

BRIEFING

OCTOBER 2017

2020-2030 CO₂ standards for new cars and light-commercial vehicles in the European Union

New passenger cars and light-commercial vehicles (vans) in the European Union (EU) are subject to mandatory carbon dioxide (CO₂) standards up to the year 2020-2021. The European Commission, European Parliament and EU member states are preparing to extend the light-duty vehicles' CO₂ regulation to the 2025-2030 timeframe. As part of this briefing paper we summarize the key findings of previous ICCT studies, including aspects such as technology potential and associated compliance cost, the role of electrified vehicles, and the switch to a new emissions testing procedure.

EU LIGHT-DUTY VEHICLE CO₂ REGULATION BETWEEN 1995 AND 2020

As part of a voluntary self commitment, in 1998 the European car manufacturers agreed to reduce the average CO₂ emissions of their new cars from 186 g/km in 1995 to a level of 140 g/km by 2008, a reduction rate of 2.1% a year¹ (Figure 1). However, CO₂ emissions decreased more slowly than expected. In 2007 the European Commission said it would replace the manufacturers' voluntary agreement with a mandatory regulation. In 2009, the EU's first CO₂ regulation for cars was adopted, setting a mandatory average target of 130 g/km by 2015.² The annual CO₂ reduction rate was lower than under the previous voluntary agreement: 1.7% a year, based on the original 1995 baseline. In 2013, EU policy makers added a second regulation. The new CO₂ target was defined as 95 g/km by 2020

1 Communication COM (1998) 495 final from the Commission to the Council and the European Parliament of 29 July 1998 implementing the community strategy to reduce CO₂ emissions from cars: An environmental agreement with the European automobile industry. Retrieved from <http://aei.pitt.edu/3388/1/3388.pdf>

2 Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO₂ emissions from light-duty vehicles. Retrieved from <http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32009R0443>

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with a phase-in until 2021.³ That put the annual CO₂ reduction rate over 2015-2021 at 5.1%. For light-commercial vehicles, which account for about 10% of the EU's light-duty vehicle market, the first CO₂ regulation was adopted in 2011, setting an average target of 178 g/km for 2017.⁴ The second regulation, adopted in 2013, set a target of 147 g/km for 2020, requiring an annual CO₂ reduction of 3.1% between 2017 and 2020⁵ (Figure 2).

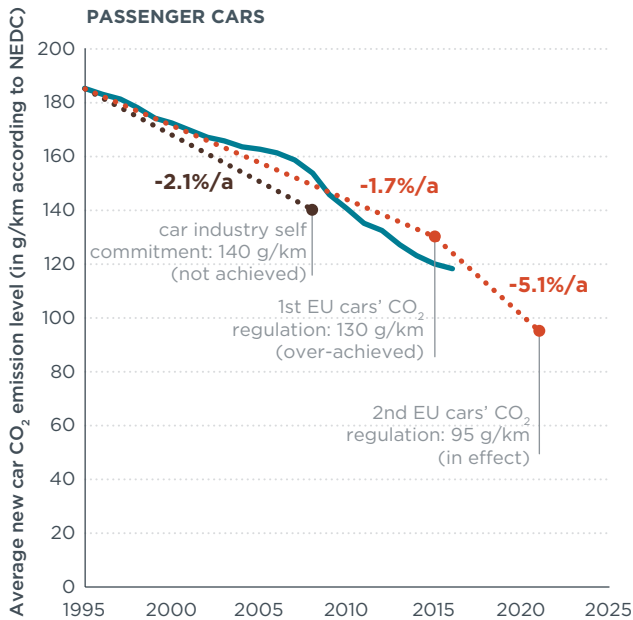


Figure 1. Average CO₂ emission level of new cars in the EU (in blue), target values set by car manufacturers (in brown) and the EU regulatory bodies (in red).

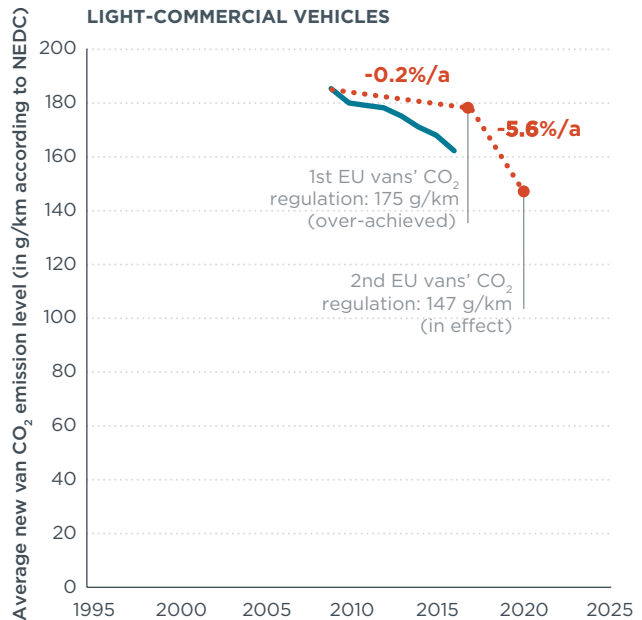


Figure 2. Average CO₂ emission level of new light commercial vehicles (vans) (in blue) and target values set by the EU regulatory bodies (in red). [Ed: corrected 11.29.17]

All major passenger car manufacturers met their CO₂ target levels for 2015 (Figure 3). On average, the new-car CO₂ level in 2015 was 120 g/km.⁶ For 2016, the preliminary average level was determined to be 118 g/km.⁷ There are significant differences between EU member states: New cars sold in the Netherlands on average emit about 102 g/km of CO₂, whereas in Germany, Sweden, and Luxembourg the average emission level is about 127 g/km. In the case of light-commercial vehicles, the preliminary average new-vehicle CO₂ level in 2016 was 164 g/km, with some manufacturers already being close to meeting their 2020 target value (Figure 4).⁸

3 Regulation (EC) No 333/2014; for a summary see Mock, P. (2014). *EU CO₂ standards for passenger cars and light-commercial vehicles*. International Council on Clean Transportation (ICCT), retrieved from <http://theicct.org/eu-co2-standards-passenger-cars-and-lcvs>

4 Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011 setting emission performance standards for new light-commercial vehicles as part of the Union's integrated approach to reduce CO₂ emissions from light-duty vehicles. Retrieved from <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011R0510>

5 Regulation (EU) No 253/2014 of the European Parliament and of the Council of 26 February 2014 amending Regulation (EU) No 510/2011 to define the modalities for reaching the 2020 target to reduce CO₂ emissions from new light commercial vehicles. Retrieved from <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014R0253>

6 Mock, P. (ed.) (2016). *European Vehicle Market Statistics – Pocketbook 2016/17*. ICCT, retrieved from <http://eupocketbook.org>

7 EEA (2017). *Fuel efficiency improvements of new cars in Europe slowed in 2016*. European Environmental Agency (EEA), retrieved from <https://www.eea.europa.eu/highlights/fuel-efficiency-improvements-of-new>

8 EEA (2017). *Carbon dioxide emissions from new vans in Europe continued to fall in 2016*. European Environmental Agency (EEA), retrieved from <https://www.eea.europa.eu/highlights/carbon-dioxide-emissions-from-new>

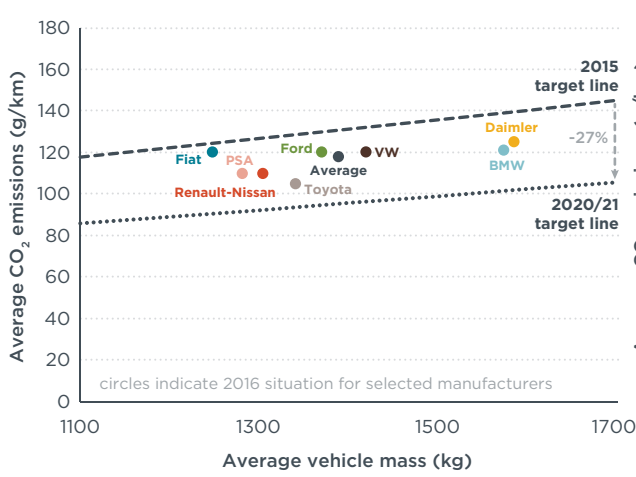


Figure 3. Performance of the top-selling EU passenger car manufacturer groups for 2016, along with the 2015 and 2020 (effectively 2021) fleet average target lines.

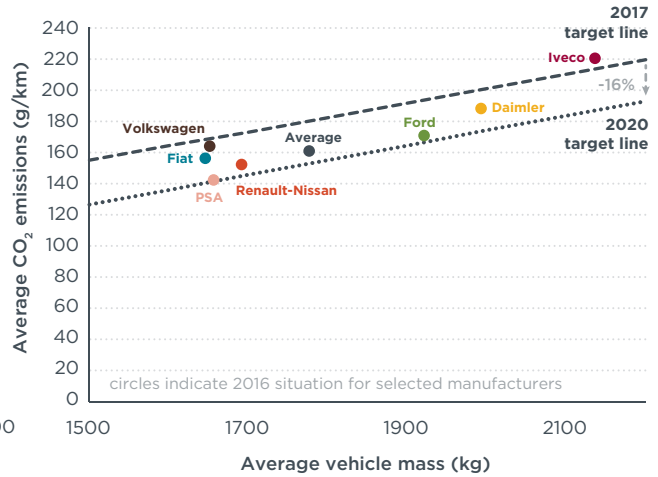


Figure 4. Performance of the top-selling EU light-commercial vehicle manufacturer groups for 2016, along with the 2017 and 2020 fleet average target lines.

CO₂ REDUCTION REQUIREMENTS POST-2020

The EU has set a goal for 2050 of reducing greenhouse gas (GHG) emissions from all sources by 80-95% from 1990 levels.⁹ While other sectors have reduced emissions in recent years, transportation is the only one that has recorded an increase at the European level since 1990 (Figure 5). This is despite a decrease in test-cycle CO₂ emissions for new vehicles and largely reflects growth in the number of vehicles, the number of kilometers driven, a shift toward larger vehicles, and a widening gap between test-cycle findings and real-world emissions (see following section).

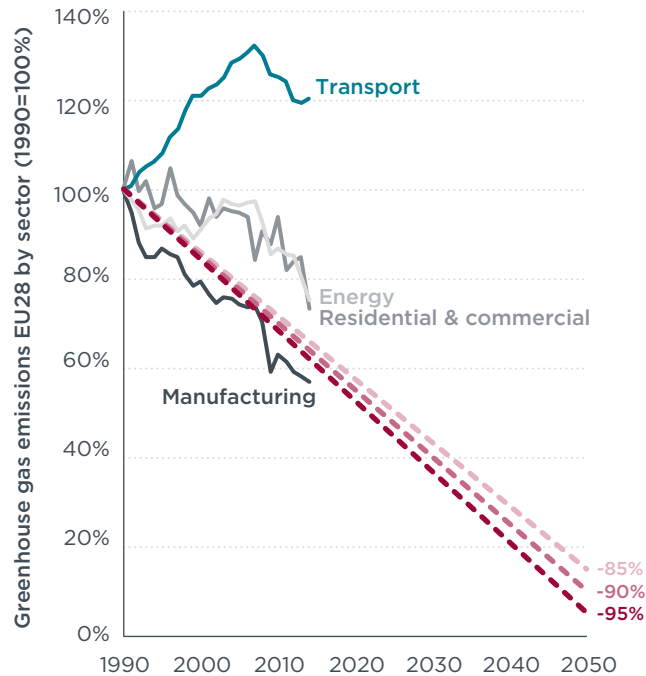


Figure 5. Greenhouse gas emissions in the EU by sector, including a target range for reducing emission levels by 85-95% by 2050.¹⁰

9 Communication COM (2011) 885 final of the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 15 December 2011: Energy Roadmap 2050. Retrieved from <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0885:FIN:EN:PDF>.

10 Data source: EC (2016). *Statistical Pocketbook 2016*. European Commission (EC), retrieved from https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2016_iv. The ton kilometer driven by road freight vehicles decreased by 10% from 2007-2014, while the share of biofuels, which are counted as having zero emissions, increased. These two factors explain the majority of the emissions decline for the transport sector from 2007-2014.

For 2030, the EU has established a binding target for reducing GHG emissions: 40% below 1990 levels.¹¹ For sectors not covered by the EU's emissions trading system, such as transport, an average reduction in annual GHG emissions of 30% below a 2005 baseline is required by 2030. It is expected that the transport sector will have to overachieve its target, as the contribution from the agriculture and building sectors most likely will be less than 30%. Furthermore, some member states have opted for more stringent targets at the national level. For example, Germany has committed to reducing GHG emissions from the transport sector by 40-42% by 2030 from the 1990 level.¹²

The transport sector accounts for about 23% of GHG emissions in the EU. CO₂ emissions from passenger cars, light-commercial vehicles, and heavy-duty vehicles constitute by far the largest portion of transport GHG emissions. In Europe, mandatory CO₂ emission standards for new vehicles currently are in place only for cars and light-commercial vehicles. The EU is the only major vehicle market in the world without mandatory CO₂ emission standards for heavy-duty vehicles.¹³

The European Commission is expected to propose mandatory heavy-duty CO₂ standards in the spring of 2018. For our analysis, we assume that these standards would require annual CO₂ reductions of 3.5% for buses and medium-size trucks and 4.0% for large trucks starting in 2020.¹⁴ These annual reduction rates are in line with our assessment of the technical potential and the associated investment cost for heavy-duty vehicles.¹⁵

For new passenger cars and light-commercial vehicles, the required annual CO₂ reduction rate between 2021-2030 would then need to be about 9% to achieve the EU's overall 30% reduction target by 2030 (Figure 6). This equals a total reduction in the average new car/new van CO₂ level of about 58% between 2021 and 2030.

On top of vehicle CO₂ standards, other measures such as an increased share of biofuels or a modal shift from road to rail transportation are expected to contribute an additional CO₂ reduction by 2030. This additional reduction is likely to be negligible, though, while a 30% reduction requirement for the transport sector by 2030 most likely reflects a conservative assumption. In addition, for our calculations we neglect rebound effects that would cause CO₂ emissions to increase as consumers drive more with their more efficient vehicles. This would require new-vehicle CO₂ emissions to drop even more to achieve the required overall emission reduction.

11 EC (2016). *2030 climate & energy framework*. European Commission (EC), retrieved from https://ec.europa.eu/clima/policies/strategies/2030_en

12 BMUB (2016). *Klimaschutzplan 2050* [Climate Action Plan 2050]. German Ministry for Environment (BMUB), retrieved from <http://www.bmub.bund.de/themen/klima-energie/klimaschutz/klima-klimaschutz-download/artikel/klimaschutzplan-2050-1/>

13 EC (2016). *A European strategy for low-emission mobility*. European Commission (EC), retrieved from https://ec.europa.eu/transport/sites/transport/files/themes/strategies/news/doc/2016-07-20-decarbonisation/com%282016%29501_en.pdf

14 For details, see Muncrief, R. (2016). *Europe should set binding CO₂ reduction targets for trucks*. ICCT, retrieved from <http://www.theicct.org/blogs/staff/europe-should-set-binding-co2-reduction-targets-trucks>

15 Delgado, O., Rodríguez, F., & Muncrief, R. (2017). *Fuel efficiency technology in European heavy-duty vehicles: Baseline and potential for the 2020-2030 timeframe*. ICCT, retrieved from <http://www.theicct.org/EU-HDV-fuel-efficiency-tech-2020-2030>

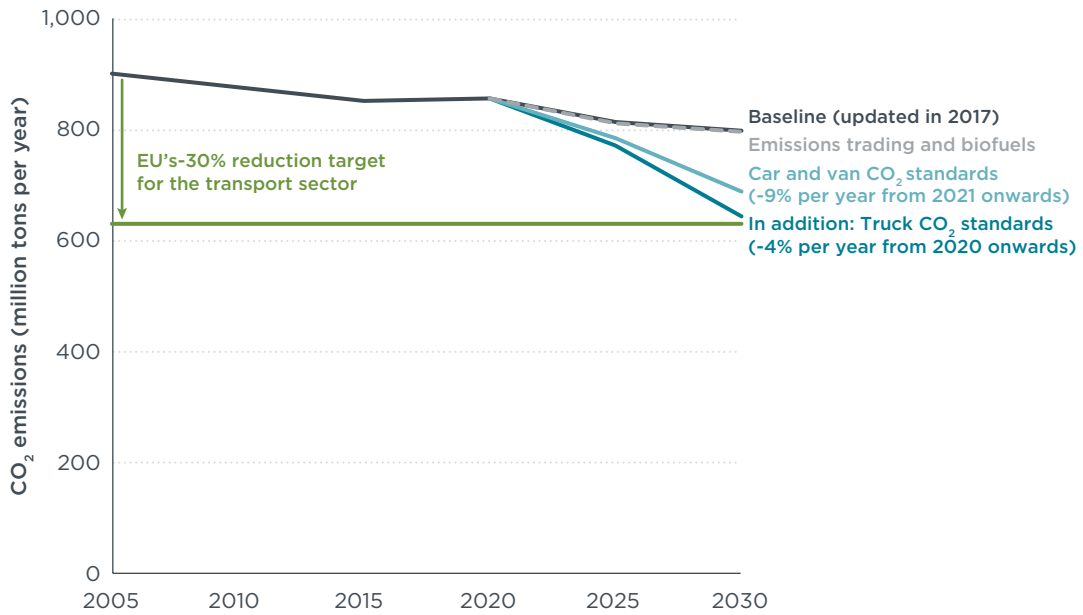


Figure 6. Annual (direct) CO₂ emissions from road vehicles in the EU.¹⁶

If expressed in New European Driving Cycle (NEDC) terms, the required reduction rates would translate into a 2030 target of about 40 g/km for passenger cars (Figure 7) and 54 g/km for light-commercial vehicles (Figure 8). Assuming a constant annual rate of reduction, intermediate target values for 2025 would be about 65 g/km for passenger cars and 89 g/km for light-commercial vehicles.

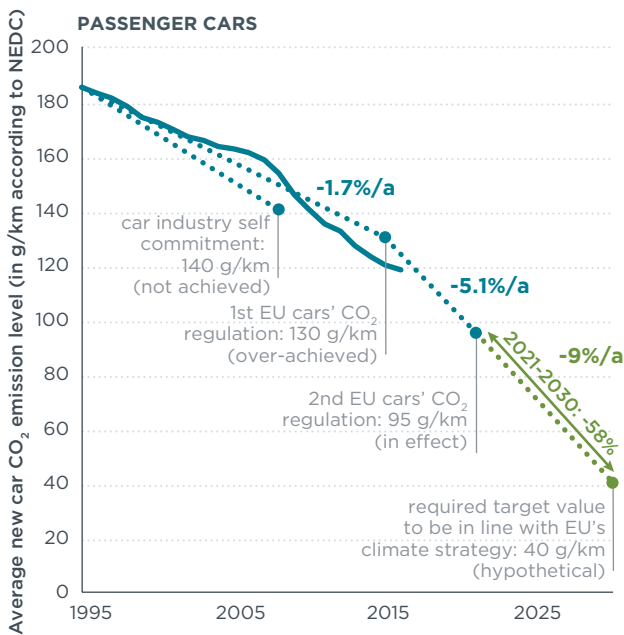


Figure 7. Historic development of average passenger car target CO₂ emission levels and required further development in the 2021-2030 time period to be in line with the EU's climate strategy.¹⁷

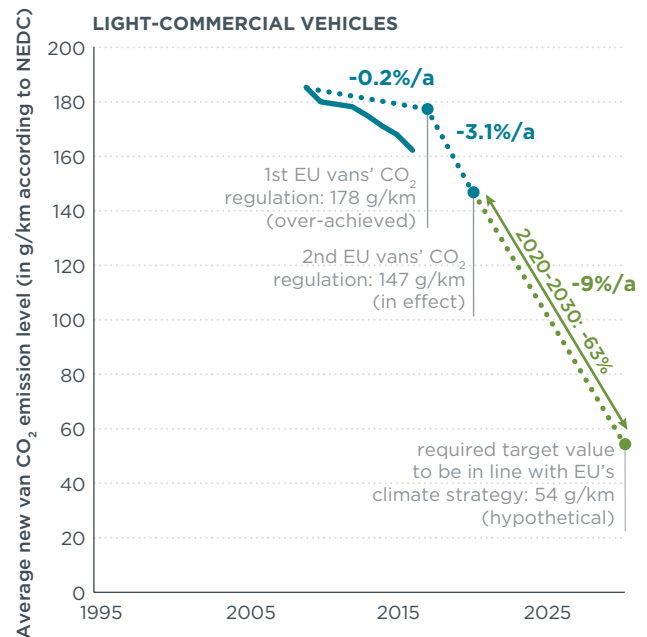


Figure 8. Historic development of average light-commercial vehicle target CO₂ emission levels and required further development in the 2020-2030 time period to be in line with the EU's climate strategy.

16 For details, see Miller, J. (2016). *Reducing CO₂ emissions from road transport in the European Union: An evaluation of policy options*. ICCT, retrieved from <http://theicct.org/evaluating-policy-options-reducing-co2-from-transport-eu>. Please note that the baseline scenario was updated for this briefing paper to reflect the European Commission's EU Reference Scenario released in July 2016.

17 Please note that the reduction rates between 2015-2021 and 2021-2030 appear as a straight line when expressed in absolute g/km terms, even though the annual percentage reduction post-2021 is higher than pre-2021. This is because the starting point in g/km for post-2021 is lower, and absolute CO₂ reductions in g/km for the same percentage reduction are now lower.

TECHNOLOGY CO₂ REDUCTION POTENTIAL AND ASSOCIATED COST

Mandatory CO₂ standards have stimulated the diffusion of innovative vehicle efficiency technologies and designs in the EU as in other markets. However, the extent to which the most advanced vehicle technologies, especially the most costly technologies, are needed for manufacturers to reach CO₂ emission targets has been systematically overestimated, as have the final per-vehicle costs of meeting standards. For example, industry studies in 2003 and 2009 estimated that reducing average new-car CO₂ emissions to 120 g/km in the EU would cost €1,000 to €3,900 per vehicle and require hybrid-electric vehicles to exceed 20% of new vehicle sales. In reality, when new-car CO₂ emissions fell to 123 g/km in 2014, the hybrid market share was less than 3%, and the average additional cost per vehicle was €200 (Figure 9).

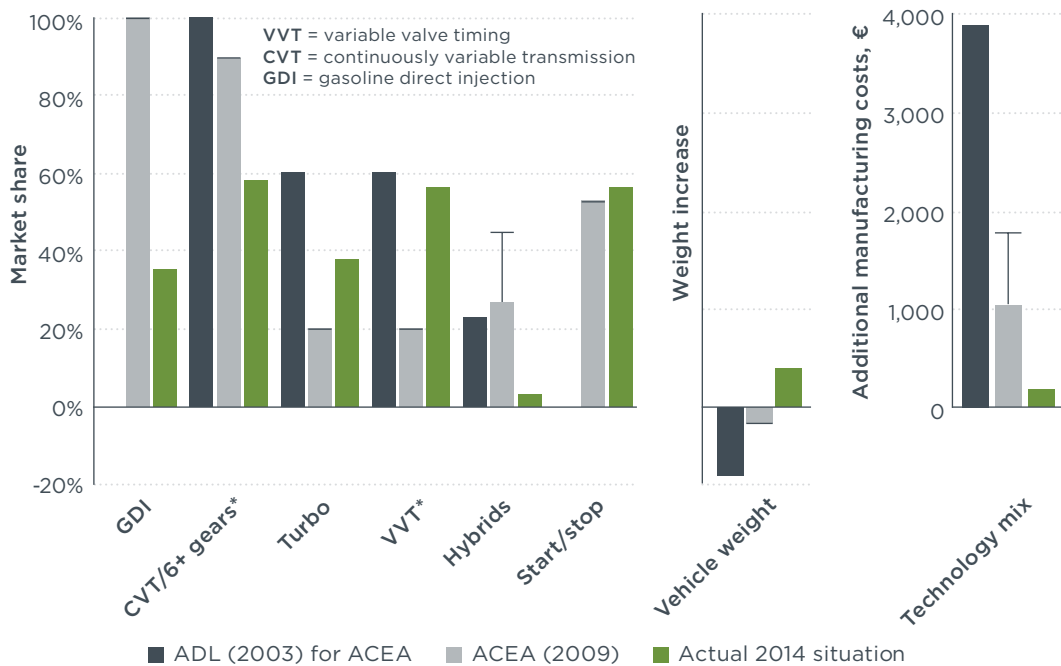


Figure 9. Comparison of advance industry studies by ADL and ACEA and actual assessments for meeting average car CO₂ level of 120 g/km. *Actual share for 2013.¹⁸

One reason for the discrepancy between advance technology assessments and actual results in the EU in the past has been the extensive reliance on industry stakeholder surveys to estimate technology potential and future costs. In setting its 2017–2025 light-duty vehicle CO₂ targets, the U.S. Environmental Protection Agency (EPA) instead used detailed computer simulation of CO₂ reduction technologies and bottom-up “tear-down” cost assessments of individual parts. This assessment method is more transparent and robust, though also more expensive and time-consuming.¹⁹

The ICCT commissioned the German engineering services provider FEV to carry out similar detailed computer simulations and bottom-up cost estimates for individual technologies and technology packages that can help to reduce CO₂ emissions of European passenger cars and vans in the 2025 timeframe.²⁰ The ICCT supplemented the

18 Wolfram, P., German, J., Mock, P., & Tietge, U. (2016). *Deployment of passenger car technology in Europe and the United States*. ICCT, retrieved from <http://www.theicct.org/EU-and-US-PV-technology-deployment>

19 EPA (2009). *Light-Duty Technology Cost Analysis Pilot Study – Peer Review Report*. U.S. Environmental Protection Agency (EPA), <https://www3.epa.gov/otaq/climate/fev-peerreview-rpt.pdf>

20 FEV (2015). *2025 Passenger Car and Light Commercial Vehicle Powertrain Technology Analysis*. Retrieved from <http://www.theicct.org/2025-passenger-car-and-light-commercial-vehicle-powertrain-technology-analysis>

raw powertrain data results provided by FEV with estimates of the cost-benefit effects of improvements in road-load reduction (reducing vehicle weight, rolling resistance, and aerodynamic resistance), indirect costs and learning out to 2030, type-approval test procedure flexibilities and performance-based adjustments, off-cycle technologies, and electric vehicles.²¹

The analysis assumed that vehicle segments and vehicle performance characteristics within each segment would remain constant between the baseline year 2014 and 2030, to exclude the impact of any potential shift in consumer preferences over time. For purposes of estimating costs, it assumed for all non-electric vehicle technologies that 77% were manufactured in the Western EU countries and 23% in Eastern EU countries, reflecting the current production network. Drawing on a previous review of technology cost estimates for electric vehicles, the analysis assumed that direct battery manufacturing costs for battery-electric vehicles at the battery-pack level would fall to €100 per kilowatt-hour (kWh) by 2030 in a lower-bound scenario, and 160 €/kWh in an upper-bound scenario.²²

Based on that analysis, we estimate that a 2025 passenger-vehicle CO₂ standard of around 70 g/km as measured on the NEDC would require few or possibly no electric vehicle sales. The range of combustion engine technologies, including 48-volt belt starter-generator and full parallel P2 hybrid electric vehicles, would be sufficient to reduce fleet average CO₂ emissions to that level. The current version of the Toyota Prius might serve as a practical example, already in 2017 achieving an NEDC CO₂ emission level of 70 g/km for a midsize vehicle that is slightly heavier and more powerful than the average new car in the EU.

The average per-vehicle cost increment to reach that target, including indirect costs but excluding taxes, would be between €1,000 and €2,150 in 2025, compared with the 2014 baseline (Figure 10). A passenger car standard of 40 g/km on the NEDC could be achieved by 2030 at an average per-vehicle cost increment of between €1,600 and €3,000. Reaching that target would require that electric vehicles make up a significant share of new sales.

21 Meszler, D., German, J., Mock, P., Bandivadekar, A. (2016). *CO₂ reduction technologies for the European car and van fleet, a 2025-2030 assessment*. ICCT, retrieved from <http://www.theicct.org/co2-reduction-technologies-european-car-and-van-fleet-2025-2030-assessment>

22 Wolfram, P. & Lutsey, N. (2015). *Electric Vehicles: Literature review of technology costs and carbon emissions*. ICCT, retrieved from <http://www.theicct.org/lit-review-ev-tech-costs-co2-emissions-2016>

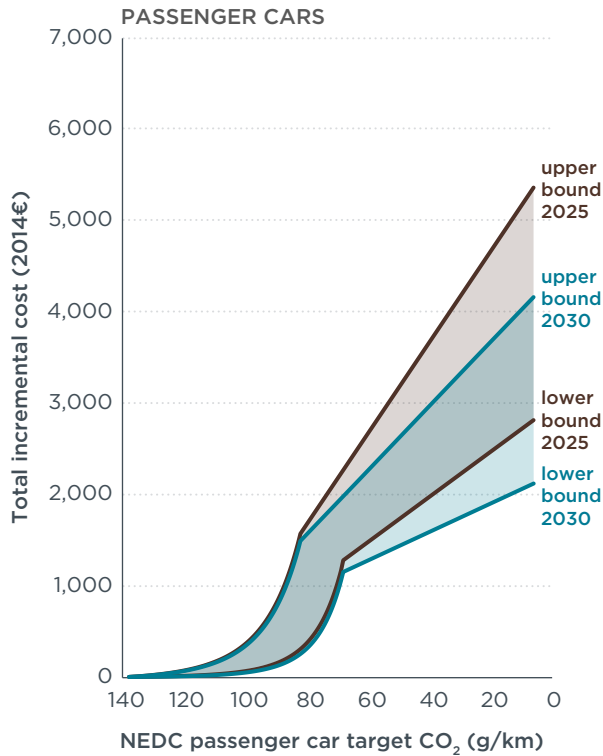


Figure 10. Total incremental cost (including indirect costs but excluding taxes) of reducing the CO₂ emissions of the average passenger car in the EU by 2025/2030 in an upper- and a lower-bound scenario, assuming full deployment of combustion-engine technologies before transitioning to electric vehicles.²³

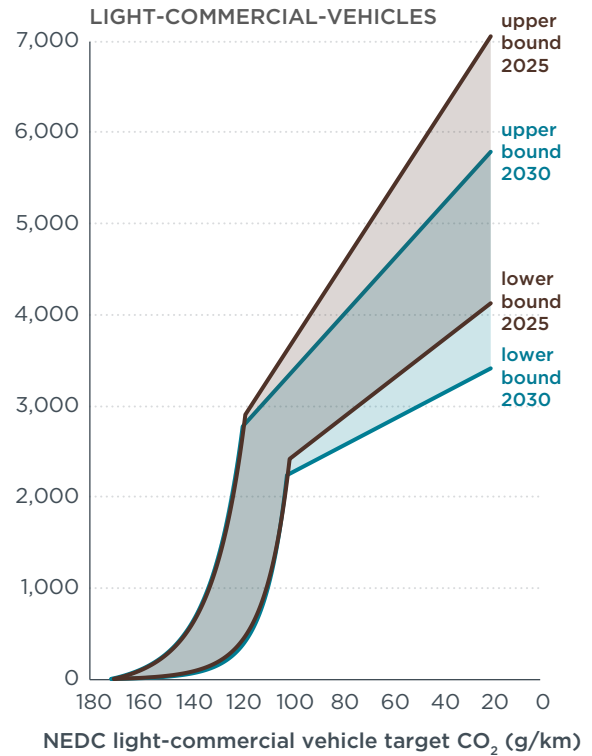


Figure 11. Total incremental cost (including indirect costs but excluding taxes) of reducing the CO₂ emissions of the average light-commercial vehicle in the EU by 2025/2030 in an upper- and a lower-bound scenario, assuming full deployment of combustion-engine technologies before transitioning to electric vehicles.

For a 70 g/km 2025 target, our analysis found the average consumer-payback period, or the amount of time before the initial cost increment of efficiency technology is offset by cumulative savings on fuel costs, to be about four years in the upper-bound scenario and about two years in the lower-bound scenario. The analysis assumes an average fuel price of €1.50 per liter and annual vehicle distance traveled of 15,000 kilometers.

With respect to light-commercial vehicles, CO₂ standards as low as 90-100 g/km on the NEDC can be achieved with few or no electric vehicles in the new-vehicle market. A 2025 CO₂ target of 90 g/km would lead to an average cost increment of €2,600 to €4,100 per vehicle, while a 60 g/km standard in 2030 would cost between €2,800 and €4,500 per vehicle relative to today (Figure 11). The average payback period for a 90 g/km standard for light-commercial vehicles would be on the order of three to five years, assuming the same annual distance traveled as for passenger cars.

Compliance costs for individual manufacturers will differ from these average fleet values as will the technology mix each manufacturer ultimately adopts. Also, our analysis did not consider either genuinely new technology developments or future optimization of existing technologies through product redesigns that take advantage of evolving knowledge. Consequently, these cost curves represent conservative estimates. Actual costs are likely to be lower.

A rough comparison of the 2016 FEV/ICCT cost curves for the 2025 time range with other available estimates (Figure 12) shows them to be slightly lower than the interim

²³ Differences between the upper- and lower-bound scenarios include assumptions on the production cost of batteries, the use of off-cycle credits (eco-innovations), mass-reduction cost savings, vehicle performance-based adjustments of CO₂ and costs, as well as the exploitation of test procedure flexibilities.

results of a 2015 AEA study for the European Commission²⁴ and less than a third of the outcome of a 2015 IKA study for the German Ministry for Economics.²⁵ This is similar to earlier estimates for the 2020 time range, in which the 2013 ICCT results²⁶ were slightly below those of European Commission consultants TNO in 2011 and significantly below those in a 2012 IKA study for the German Ministry for Economics. For 2015, the actual AEA compliance costs were about one-third of the original 2006 estimates by TNO for the European Commission and about one-fifth of the 2009 ACEA estimates by the European vehicle manufacturers' association.

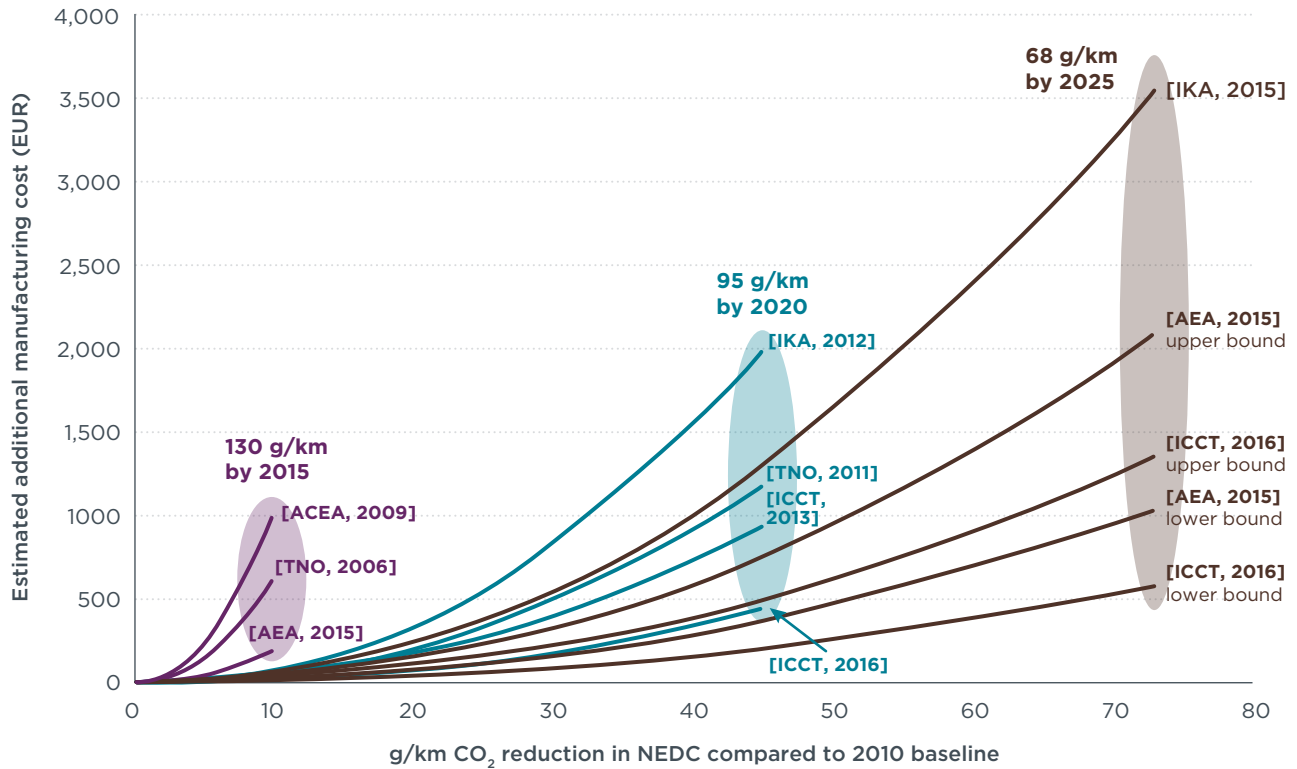


Figure 12. Schematic illustration of various technology cost curve studies for the EU's passenger vehicle fleet for the 2015, 2020, and 2025 time ranges.

THE ROLE OF ELECTRIC VEHICLES

As explained in the previous section, 2025 passenger-vehicle CO₂ standards as low as 70 g/km and light-commercial vehicle standards as low as 90-100 g/km can be achieved with few or no electric vehicles in the new-vehicle market. This approach would correspond to a compliance strategy under which combustion engine technologies would be deployed until no further reduction in CO₂ emissions could be gained, forcing an abrupt shift to electric vehicles. However, in that case, the incremental per-vehicle technology deployment cost toward the end of the combustion-engine part of the cost curve would be relatively high, as illustrated by the sharp increases in Figure 10 and Figure 11.

²⁴ Ricardo-AEA (2015). *Improving understanding of technology and costs for CO₂ reductions from cars and LCVs in the period to 2030 and development of cost curves*. 28 July 2015 draft version, distributed at a stakeholder workshop of the European Commission DG CLIMA. A final version has not been published to date.

²⁵ IKA (2020). *CO₂-Emissionsreduktion bei Pkw und leichten Nutzfahrzeugen nach 2020* (CO₂ emission reduction for cars and light-commercial vehicles post-2020). Institut für Kraftfahrzeuge (IKA), retrieved from German Ministry for Economics (BMWI), <http://www.bmw.de/DE/Mediathek/publikationen.did=686692.html>

²⁶ ICCT (2013). *CO₂ Reduction Technologies for the European Car and Van Fleet: A 2020–2025 Assessment*. ICCT, retrieved from <http://www.theicct.org/series/co2-reduction-technologies-european-car-and-van-fleet-2020-2025-assessment>

Under a second compliance strategy, vehicle manufacturers would transition from combustion-engine to electric vehicles sooner. Manufacturers could thus avoid having to invest in relatively expensive efficiency technologies for combustion-engine vehicles, instead meeting their overall fleet CO₂ targets by deploying a certain share of electric vehicles, including plug-in hybrid and full battery-electric vehicles. This approach would reduce the technology deployment and compliance cost in the intermediate term, leaving aside any potential market barriers such as availability of infrastructure and customer acceptance (Figure 13).

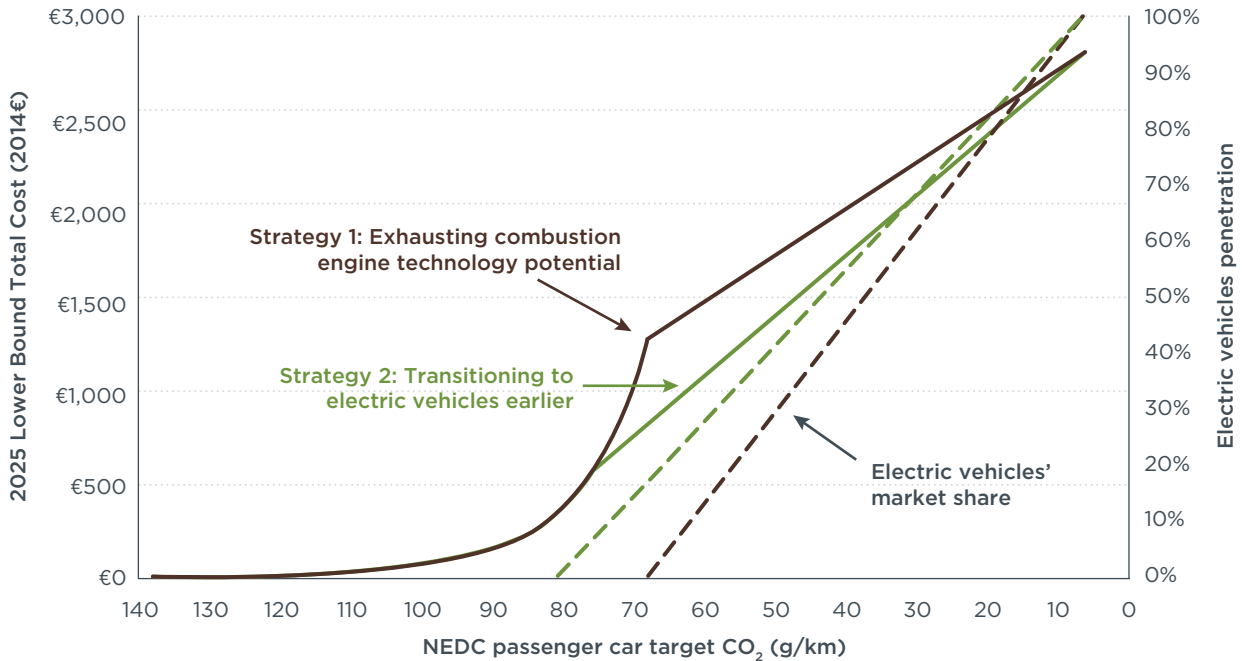


Figure 13. Total incremental cost, including indirect costs but excluding taxes, of reducing CO₂ emissions of the average passenger car in the EU by 2025 in a lower-bound scenario, comparing full deployment of combustion-engine technologies before transitioning to electric vehicles with a least-cost strategy of transitioning to electric vehicles earlier.

Switching to electric vehicles earlier and following a least-cost technology strategy, rather than exhausting the full potential of combustion-engine technologies, would reduce the costs of meeting a 70 g/km CO₂ emissions target for passenger cars by about €350 per vehicle in 2025. The required market share for electric vehicles would be about 17%, at the lower end of estimates issued by vehicle manufacturers such as BMW, Daimler, and Volkswagen.²⁷ In a lower-bound scenario, this would result in overall compliance cost for reaching a 70 g/km CO₂ target of about €650 by 2025. For combustion-engine vehicles, the implicit CO₂ target would be around 83 g/km, meaning the remaining CO₂ reduction to reach an overall fleet target of 70 g/km would come from electric vehicles (Table 1).

²⁷ BMW and Daimler announced that 15-25% of their sales by 2025 would be electric cars. Volkswagen announced that 20-25% of its 2025 sales would be electric cars. For details see IEA (2017). *Global EV Outlook 2017*. International Energy Agency (IEA), retrieved from <https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf> as well as Lambert, F. (2017). "Tesla has freed the electric car from its granola image," says Daimler CEO. Electrek, retrieved from <https://electrek.co/2017/03/24/tesla-electric-car-granola-image-daimler-ceo/>.

Table 1. Summary of incremental cost, including indirect costs but excluding taxes, of reducing CO₂ emissions of the average passenger car in the EU by 2025/2030 following a least-cost strategy of transitioning to electric vehicles earlier.*

CO ₂ fleet target (NEDC)	Electric vehicles' market share	Avg. CO ₂ level EVs (NEDC)	CO ₂ target non-EVs (NEDC)	Total incremental cost (2014€)	
				2025	2030
80 g/km	4%	6 g/km	83 g/km	€300	€250
70 g/km	17%	6 g/km	83 g/km	€650	€500
60 g/km	30%	6 g/km	83 g/km	€1,000	€750
50 g/km	43%	6 g/km	83 g/km	€1,300	€1,000
40 g/km	56%	6 g/km	83 g/km	€1,650	€1,250

* In a lower-bound cost scenario, assuming no super-credits for electric vehicles (EVs). For the B and C segments, all EVs are assumed to be battery-electric vehicles; for the D, E and SUV segments, all EVs are assumed to be plug-in hybrid electric vehicles with an electric driving range of approximately 40 km.

For light-commercial vehicles, a CO₂ target of 90 g/km in 2025 could be met for about €1,000 less per vehicle, if switching to electric vehicles earlier and reaching a share of about 30% for electric vehicles for new sales instead of exhausting all remaining combustion engine potential. The implicit CO₂ target for combustion-engine vehicles would be around 120 g/km and the overall compliance cost would be about €1,550 (Table 2).

Table 2. Summary of incremental cost, including indirect costs but excluding taxes, of reducing CO₂ emissions of the average light-commercial vehicle in the EU by 2025/2030 following a least-cost strategy of transitioning to electric vehicles earlier.*

CO ₂ fleet target (NEDC)	Electric vehicles' market share	Avg. CO ₂ level EVs (NEDC)	CO ₂ target non-EVs (NEDC)	Total incremental cost (2014€)	
				2025	2030
90 g/km	30%	20 g/km	120 g/km	€1,550	€1,250
80 g/km	40%	20 g/km	120 g/km	€1,900	€1,550
70 g/km	50%	20 g/km	120 g/km	€2,250	€1,850
60 g/km	60%	20 g/km	120 g/km	€2,650	€2,150
50 g/km	70%	20 g/km	120 g/km	€3,000	€2,450

* In a lower-bound cost scenario, assuming no super-credits for EVs. Of all EV sales in the light-commercial vehicles segment, approximately 40% are assumed to be battery-electric and the remaining 60% to be plug-in hybrid electric vehicles with an electric driving range of approximately 40 km.

To ensure a minimum share of electric vehicles and to provide a certain level of planning security for vehicle manufacturers and infrastructure providers, governments can define a sales target for electric vehicles, as has been the case in California since the 1990s and as was recently announced for China. This policy approach would reduce the costs of eventually transitioning to zero-emission vehicles by ensuring that all vehicle manufacturers steadily scale up their electric vehicle offerings instead of relying on increasingly expensive and ultimately insufficient internal combustion-engine technologies. Yet, considering the variability in manufacturers' current investments and electric vehicle offerings, there is potential to further reduce the costs of compliance with a flexible zero-emission vehicle mandate. Under this approach, all vehicle manufacturers would have to sell a minimum number of electric vehicles but at the same time maintain some flexibility on whether to over-achieve on electric-vehicle sales and in return under-achieve on combustion-engine vehicle CO₂ reductions, or the other way around.²⁸

²⁸ For details, see Stewart, A. & Dodson, T. (2016). *Towards a European market for electro-mobility*. ElementEnergy. Retrieved from Transport & Environment (T&E), <https://www.transportenvironment.org/sites/te/files/Towards%20a%20European%20Market%20for%20Electro-Mobility%20report%20by%20Element%20Energy.pdf>

THE ROLE OF DIESEL VEHICLES

Between 1990 and 2015, the average share of new diesel cars in Europe increased from about 14% to 52%, reaching a maximum of 56% in 2011. Apart from Europe, the only major car markets worldwide with a significant share of diesel passenger cars are India and South Korea. In China, Japan, and the United States, diesel cars account for less than 5% of deliveries.

However, the diesel market share in Europe is falling and is expected to continue declining for several reasons. First, a number of large cities are threatening to ban diesel cars from city centers as air-quality problems related to nitrogen oxide (NO_x) emissions grow and as consumers turn against them (Figure 15). Second, policies that hold manufacturers increasingly accountable for reducing real-world NO_x emissions, as opposed to laboratory emissions only, are forcing the adoption of more expensive exhaust aftertreatment technology. As a result, diesel cars are less cost-competitive than under laxer environmental protections. Third, some EU member states are cutting tax benefits from which diesel fuel benefited in the past, further weakening the competitive position of diesel cars.

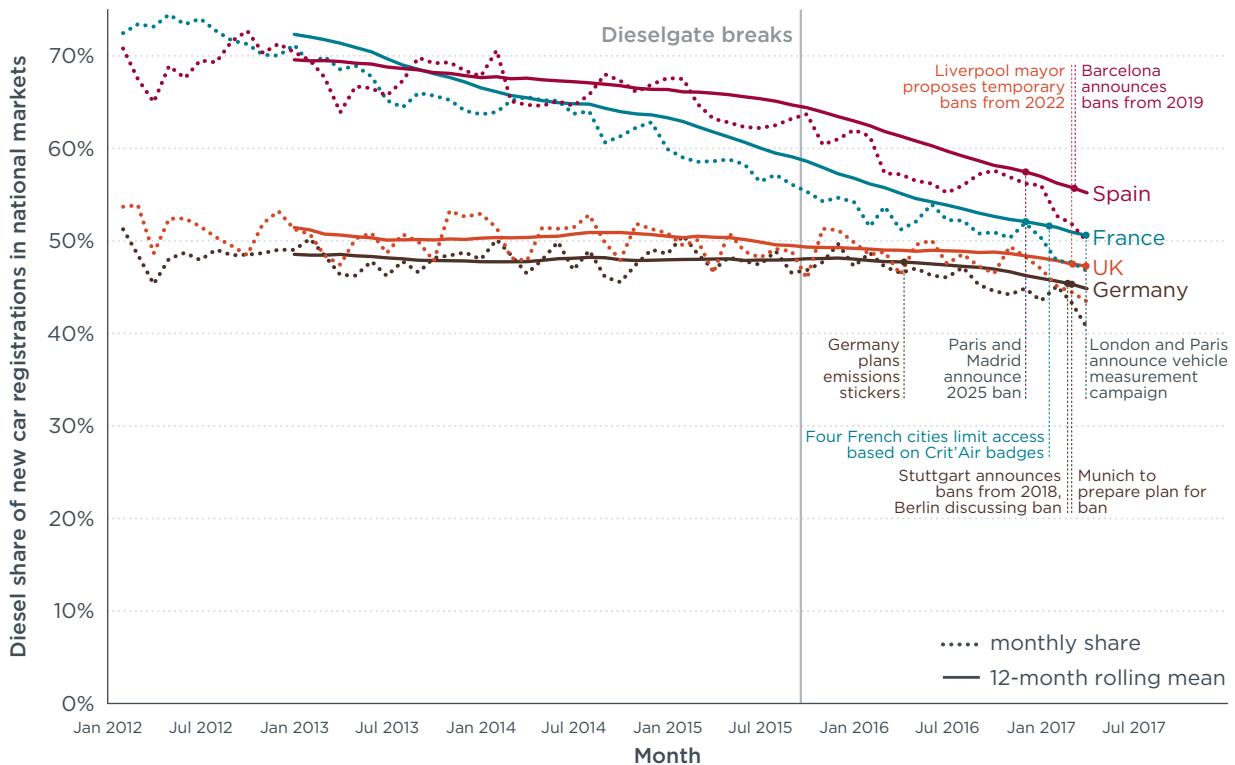


Figure 15. Diesel shares of new car registrations in France, Germany, Spain, and the United Kingdom. Round markers denote policy developments.²⁹

The average diesel car in Europe typically emits about 17% less CO₂ than a similar conventional gasoline car in the same vehicle segment. That is why diesel cars are often portrayed as an essential part of reducing CO₂ emissions. However, across all vehicle segments, average CO₂ emissions of new diesel and gasoline cars are nearly identical – 119 g/km for diesel and 123 g/km for gasoline. This indicates that efficiency gains from diesel engines often are counterbalanced by higher engine power and higher weight for diesel cars.

²⁹ Tietge, U. (2017). *Cities driving diesel out of the European car market*. ICCT, retrieved from <http://theicct.org/blogs/staff/cities-driving-diesel-out-european-car-market>

Furthermore, hybrid electric cars today often are cheaper than diesel cars within the same vehicle segment. In Germany, the average hybrid car in the lower medium segment, also known as the “Golf” segment, in 2015 sold for €26,700, whereas the average diesel car within the same segment cost €1,700 more.³⁰ This additional cost is a result of higher temperatures and pressures for the diesel combustion process and more complex aftertreatment systems, which increase the production costs of diesel engines. Given that the average hybrid car emits about 18% less CO₂ and is cheaper than the average diesel car within a specific vehicle segment, switching to hybrid cars is already a more cost-efficient way of reducing CO₂ than sticking with diesel engine technology. In future years, the cost of hybrid cars—in particular, plug-in hybrid—and battery-electric vehicles is expected to decrease further as a result of continued advances in battery technology.

Figure 16 shows various scenarios for meeting future CO₂ targets without diesel technologies. Assuming a 2025 fleet-wide CO₂ target of 70 g/km on the NEDC and reducing the diesel car market share gradually from 55% to 15%, it becomes clear that the EU can still meet future CO₂ standards despite the projected decline in diesel car sales. In the “exhausting combustion engine technology” scenario, diesel vehicles are replaced by advanced gasoline vehicles including hybrid vehicles and, when the diesel share falls below 25%, also partly by electric vehicles. In the “transitioning to electric vehicles earlier” scenario, manufacturers comply with the target by offering more electric, hybrid, and advanced gasoline vehicles in place of diesels. In both cases, the required investment in vehicle efficiency technologies increases but is counterbalanced taking into account the cost savings when moving away from diesel engines. This is because the production costs of diesel engines are generally higher than for gasoline engines. As a result, the net compliance cost for reaching a 70 g/km target by 2025 would decline by €10 to €280 per vehicle if the diesel market share dropped as low as 15%.

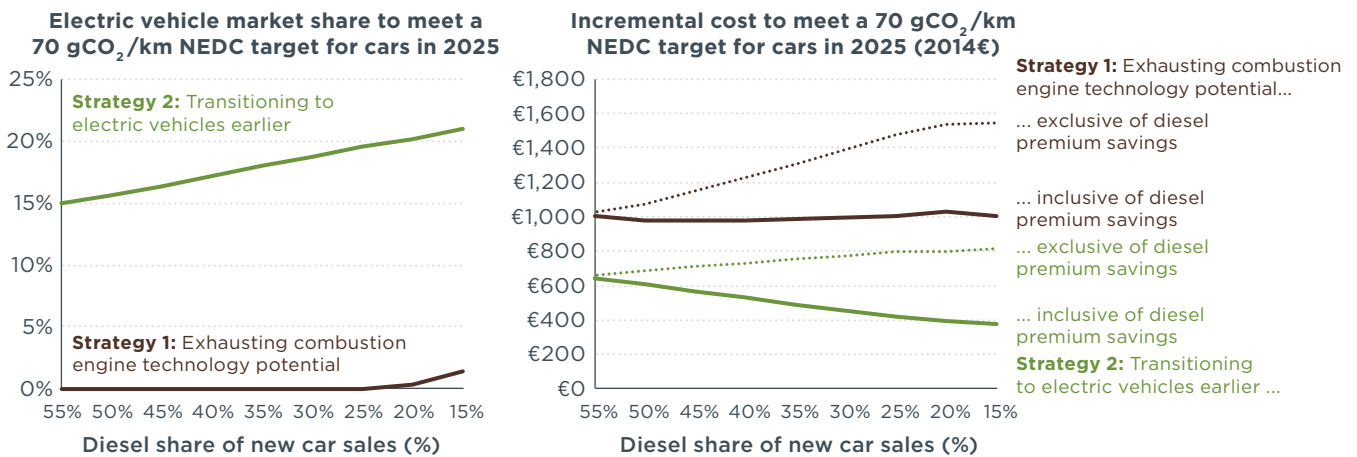


Figure 16. Change in electric vehicle market shares (left-hand side) and compliance costs (right-hand side) for meeting a 70 g/km NEDC target for cars in 2025 with different diesel market shares.³¹

VEHICLE WEIGHT VS. SIZE AS UTILITY PARAMETER FOR CO₂ REGULATION

When the EU introduced its first set of mandatory new-vehicle CO₂ regulations, policy makers chose vehicle mass as the utility parameter because data on mass was readily

³⁰ For more details, see Diaz, S., Miller, J., Mock, P., Minjares, R., Anenberg, S., & Meszler, D. (2017). *Shifting gears: The effects of a future decline in diesel market share on tailpipe CO₂ and NO_x emissions in Europe*. ICCT, retrieved from <http://theicct.org/effects-of-future-EU-diesel-mkt-share-decline>

³¹ See footnote 31.

available. This means that heavier vehicles are allowed to emit more CO₂ than lighter vehicles. However, the regulation required the European Commission to collect data on alternative utility parameters and to consider switching at a later time to another parameter, such as vehicle footprint, an expression of vehicle size measured as track width times wheelbase. For the 2020 passenger-car regulation, the European Parliament suggested vehicle footprint as an alternative compliance option for the final regulation. However, vehicle weight was kept as the utility parameter, putting off consideration of changing to footprint for future review. In the United States, vehicle footprint is used as the utility parameter for both passenger cars and light trucks.

The heavier a vehicle is, the greater its CO₂ emissions. Mass reduction therefore is an effective way to reduce vehicle emissions. However, the EU's current CO₂ target system offers little incentive to apply mass reduction: The lighter a manufacturer's fleet, the lower its assigned CO₂ target. If a manufacturer reduces the mass of its vehicles, it must then hit a lower g/km target. This erases most of the manufacturer's weight-reduction advantage and puts mass reduction at a competitive disadvantage compared with other CO₂ saving technologies. The situation is very different in a target system based instead on vehicle footprint. Here, the manufacturer's CO₂ target does not change with mass reduction, and the manufacturer fully benefits from the CO₂ reduction effect of lightweighting (Figure 17).

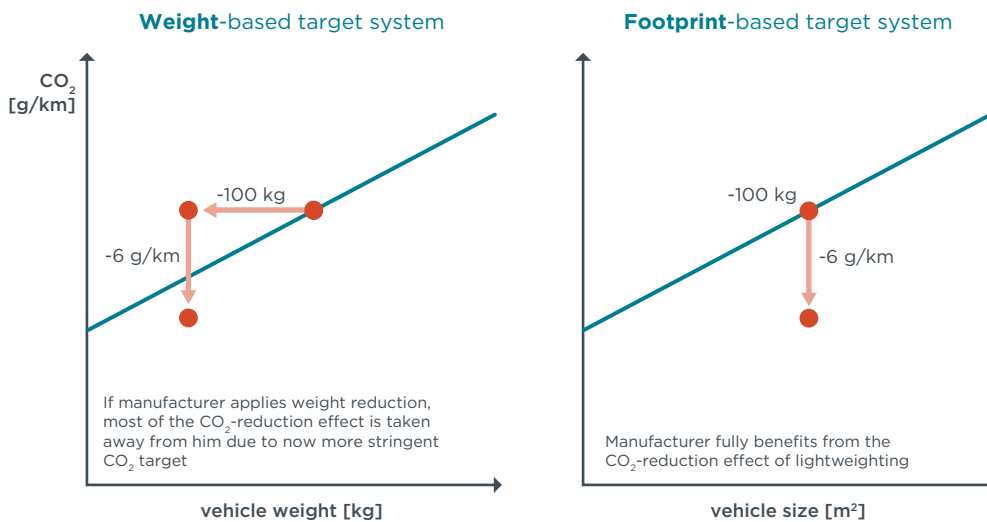


Figure 17. Weight reduction in a weight-based CO₂ target system (left) and in a footprint-based system (right).

Because a weight-based CO₂ target system discourages the use of lightweighting, it takes away innovation flexibility and increases the cost for regulatory compliance. For passenger cars, the cost of meeting a 2025 target value of 70 g/km in a weight-based target system is between €250 and €500 higher than in a footprint-based system. For light-commercial vehicles, the cost for meeting a 2025 target value of 110 g/km is between €400 and €1,850 higher under a weight-based system than if switching to a footprint-based target system. For a target value of 90 g/km, the effect is not as strong, but compliance costs are still between €400 and €500 higher than if switching to a footprint based target system.³²

³² Meszler, D., German, J., Mock, P., Bandivadekar, A. (2017). *CO₂ reduction technologies for the European car and van fleet, a 2025-2030 assessment*. ICCT, retrieved from <http://www.theicct.org/EU-CO2-reduction-tech-2025-2030-assessment>

OFFICIAL VS. REAL-WORLD CO₂ EMISSIONS

The gap between official type approval and real-world CO₂ emissions results for new passenger cars increased from about 9% in 2001 to 42% in 2015 (Figure 18). The trend was particularly pronounced in recent years, with the gap more than doubling between 2009 and 2015. As a result, less than half of the on-paper reductions in CO₂ emissions since 2001 have been realized in practice. Since 2010, hardly any real-world reductions in CO₂ emissions have been achieved.³³ The main reason for the widening gap is increasingly unrealistic type-approval CO₂ values that are generated as vehicle manufacturers more and more exploit loopholes in the NEDC testing procedure.³⁴

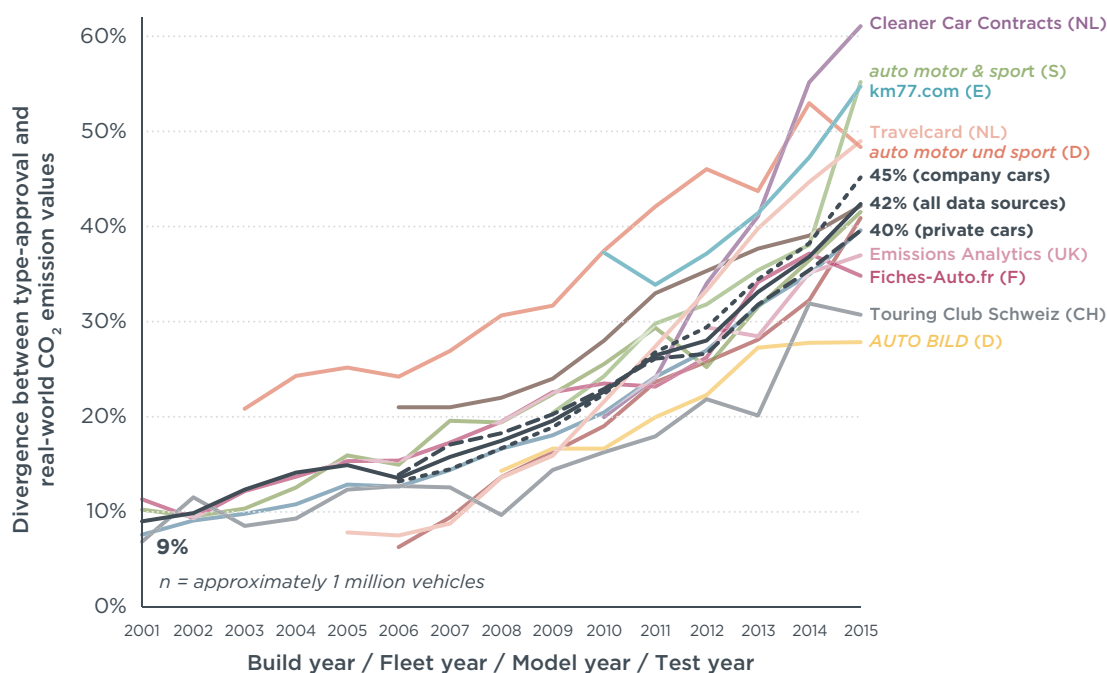


Figure 18. Divergence between real-world and manufacturers' type-approval CO₂ emission values for various on-road data sources, including average estimates for private cars, company cars, and all data sources.

As a first step for reducing the gap between official and real-world CO₂ emission levels, a new vehicle-emissions testing procedure will be introduced, the Worldwide harmonized Light vehicles Test Procedure (WLTP). The WLTP was phased in starting with new vehicle types from September 2017 onward, then all new vehicles starting in September 2018, and finally all end-of-series vehicles from September 2019 onward.³⁵ The WLTP is expected to reduce, though not eliminate, the gap between type-approval and real-world CO₂ emissions.³⁶

33 Tietge, U., Diaz, S., Mock, P., German, J., & Bandivadekar, A. (2016). *From Laboratory to Road – A 2016 update of official and 'real-world' fuel consumption and CO₂ values for passenger cars in Europe*. ICCT, retrieved from <http://www.theicct.org/laboratory-road-2016-update>

34 Stewart, A., Hope-Morley, A., Mock, P., & Tietge, U. (2015). *Quantifying the impact of real-world driving on total CO₂ emissions from U.K. cars and vans*. ElementEnergy and ICCT. Retrieved from the U.K. Committee on Climate Change (CCC), <https://www.theccc.org.uk/publication/impact-of-real-world-driving-emissions/>

35 Regulation (EC) No 1153/2017 (passenger cars) and No 1152/2017 (light-commercial vehicles) setting out a methodology for determining the correlation parameters necessary for reflecting the change in the regulatory test procedure and amending Regulation (EU) No 1014/2010 as of 2 June 2017. Retrieved from http://eur-lex.europa.eu/eli/reg_impl/2017/1153/oj

36 Fontaras, G., Ciuffo, B., Zacharof, N., Tsiakmakis, S., Marotta, A., Pavlovic, J., & Anagnostopoulos, K. (2016). *The difference between reported and real-world CO₂ emissions: How much improvement can be expected by WLTP introduction?* World Conference on Transport Research - WCTR 2016 Shanghai. 10-15 July 2016. Retrieved from ScienceDirect, <https://doi.org/10.1016/j.trpro.2017.05.333>

While for air pollutant emissions, the NEDC limit values will be kept identical under WLTP, for CO₂ emissions it was decided to apply vehicle-specific NEDC-WLTP correlation factors.³⁷ For the determination of these correlation factors, the CO₂MPAS software tool was developed.³⁸ Figure 19 summarizes the anticipated approach of switching from NEDC to WLTP, with the following observations regarding the politically agreed correlation procedure:

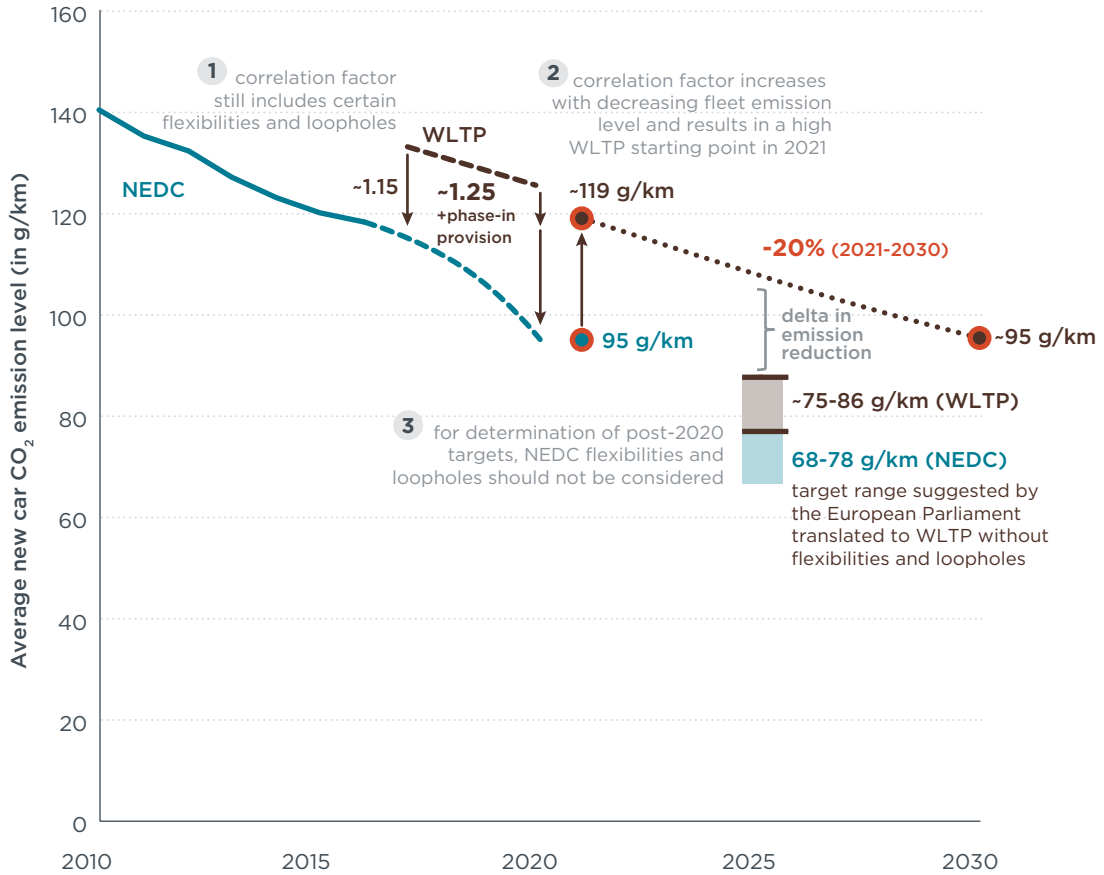


Figure 19. Schematic illustration of the planned switch from the NEDC to the WLTP test procedure (dashed lines) as well as an alternative approach (dotted line).

1. The WLTP will help to eliminate flexibilities and loopholes that were part of the NEDC and were exploited by manufacturers to lower declared CO₂ values. However, it was decided to include some of these questionable framework conditions of the NEDC as part of the WLTP-NEDC correlation procedure.³⁹ If only the procedural differences, in particular higher road load and more dynamic speed profile, between the NEDC and WLTP were accounted for, the resulting average

³⁷ Regulation (EC) No 1153/2017 (passenger cars) and No 1152/2017 (light-commercial vehicles).

³⁸ Ciuffo, B. & Fontaras, G. (2017). *Models and scientific tools for regulatory purposes: The case of CO₂ emissions from light duty vehicles in Europe*. Energy Policy 109 (2017) 76-81, retrieved from <https://doi.org/10.1016/j.enpol.2017.06.057>.

³⁹ For example, in the NEDC it is not explicitly forbidden to fully charge the starter battery of a combustion-engine vehicle before the emissions test and to end the test with a battery that is only partially charged, i.e. using some of the battery's energy for reducing type-approval CO₂ emissions of the vehicle. In WLTP, this practice is explicitly forbidden as it results in lower type-approval CO₂ emissions while keeping real-world emissions constant, increasing the gap. This loophole is overcome by introduction of a preconditioning phase during which the battery is brought from fully charged to a charge level that is representative of real-world driving. Nevertheless, the WLTP-NEDC correlation factor will provide a credit for manufacturers exploiting this legal loophole of pre-test battery charging in the past. In practice, the manufacturer will test a vehicle according to WLTP, with the starter battery only partially charged, and will then apply the correlation procedure to calculate a corresponding NEDC CO₂ emission figure that is artificially lower as it assumes the manufacturer would have fully charged the battery of the vehicle if the test had been carried out in NEDC.

correlation factor would be less than 1.10.⁴⁰ Including the flexibilities and loopholes that were common practice in the NEDC and are accounted for as part of the correlation exercise, the fleet average WLTP-NEDC correlation factor is expected to be closer to 1.15.⁴¹ Thus, WLTP CO₂ emissions will be about 15% higher than the NEDC figures simulated by CO₂MPAS.

2. The 2021 WLTP CO₂ target for each manufacturer will be calculated based on its 2020 performance according to the NEDC level simulated by CO₂MPAS. If the simulated 2020 NEDC level of a manufacturer is 5% below its respective 2020 NEDC target,⁴² then the 2021 WLTP target for this manufacturer will be set 5% above its 2020 WLTP level. Or, expressed differently, the 2021 WLTP target for a manufacturer equals its 2020 NEDC target times the fleet average WLTP-NEDC correlation factor for this specific manufacturer. Hence, manufacturers have a strong incentive to achieve an NEDC CO₂ level in 2020 that is as low as possible while at the same time keeping their 2020 WLTP CO₂ level as high as possible. In other words, they would aim to achieve as high a WLTP-NEDC fleet average correlation factor as possible. This is particularly important if post-2021 CO₂ targets were connected in any way to a manufacturer's 2021 WLTP performance. In this case, securing a high 2021 WLTP CO₂ starting point would make it easier for manufacturers to demonstrate higher percentage reductions in subsequent years. With this in mind, it is important to point out that with decreasing CO₂ fleet emission averages, the fleet average WLTP-NEDC correlation factor is expected to increase from about 1.15 today to about 1.25 by 2020.⁴³
3. The resulting effect can be illustrated using two scenarios. In scenario A, manufacturers on average would meet exactly their respective CO₂ targets for 2020, and the NEDC 95 g/km fleet average target would be translated to a 119 g/km WLTP target for 2021, which would be defined as the starting point for any post-2021 reductions. Assuming an average 20% CO₂ reduction between 2021 and 2030, or 2.4% a year as suggested by the European vehicle manufacturers' association,⁴⁴ the resulting fleet average in 2030 would be about 95 g/km in WLTP terms. The corresponding 2025 fleet average would be 108 g/km. In scenario B, post-2021 CO₂ targets would be defined independently from the outcome of the 2021 target evaluation and by applying a WLTP-NEDC correlation factor that does not give credit for any of the flexibilities and loopholes of the NEDC. Taking the 68-78 g/km NEDC CO₂ target range suggested earlier by the European Parliament⁴⁵ for 2025 and a WLTP-NEDC correlation factor of 1.1,⁴⁶ the resulting fleet average target in WLTP terms would be 75-86 g/km. The difference between the 108 g/km for 2025 in scenario A and the 75-86 g/km in scenario

40 Mock, P., Kuhlwein, J., Tietge, U., Franco, V., Bandivadekar, A., & German, J. (2014). *The WLTP: How a new test procedure for cars will affect fuel consumption values in the EU*. ICCT, retrieved from <http://www.theicct.org/wltp-how-new-test-procedure-cars-will-affect-fuel-consumption-values-eu>

41 ICCT estimate based on Tsiakmakis, S. et al. (2017). *A simulation-based methodology for quantifying European passenger car fleet CO₂ emissions*. Applied Energy 199 (2017) 447-465, retrieved from <https://doi.org/10.1016/j.apenergy.2017.04.045>

42 The 2020 NEDC target of a manufacturer is essentially the same as its 2021 target, with the important difference that the 5% of vehicles with the highest CO₂ emission levels will not be counted because of the phase-in provision.

43 ICCT estimate based on Tsiakmakis, S., Fontaras, G., Ciuffo, B., & Samaras, Z. (2017). *A simulation-based methodology for quantifying European passenger car fleet CO₂ emissions*. Applied Energy 199 (2017) 447-465, retrieved from <https://doi.org/10.1016/j.apenergy.2017.04.045>

44 See press release "CO₂ targets for cars: European auto industry sets out post-2021 framework," 13-09-2017, retrieved from <http://www.acea.be/press-releases/article/co2-targets-for-cars-european-auto-industry-sets-out-post-2021-framework>

45 European Parliament press release "Car CO₂: mapping the route to 95g and beyond," 24-04-2013, retrieved from <http://www.europarl.europa.eu/news/en/press-room/20130422IPRO7527/car-co2-mapping-the-route-to-95g-and-beyond>

46 Estimate based on Mock, P. et al. (2014) and Tsiakmakis, S. et al. (2017).

B reflects the fact that the European Parliament was suggesting an annual CO₂ reduction rate that is about twice as high as the current proposal of the vehicle manufacturers' association—3.9-6.5% versus 2.4%. The difference also reflects the risk of significantly weakening the EU CO₂ regulation by allowing flexibilities and loopholes of the old NEDC test procedure to be implicitly transferred into a post-2021 regulatory framework.

Apart from the risks hidden in the translation from NEDC to WLTP, it should not be forgotten that the WLTP by itself is not a guarantee for lowering real-world CO₂ emissions. As with any other vehicle emissions test procedure, the WLTP contains flexibilities and errors that can be exploited by vehicle manufacturers. For this reason, it is important to closely track not only official type-approval CO₂ figures, whether in the NEDC or WLTP, but also the real-world CO₂ performance of new vehicles.⁴⁷ For the air pollutant emissions nitrogen oxide and particulates, the Real Driving Emissions (RDE) procedure ensures since September 2017 that new vehicles are tested not only in the laboratory but also on the road.⁴⁸ This RDE test procedure could be extended to also cover CO₂ emissions and could be used to implement a fleet-wide not-to-exceed limit for CO₂. It is only through a combination of tightened CO₂ standards and improved enforcement, implementing and further improving the WLTP, implementing on-road CO₂ testing, setting a not-to-exceed limit for CO₂, and market surveillance by member states and independent third parties that the gap between official and real-world CO₂ emissions can be narrowed and real-world emissions decreased in future years (Figure 20).

47 SAM (2016). *Closing the gap between light-duty vehicle real-world CO₂ emissions and laboratory testing*. European Commission Scientific Advice Mechanism (SAM) High Level Group of Scientific Advisors, Scientific Opinion No. 1/2016, retrieved from https://ec.europa.eu/research/sam/pdf/sam_co2_emissions_report.pdf#view=fit&pagemode=none

48 Mock, P. (2017). *Real-Driving Emissions test procedure for exhaust gas pollutant emissions of cars and light commercial vehicles in Europe*. ICCT, retrieved from <http://www.theicct.org/RDE-test-procedure-exhaust-gas-pollutant-emissions-cars-and-LCVs>

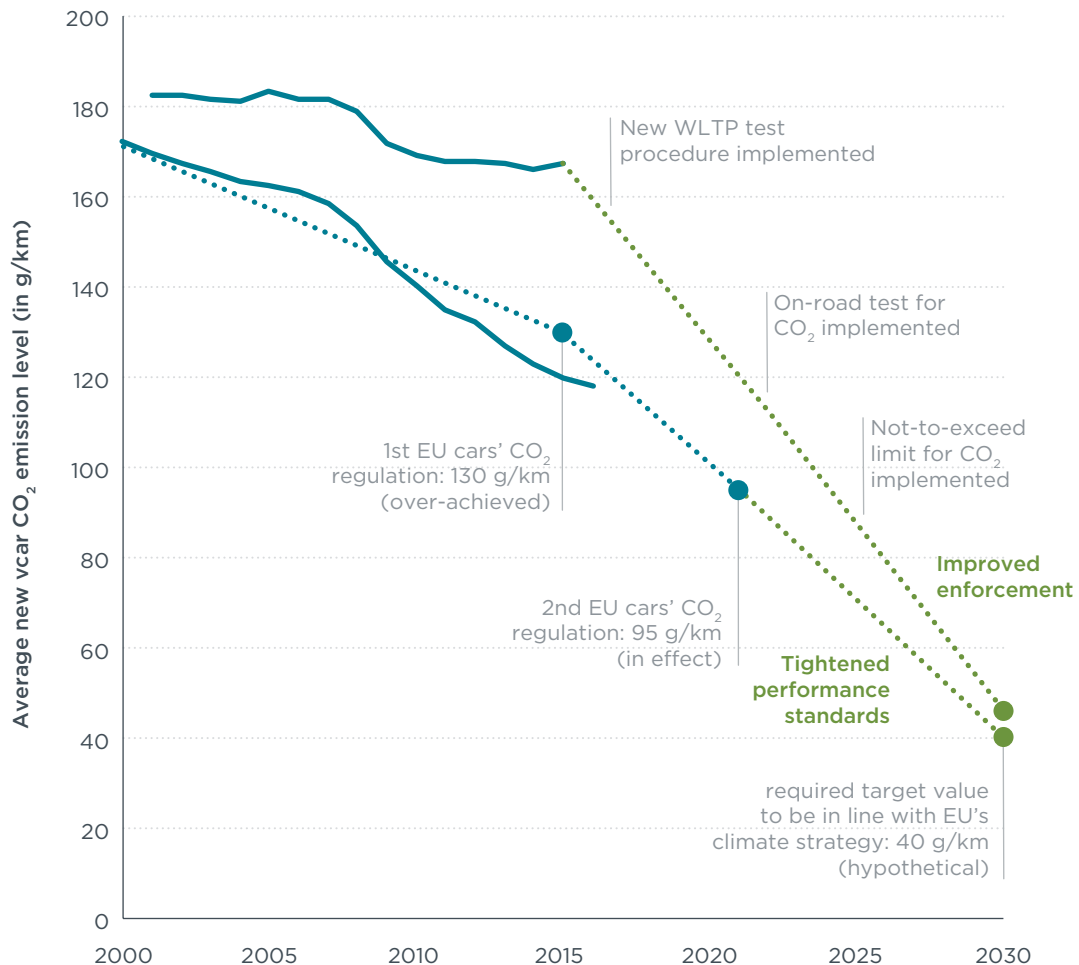


Figure 20. Historic development of average official and real-world CO₂ emissions for new passenger cars, including expected development for future years, demonstrating how tightened CO₂ performance standards in combination with improved enforcement can help to bring official and real-world levels closer together and to achieve real-world emission reductions.

CONCLUSIONS

CO₂ standards have proven effective for driving down test-cycle emission levels of new vehicles in recent years. To meet agreed climate targets, the annual CO₂ reduction rate for vehicles coming to the market in 2020-2030 needs to be significantly higher than in previous years. In addition, the gap between official test cycle and real on-road emission levels needs to be reduced by putting a stronger emphasis on regulatory enforcement. From a technical and economic perspective, stronger CO₂ reduction efforts are feasible. A 70 g/km NEDC target for new cars by 2025 can be reached largely without electrification and within a payback period of two to four years; however, accelerated deployment of electric vehicles will help to further reduce compliance cost for meeting 2020-2030 CO₂ emission targets. A 17% electric vehicle share by 2025 would reduce compliance cost by approximately €350 per vehicle. A lower share of diesel cars will be no hurdle for greenhouse gas reductions and is likely to drive further acceleration of electric vehicles' deployment and further reduced compliance cost.