_2$ mandates are less cost effective than an emission trading scheme, with year-on-year consumption loss rising to 0.69% in 2025 under the proposed high emission standard, compared to 0.08% under an emission trading system that reaches the same target for emissions reduction.

Our analysis suggests that policies that appear “fair” by requiring equal emissions reductions from all sectors may incur a hefty toll. By contrast, market-based instruments that achieve an equivalent overall reduction shrink the economic pie by a substantially smaller margin. The emission trading system results in modest reductions in refined oil use in passenger vehicle transportation, while standards would require large reductions from the transportation sector. We stress the need and importance of the detailed studies on additional costs for meeting $CO_2$ standards in the EU. We base our results on the U.S. studies as we are not aware of the comparable EU exercises. Such study requires an involvement of the industry and transportation research centers. The existing TNO (2011) report needs to be expanded to include the latest car industry data.

Our results suggest that bringing transportation under the EU Emission Trading Scheme (ETS) is an alternative to the $CO_2$ standards that is worth considering. It may seem fair to require same percentage reduction from all sectors, but it turns out that at least for transportation sector this equal reduction design leads to severe distortions in terms of the total economic cost of a policy. The advantage of an emissions trading system is that it searches out the cheapest way to reduce emissions. If it is more expensive to reduce emissions from cars, it can reduce emissions elsewhere. An efficient regulation of $CO_2$ emissions will improve the feasibility of far reaching emission reduction goals in Europe.

While the current EU ETS is mostly related to electricity and energy-intensive industries, it would be feasible to extend it to transportation fuels. Such an expansion could involve completely integrating the transport sector, which would be the most cost effective regulation, or it could – at least temporarily - consist of a parallel trading scheme with a gateway as done for aviation. In order to incentivize abatement measures along the fuel chain and taking transaction costs into account, the most suitable choice of regulated entity for private transport would be the fuel providers. With emissions trading that covered transportation fuels, the currently targeted EU-wide emission reductions would be achieved at a lower cost.

The presence of additional market failures and path dependencies affecting the development and deployment of new technologies implies that an optimal policy for transportation is likely to require policy measures complementary to emissions trading. Such policy measure should directly address the positive knowledge externality from innovation as well as the coordination problems which impair the expansion of necessary infrastructure. Bringing transport under the ETS will not solve all market failures in the transportation sector. However, it would address one market failure in an economically sensible way and would free resources to address the other problems.

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