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Impacts of CO_2 Mandates for New Cars in the European Union

Sergey Paltsev[*†], Y.-H. Henry Chen[*], Valerie Karplus[*], Paul Kishimoto[*] and John Reilly[*]

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 the mandates lower oil expenditures by about €6 billion, but at a net added cost of €12 billion in 2020. Emissions from transport are about 50MtCO_2 lower with the vehicle emission standards, but with the economy-wide emission trading, lower emissions in transport allow an equal increase in emissions elsewhere in the economy. We estimate that tightening CO_2 standards further after 2020 would cost the EU economy an additional €24–63 billion in 2025 compared with achieving the same reductions with an economy-wide 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, 2014). 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 summarizes the results and conclusions.

2. FUELS 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 US (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 US and EU, credits are available for reductions of hydrofluorocarbons (HFCs) used as refrigerants in air conditioning. Anderson and Sallee (2011) 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 vehicle emission standard and can substantially reduce the estimated compliance costs (Anderson and Sallee, 2011).

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 vehicles may be reduced and old vehicles may be retained in the fleet longer. New cars that are purchased that meet efficiency standards have lower fuel costs per distance traveled, and that may lead to an increase in travel—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 older inefficient 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, non-transport sectors, or 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, 2012), 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 emission trading and fuel economy standards include that of Rausch and Karplus (2014), who find that in the US, an emission trading system is more efficient than vehicle emission standards. Paltsev *et al.* (2014) considered a sequential policy design, where global emissions were first regulated in electricity and private transportation, but then later were combined with economy-wide emissions trading. Economy-wide emissions trading reduced the cost of mitigation.

Ellerman *et al.* (2006) examined possible links between CAFE standards in the US with a proposed emission trading 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 emission trading 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 (fuel provider) and downstream (car owner) actors.

2.2 European 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 of 130 g/km for all new passenger cars registered in the EU in 2015 (EC, 2009). The legislation included a so-called "limit value curve", allowing 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 2014 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). In 2014 the EU issued a regulation (EU, 2014) that the vehicle CO_2 target should be achieved "in a cost-effective manner."

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 US 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: 130 g/km in 2015 and 95 g/km in 2021. 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.

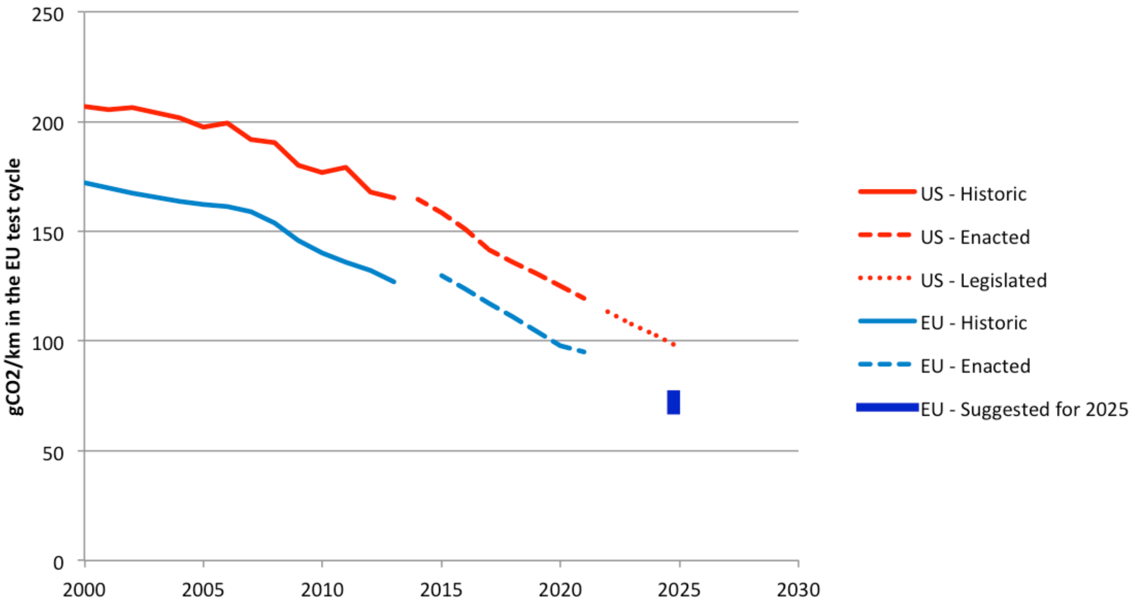

Figure 1. CO_2 regulations for cars in USA and EU normalized to the EU NEDC test cycle. Data source: ICCT (2014a), EPRS (2014).

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 US, and changes have been proposed for the testing and labeling 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, which is 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, SO_x; nitrogen oxides, NO_x; black carbon, BC; organic carbon, OC; carbon monoxide, CO; ammonia, NH_3; 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.* (2013b).

Table 1. Sectors and regions in the EPPA model.

	Sectors	**Regions**
Non-Energy	Agriculture	Europe (EUR)
	Forestry	United States (USA)
	Energy-Intensive Products	Canada (CAN)
	Other Industries Products	Japan (JPN)
	Industrial Transportation	Mexico (MEX)
	Household Transportation	Australia & Oceania (ANZ)
	Food	Russia (RUS)
	Services	China (CHN)
Energy	Coal	India (IND)
	Crude Oil	Brazil (BRA)
	Refined Oil	Rest of Latin America (LAM)
	Natural Gas	Higher-Income Asia (ASI)
	Electricity Generation Technologies	Rest of East Asia (REA)
	Fossil	Middle East (MES)
	Hydro	Africa (AFR)
	Nuclear	Rest of Europe and Central Asia (ROE)
	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.

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 vehicle-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 according to 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 fuels 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).

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 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.

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.

4.2. Energy and Environmental Impacts of the Current Policies

We now consider the net effect of the current EU CO_2 vehicle emission standards 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.

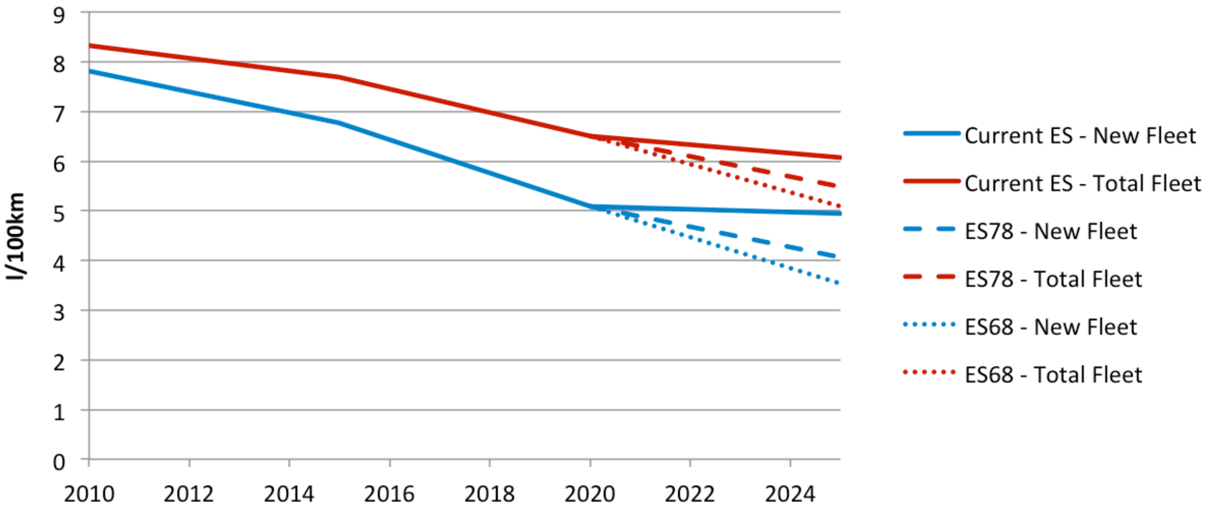

Figure 2. On-road fuel consumption for an average new car and total fleet.

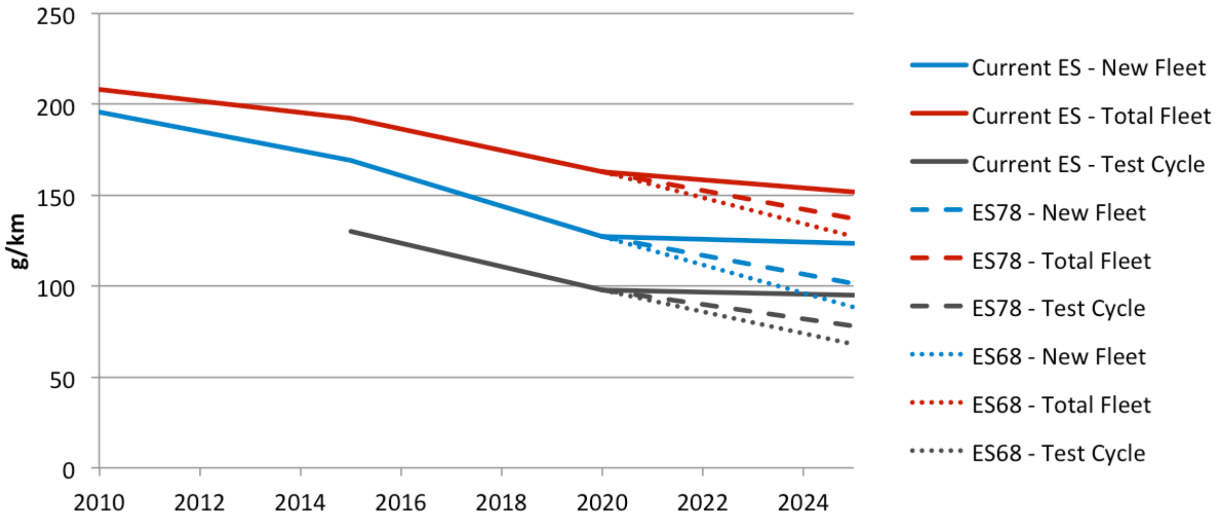

Figure 3. CO_2 mandates for new cars based on the test cycle (“test cycle”), on-road CO_2 emissions for an average new car (“new fleet”), and total fleet (“total fleet”).

Table 3. Oil use (mtoe) in the *No Policy* scenario 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*

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

	Economy-wide emissions *$MtCO_2$*		Reduction in Vehicle Emissions from *No Policy* *$MtCO_2$*	
	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*

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 vehicles 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, given the structure of the scenarios, that means the greater vehicle emissions reduction under the *Current ES* allows higher emissions in other sectors. 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 *Current ES* compared with *No Policy* is only about 2% of economy-wide emissions.

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). We consider the cost effectiveness of achieving these reductions relative to an efficient instrument targeting CO_2 in the next section.

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 and adding to the cost of the policy. As another example, reduced demand for oil leads to a reduction in the world oil price, and since Europe is a net oil importer it benefits from this 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 about €5 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 by €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 Euro 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).

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

	Emission Trading *bn €/year*	**Emission Standards** *bn €/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*

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 the costs of €4.9 billion and €17.2 billion reported in Table 5, we can compare the average economy-wide costs of CO_2. With €22 per tonne in the *Emission Trading* scenario and €78 per tonne in the *Current ES* scenario, this makes the current standards about 3.5 times more costly. 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—€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 tonnes 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.

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). Gitiaux *et al.* (2012) showed that tax reform reducing the very high fuel taxes in Europe and replacing the revenue with other taxes could actually improve welfare.

5. CONCLUSIONS

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 vehicle emission standards cost an additional €12 billion in 2020 (net of fuel savings and terms of trade benefits). 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. In percentage terms, emissions trading results in a 0.08% loss in macroeconomic consumption in 2025. Adding vehicle emission standards increases the loss to 0.69% and leads to no greater reduction in economy-wide CO_2 emissions. The vehicle emission standards do result in a greater reduction in petroleum use, one of the goals of broader energy policy in Europe. We estimated the additional petroleum reduction to be about 12 mtoe in 2020, or about 2% of total petroleum use in Europe. This rises to about 14 mtoe in 2025, or about 2.5% of petroleum use, by which time the standards are fully phased in (although the old car fleet has not been fully replaced). Our analysis was based on technical studies of vehicle efficiency improvements conducted in the US. Ideally, we would base our vehicle cost and efficiency estimates on an assessment of the specific types vehicles sold in Europe, but no comparably detailed assessment has been conducted.

The motivation for separate sectoral policies, especially on vehicles, is often that an economy-wide carbon price will not induce a significant reduction in fuel use, and the sector ought to contribute a “fair share” of the economy-wide reduction. Our analysis suggests that policies that require greater emissions reductions from sectors that otherwise might not reduce as much incur a hefty toll on the economy. By contrast, market-based instruments that allow greater emissions reductions in sectors where they cost less shrink the economic pie by a substantially smaller margin.

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