

## **EVs and post 2020 CO<sub>2</sub> targets for passenger cars**

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### **Abstract**

This paper analyses what post 2020 targets may be necessary for the European CO<sub>2</sub> legislation for passenger cars in order to reach the overall sectoral goal of 60% reduction of transport's greenhouse gas emissions by 2050 relative to 1990, as defined in the European Commission's White Paper. The required target levels are found to depend strongly on the contribution that passenger cars need to make to reaching the overall target, on the assumed growth of passenger car mobility, and on the extent to which biofuels could be available for fuelling passenger cars. To what extent electric vehicles and other low emission vehicles such as plug-in hybrids and fuel cell electric vehicles are needed to meet the post-2020 targets depends on the target level and on the minimum CO<sub>2</sub> emissions that can be reached in conventional vehicles. Almost all assessed scenarios, require significant amounts of low emission vehicles to be sold from 2030 or 2035 onwards. Electric and plug-in vehicles are in the early stage of market introduction now, but developments are fragile could end up in a "valley of death". Defining a sufficiently low passenger car CO<sub>2</sub> target for 2025 may be an effective instrument to motivate manufacturers to continue their efforts in the marketing and further development of these vehicles. This is important for maintaining the momentum of the transition towards large-scale application of low CO<sub>2</sub> emitting vehicles.

*Keywords: emissions, EU (European Union), EV (electric vehicle), policy, regulation, ZEV (zero emission vehicle)*

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### **1 Introduction**

A very important and challenging goal of the European Union is to reduce greenhouse gas emissions (GHG) until 2050 by 80%. In order to achieve this goal, increasing GHG constraints are required in every sector of the economy. Transport is one of the main CO<sub>2</sub> emitting sectors in Europe, and the only one that continues to grow substantially. Since road transport is responsible for the majority of the overall transport emissions, regulations have been adopted for the purpose of reducing CO<sub>2</sub> emissions from passenger cars and light commercial vehicles. The CO<sub>2</sub> legislation for passenger cars, laid down in Regulation (EC)

443/2009, requires the CO<sub>2</sub> emissions of new passenger cars in Europe to be reduced to 130 g/km by 2015. For 2020 a target for the new car fleet average of 95 g/km is specified [1]. A similar regulation has been implemented for light commercial vehicles (Regulation (EU) 510/2011), setting a target of 175 g/km for 2017 and of 147 g/km for the year 2020 [2].

The European Commission is currently considering what framework could or should be established for regulating light duty vehicle GHG emissions beyond 2020. Considerations relate to post 2020 target levels as well as to the metric on which these targets are based.

The current metric is based on tailpipe CO<sub>2</sub> emissions (= tank-to-wheel (TTW)), as measured on the type approval test. In the target year for each manufacturer the average of the TTW CO<sub>2</sub> emissions in g/km for the new vehicle sales may not exceed a value given by a linear target function that specifies the target as function of vehicle mass. If all manufacturers meet their target, the overall sales weighted average equals the overall target. This metric may overstimulate electric vehicles (EVs) and fuel cell vehicles (FCEVs), as these count as zero emission under a TTW CO<sub>2</sub> based metric. The use of biofuels, on the other hand, does not (significantly) affect a manufacturers average as direct CO<sub>2</sub> emissions of biofuels roughly equal those of conventional fuels.

Alternative metrics include regulating well-to-wheel (WTW) CO<sub>2</sub> emissions or tank-to-wheel or well-to-wheel energy consumption of vehicles. Evaluations of these options are reported in [3] and [4]. A WTW-based metric will stimulate manufacturers to take account of upstream emissions or energy consumption in the choice of technologies implemented to meet the target.

As no decision has been taken yet on the metric for future regulation, this paper assumes that the current TTW CO<sub>2</sub> based metric will be continued. Similar analyses, however, could be performed for the other metrics as well. Such an analysis has not been done yet, but the possible consequences of applying other metrics are briefly discussed.

The evolution of this legislation needs to be in line with the overall objectives set to achieve the EU high level objective of achieving an 80 to 95% reduction in economy-wide GHG emissions by 2050 compared to 1990 levels. The European Commission's 2011 Transport White Paper [5] further elaborates on the transport related aspects and specifies 2 targets: a 20% reduction from 2008 levels by 2030 and a 60% reduction from 1990 levels by 2050.

This paper analyses what post 2020 targets for passenger cars may be necessary for reaching the overall sectoral goal of 60%. Furthermore it discusses why and how post 2020 targets can be important for the momentum of the transition towards large-scale application of electric vehicles (EVs) and other Low Emission Vehicles

(LEVs) such as plug-in hybrids (PHEVs) and fuel cell electric vehicles (FCEVs).

## 2 Motivation of post-2020 targets

### 2.1 Gradual approach towards the 2050 target

Appropriate intermediate targets for vehicles are necessary to make sure that technologies, needed to make the 2050 passenger car fleet meet the target, are developed and marketed in time.

Different approaches are possible for determining intermediate target levels for passenger cars between 2020 and 2050:

- Extrapolation of annual reduction levels that are considered feasible;
- Bottom-up assessment of what is technically feasible at acceptable costs in consecutive target years;
- Top-down back casting of the path along which the vehicle target should develop in order to reach the overall 60% target for 2050.

A problem with the first option is that average reduction levels achieved in the past (e.g. the annual reduction from 130 g/km in 2015 to 95 g/km in 2020 is 5%) may not be achievable in the future. Technical challenges and marginal costs increase with increasing levels of CO<sub>2</sub> reduction and beyond some point alternative propulsion technologies are needed to achieve further reduction of the average emissions of new cars.

The second approach would take account of such effects, and has been used to motivate the European passenger car targets for 2015 [6] and 2020 [7]. For reductions beyond 2020 only limited information is available, e.g. from studies in support of the US legislation (see e.g. [8]) which include projections until 2025. For the longer term, however, the evolution of technology performance and costs is difficult to predict.

This paper uses the back casting approach. Starting point for that is identifying the possible contribution from passenger cars to reaching the overall 60% target for transport in 2050.

In this respect it should be noted that the White Paper target of 60% is a sectoral target, defined according to IPCC rules. This means that EVs and FCEVs count as zero emission, while WTT emissions for electricity and hydrogen production

are attributed to the energy sector. This is equivalent to their treatment under the TTW CO<sub>2</sub> based regulation. Biofuels also count as zero emission for the transport sector, while WTT emissions for cultivation of biomass and production of biofuels are attributed to agriculture and the energy sector. On this aspect the existing regulatory metric and the IPCC definition differ. As a consequence a biofuel share has to be assumed to translate average TTW CO<sub>2</sub> emissions of new vehicles into emissions attributed to the transport sector according to IPCC guidelines.

In defining the trajectory for post 2020 CO<sub>2</sub> targets for cars it is furthermore necessary to take into account that:

- passenger cars may have to do more than 60%, as in other parts of the transport sector (e.g. long haul road freight or inland shipping 60% reductions may not be feasible;
- the volume of transport is likely to grow between 1990 and 2050;
- the share of biofuels will change over time.

## **2.2 Bridging the valley of death for transitional technologies**

To meet the European Commission's long term objective a large share of battery-electric and/or other low CO<sub>2</sub> emitting vehicles (LEVs) such as PHEVs or FCEVs will be necessary. Implementing such technologies is a complex and time consuming process, requiring large investments in new energy infrastructures and significant improvements in vehicle technology performance and costs. For EVs the dominant design of vehicles and infrastructure is still to be determined. Existing and new stakeholders are seeking to define new business models, taking account of possible alternatives for vehicle ownership and the values of integrating EVs in future energy systems based on smart grids.

The transition towards large-scale implementation of EVs, which is likely to take at least two decades, is currently at a strong risk of ending up in the so-called "valley of death". In recent years the technology has climbed the S-curve some way on the demand created by early adopters and innovators, largely in the form of pilot projects, use of EVs in government fleets and by

companies for CSR purposes<sup>1</sup>, and limited uptake by private consumers. The economic crisis now makes that consumers and companies are less willing to buy the new technology, governments have less money to promote it, and industry is less able to keep investing in a technology that does not bring return on investment in the short term. Without further market increase, however, products will not be improved and prices will not drop, which both are prerequisites for reaching the (early) mass market.

Stringent post 2020 targets could help to accelerate the marketing of EVs and other LEVs with alternative powertrains. Studies in support of the CO<sub>2</sub> legislation [7] indicate that the 95 g/km for 2020 can be reached without LEVs. From the same studies it can be concluded that 70 g/km is the lowest average that can be achieved with internal combustion engine vehicles (ICEVs) only on the basis of the current market division and vehicle models (size and performance). Post 2020 targets would thus need to be below 70 g/km before they start to become a major driver for marketing LEVs. In defining post 2020 targets the challenge therefore is to strike a balance between what is minimally required from the overall perspective of the European CO<sub>2</sub> emission reduction strategy towards 2050, and what would help to realize medium and longer ambitions with respect to the role of (L)EVs.

It is clear that sufficiently stringent post-2020 targets will help to motivate OEMs to maintain their efforts in development and marketing of LEVs over the next decade.

## **3 Back-of-the-envelope calculation**

### **3.1 Modelling assumptions**

To assess required long term regulatory targets and the role of EVs in achieving these, a simple back-of-the-envelope calculation has been developed that is based on the following assumptions:

- The average type approval CO<sub>2</sub> emission value of the fleet in 1990 is 180 g/km. New cars in 2035 must have the same average CO<sub>2</sub> emission as the entire fleet must reach in 2050. This is related to the fact that it takes around 15 years to fully renew the fleet;

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<sup>1</sup> Corporate Societal Responsibility

- Based on results from [7], it is assumed that TTW targets under 70 g/km can only be reached with a finite share of LEVs.
- For simplicity sake the calculation assumes EVs as the only LEV technology introduced. The effect of a given share of EVs can also be reached by a larger share of PHEVs. The contribution of FCEVs to meeting the sectoral target is the same as for EVs;
- The reference scenario for growth of the mobility volume is based on available information about assumptions underlying the White Paper scenario;
- Given the lifetime of vehicles and the fleet renewal rate, the simplified assumption is made that the average CO<sub>2</sub> performance (= regulatory target) of the new vehicles sales from 2035 onwards is equal to the average CO<sub>2</sub> performance of the entire passenger car fleet in 2050 which is required to meet the assumed overall CO<sub>2</sub> emission target for 2050;
- The ratio between real-world energy consumption and CO<sub>2</sub> emissions and the values measured on the type approval (RW/TA) test is assumed to be constant. As a result calculations can be based on type approval emission factors only. It should be noted that over the past decade the RW/TA has not remained constant. This will be discussed further on.
- A biofuel share in the fuels for passenger cars between 0% and 40% is assumed. As mentioned above, according to the IPCC definition direct emissions of biofuel use are considered zero.

### 3.2 Modelling approach

Based on these assumptions it is possible to calculate which 2035 CO<sub>2</sub> target for passenger cars is necessary to reach emissions at the fleet level (according to IPCC definition) in 2050 that are e.g. 60%, 70% or 80% below the 1990 level. Target levels for intermediate target years can then to first order be determined by linear interpolation between the 95 g/km target for 2020 and the estimated 2035 target level. An example calculation, for the case of a 60% reduction by 2050, is presented in Table 1.

Table 1: Example calculation of the average fleet emissions to be reached in 2050 in function of the reduction target and the assumed growth in traffic volume

	Fleet average CO <sub>2</sub> emissions (IPCC) [g/km]	Volume of pass. car transport [vkm]	Fleet average CO <sub>2</sub> emissions (IPCC) [g/km]
1990	180	1	180
change	-60%	+80%	-78%
2050	72	1.8	40

The calculation in Table 1 can be understood as follows: If the volume (total kms driven by the EU passenger car fleet) would remain the same, passenger cars in 2050 would need to have a fleet average emission of 72 g/km in order to realize a 60% reduction in total emissions. If the volume increases by 80% between the baseline year and 2050, as assumed in the White Paper scenario, the average CO<sub>2</sub> emissions of passenger cars need to be reduced to 40 g/km to achieve the same total fleet emissions in 2050. This corresponds to a 78% reduction compared to the average emissions of 180 g/km in the reference year. This fleet average in 2050 is assumed to equal the required new vehicle target in 2035.

Using the assumption that, without significant changes to vehicle designs or sales distributions, levels below 70 g/km are not feasible for ICEVs, one can then estimate the share of EVs that is necessary to reach the required target levels for new passenger cars and for the fleet. An example calculation for that is presented in Table 2. The calculations are made for two different assumptions of the share of biofuels in the fuel for ICEVs in 2050.

Table 2: Example calculation of the required share of EVs to meet the target for 2050 in the scenario assessed in Table 1, for two different assumed shares of biofuels

Fleet average CO <sub>2</sub> emission in 2050 (TTW) [g/km]	ICEVs TA CO <sub>2</sub> (TTW) [g/km]	Biofuels share [%]	ICEVs IPCC CO <sub>2</sub> [g/km]	ICEVs share [%]	EVs share [%]
40	70	0%	70	57%	43%
40	70	40%	42	95%	5%

## 4 Results for intermediate target levels

Important determinants for the outcome of the assessment using the above-described model are:

- the reduction required from passenger cars by 2050 as contribution to the overall reduction target for transport of 60%
- the availability and assumed share of biofuels for use in passenger cars;
- assumptions on the growth of passenger car transport in the coming decades.

Below calculations are presented that assess the sensitivity of the required post 2020 CO<sub>2</sub> targets to variations in the assumptions on these three determinants.

### 4.1 Sensitivity to the assumed contribution of passenger cars to meeting the overall 60% target for 2050

As already mentioned it is likely that CO<sub>2</sub> emissions of passenger cars in 2050 may have to be reduced by more than 60% relative to 1990, as in other parts of the transport sector (e.g. long haul road freight or inland shipping 60% reductions may not be feasible. A higher reduction target for passenger cars will require tighter intermediate targets for the CO<sub>2</sub> regulation, as well as a higher share of EVs or other low-emission alternatives to meet those targets.

Figure 1 shows target trajectories for scenarios based on share of 40% biofuels in the fuel for passenger cars in 2050 and a growth of the volume of 80% between 1990 and 2050. Reduction targets for passenger cars are varied between 60% and 80%.

#### 4.1.1 Evolution of average emissions since 2000

The graph also displays the targets for 2015 and 2020 (solid red line, assuming that average emissions will reduce linearly over this period), and the evolution of average type approval CO<sub>2</sub> emissions of new cars sold in Europe since 2000 (solid blue line). The latter shows a clear downward trend, with an accelerated reduction since around 2007. Extrapolating this trend indicates that the average emissions in 2015 will be well below the target of 130 g/km.

In a study for the European Commission [7], however, it has been shown that a significant part of the reported reduction on the type approval test is not the result of applying CO<sub>2</sub>-reducing technologies, but rather of increased utilisation of flexibilities in the test procedures. The dotted blue line indicatively shows how average CO<sub>2</sub> emissions would have developed, had this utilisation of test flexibilities not occurred. Extrapolating the dotted blue line suggests that based on technological improvements alone manufacturers are roughly on track to meet the 2015 target, but some acceleration in the reductions would still be required.

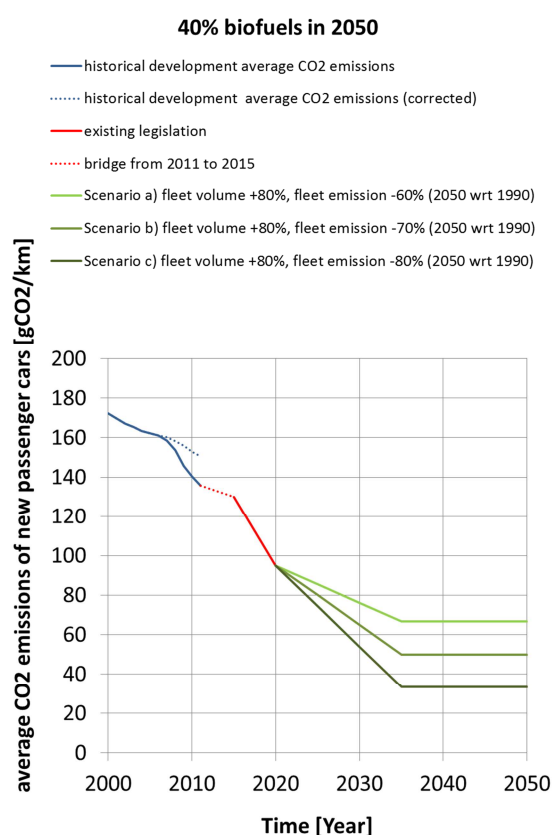


Figure 1: Estimation of the trajectory for post-2020 target levels for the CO<sub>2</sub> legislation for passenger cars for different levels of the required contribution of passenger cars to meeting the overall reduction target for transport of 60% by 2050. The assumed share of biofuels in the fuel for passenger cars is 40% in 2050.

#### 4.1.2 Intermediate targets in function of the required reduction by 2050

Table 3 lists the assumptions for scenarios a), b) and c) for which the post 2020 trajectories are displayed in Figure 1. The resulting intermediate target levels and required minimum shares of EVs are summarized in Table 4.

Table 3: Assumptions for scenarios a), b), and c), for the case of 40% biofuels in the fuel for ICEVs in 2050

**40% biofuels in 2050**

Scenario	Fleet average IPCC CO <sub>2</sub> emission	reduction of pass. car CO <sub>2</sub> emissions	Pass. car traffic volume growth	Fleet average IPCC CO <sub>2</sub> emission
	1990	2050 - 1990	2050 - 1990	2050
[#]	[g/km]	[%]	[%]	[g/km]
a)	180	-60%	+80%	66.7
b)	180	-70%	+80%	50.0
c)	180	-80%	+80%	33.3

Table 4: Intermediate target levels and required EV shares in 2050 for scenarios a), b), and c), for the case of 40% biofuels in the fuel for ICEVs in 2050

**40% biofuels in 2050**

Scenario	EVs share	TA CO <sub>2</sub> target (TTW)		
	2050	2025	2030	2035
[#]	[%]	[g/km]	[g/km]	[g/km]
a)	5%	86	76	67
b)	29%	80	65	50
c)	52%	74	54	33

A required reduction target of 80% for passenger cars is found to lead to intermediate targets that cannot be met without a significant share of EVs (around 50% of all new vehicles in 2035 and of the entire fleet in 2050). If on the hand passenger cars emissions would only need to be reduced by 60% in 2050, the required TTW CO<sub>2</sub> target for 2035 and beyond would be just below 70 g/km. Such targets can be achieved with a small share of EVs or possibly even without alternative vehicles, if in the longer term the CO<sub>2</sub> emissions of ICEVs would be reduced to below 70 g/km, either by applying reduction options not yet foreseen or by changes in the average size or performance of vehicles.

Intermediate targets below 70 g/km will require a share of LEVs to be introduced. As can be seen from Table 3, this is only the case from 2030 onwards for the scenarios assessed here.

## 4.2 Sensitivity to the share of biofuels available for passenger cars in 2050

The assessments in the previous section were made under the assumption that by 2050 40% of the fuel consumed by ICEVs would be biofuels.

How much a given share of biofuels in the fuel used by ICEVs (and PHEVs) actually is in 2050 depends on:

- the volume of passenger car mobility (vkm);
- the fuel consumption of ICEVs (per km);
- the share of ICEVs in the passenger car fleet (%).

In 2010 the average share of biofuels in transport fuels used in the EU-27 was 4.3%.

Using the general assumptions underlying the calculations presented above, specifically with respect to vehicle kms in 2050, and assuming a LEV share of around 40% by that date, the total amount of biofuels used by cars in 2050 is roughly three times the absolute amount used in 2010. The “40% biofuels” assumption is thus still relatively conservative.

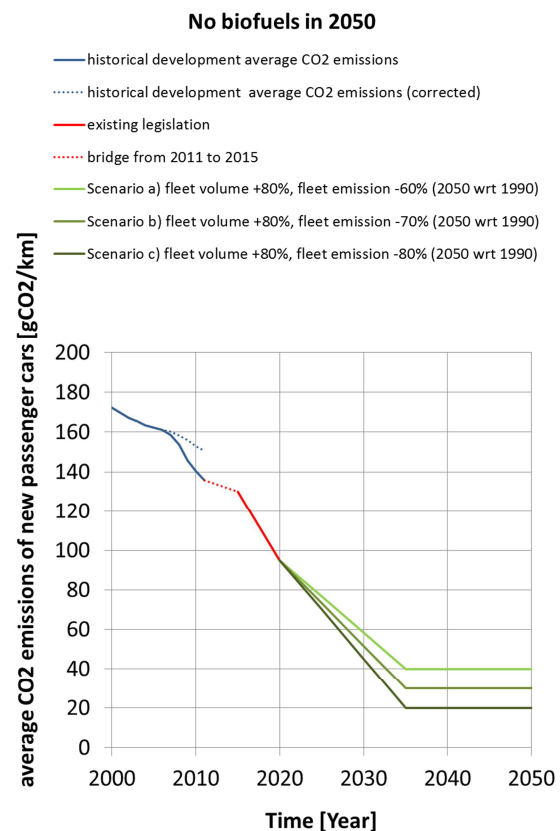


Figure 2: Estimation of the trajectory for post-2020 target levels for the CO<sub>2</sub> legislation for passenger cars, under the assumption that biofuels are not used to fuel passenger cars in 2050.

Sustainably produced biofuels will most likely not be abundantly available in the next decades. One of the strategic choices in the EU White Paper is to



reserve the use of such biofuels to transport modalities where less other de-carbonisation options are available than in passenger cars. To assess how such a strategy affects the amount of LEVs necessary to meet the target, Figure 2 shows the results of a calculation in which it is assumed that no biofuels are used in 2050. Scenario assumptions are summarized in Table 5, while the resulting EV shares and intermediate targets are listed in Table 6.

Table 5: Assumptions for scenarios a), b), and c), for the case of 0% biofuels in the fuel for ICEVs in 2050

0% biofuels in 2050				
Scenario	Fleet average IPCC CO <sub>2</sub> emission	reduction of pass. car CO <sub>2</sub> emissions	Pass. car traffic volume growth	Fleet average IPCC CO <sub>2</sub> emission
	1990	2050 - 1990	2050 - 1990	2050
[#]	[g/km]	[%]	[%]	[g/km]
a)	180	-60%	+80%	40
b)	180	-70%	+80%	30
c)	180	-80%	+80%	20

Table 6: Intermediate target levels and required EV shares in 2050 for scenarios a), b), and c), for the case of 0% biofuels in the fuel for ICEVs in 2050

0% biofuels in 2050				
Scenario	EVs share	TA CO <sub>2</sub> target (TTW)		
	2050	2025	2030	2035
[#]	[%]	[g/km]	[g/km]	[g/km]
a)	43%	77	58	40
b)	57%	73	52	30
c)	71%	70	45	20

Without biofuels in the fuel for ICEVs in 2050 intermediate targets need to more than 40% lower than in the previous case with 40% biofuels in 2050. Required EV shares in the 2050 fleet (and the 2035 new vehicle sales) are also significantly higher. In this case even a 60% reduction of the CO<sub>2</sub> emissions of the passenger car fleet requires 43% EVs. For a reduction of 80% more than 70% EVs will be necessary.

In this case intermediate targets for 2025 still do not force manufacturers to market LEVs. Targets for 2030 and 2035, however, are lower than in the case with biofuels, and will require a finite share of LEVs in the new vehicle fleet.

### 4.3 Sensitivity to growth in passenger car transport volume until 2050

A third critical parameter in the assessment is the assumed growth of passenger car kilometres until 2050. This transport volume growth depends on economic growth, but is also expected to be affected by changing consumer preferences, the availability and use of other transport modes and e.g. demographic and spatial developments. Figure 3 indicates a bandwidth of scenarios used in a range of European studies.

Recently very preliminary findings have been reported that seem to indicate the occurrence of what is called “peak car” in the US and Europe ([12] and [13]). This term stands for a levelling off and possible future decline in passenger car ownership and use. This development is highly uncertain and speculative, but for illustrative purposes a “peak car” scenario has been included in Figure 3, and in the assessments presented in Figure 4.

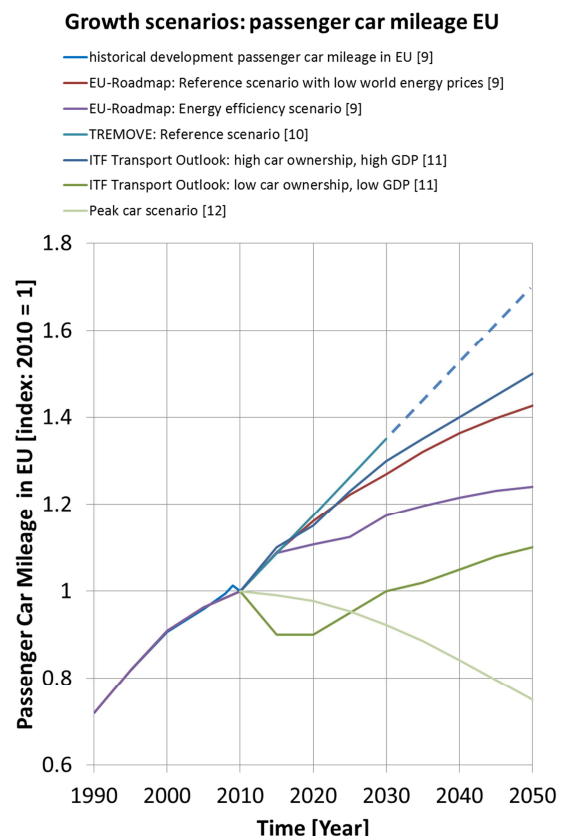


Figure 3: Bandwidth of scenario projections for the development of vehicle kilometres driven by passenger cars in EU-27 until 2050.

Scenario assumptions are summarized in Table 7, while the resulting EV shares and intermediate targets are listed in Table 7.

All scenarios are for a reduction of passenger car emissions in 2050 by 80% relative to 1990, and the case of no biofuels. Scenario d) is the speculative “peak car” scenario in which passenger car transport levels off and reduces to 1990 levels in 2050. Scenarios e), f) and g) assume net volume growths of 10%, 50% and 100% respectively. These scenarios are compared to the scenario c) which assumes an 80% volume growth consistent with the White Paper scenario.

Clearly, lower assumed volume growths lead to higher post-2020 targets. However, even in the “peak car” scenario 80% reduction still requires a 2035 target that in the longer term results in almost 50% EVs in the fleet. This leads to the conclusion that the share of EVs required to meet long term CO<sub>2</sub> reduction targets for passenger cars is more sensitive to the assumed contribution of passenger cars to the overall transport target than to the growth in transport volume.

Table 7: Assumptions for scenarios d) to g), for the case of 0% biofuels in the fuel for ICEVs in 2050

#### 0% biofuels in 2050

Scenario	Fleet average IPCC CO <sub>2</sub> emission	reduction of pass. car CO <sub>2</sub> emissions	Pass. car traffic volume growth	Fleet average IPCC CO <sub>2</sub> emission
	1990	2050 - 1990	2050 - 1990	2050
[#]	[g/km]	[%]	[%]	[g/km]
d)	180	-80%	0%	36
e)	180	-80%	+10%	33
f)	180	-80%	+50%	24
g)	180	-80%	+100%	18

Table 8: Intermediate target levels and required EV shares in 2050 for scenarios d) to g), for the case of 0% biofuels in the fuel for ICEVs in 2050

#### 0% biofuels in 2050

Scenario	EVs share	TA CO <sub>2</sub> target (TTW)		
	2050	2025	2030	2035
[#]	[%]	[g/km]	[g/km]	[g/km]
d)	49%	75	56	36
e)	53%	74	53	33
f)	66%	71	48	24
g)	74%	69	44	18

#### No biofuels in 2050

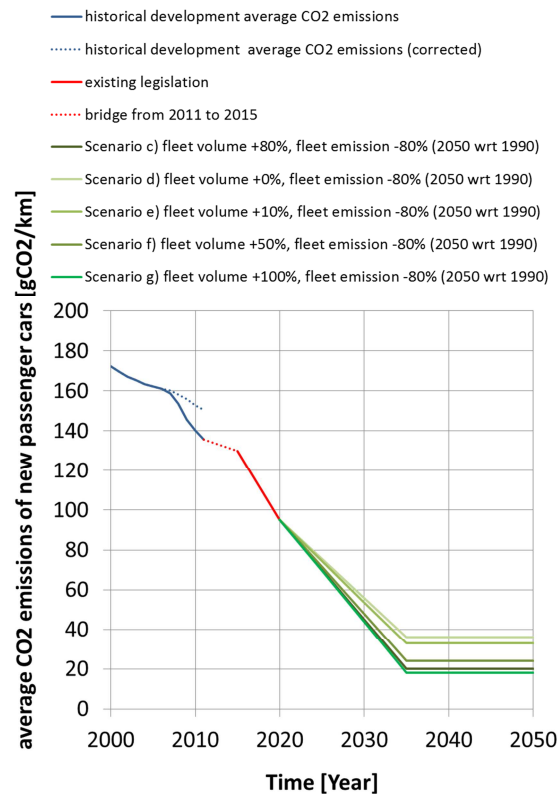


Figure 4: Estimation of the trajectory for post-2020 target levels for the CO<sub>2</sub> legislation for passenger cars, for different scenarios with respect to the development of the volume of passenger car transport.

The above observations are less prominent in the case when the fuel for ICEVs contains 40% biofuels in 2050. Results for that case are listed in Tables 9 and 10. But even with biofuels for passenger cars the “peak car” scenario would still require 14% EVs to achieve an overall reduction of passenger car CO<sub>2</sub> emissions by 80% relative to 1990.

Table 9: Assumptions for scenarios d) to g), for the case of 40% biofuels in the fuel for ICEVs in 2050

#### 40% biofuels in 2050

Scenario	Fleet average IPCC CO <sub>2</sub> emission	reduction of pass. car CO <sub>2</sub> emissions	Pass. car traffic volume growth	Fleet average IPCC CO <sub>2</sub> emission
	1990	2050 - 1990	2050 - 1990	2050
[#]	[g/km]	[%]	[%]	[g/km]
d)	180	-80%	0%	60.0
e)	180	-80%	+10%	54.5
f)	180	-80%	+50%	40.0
g)	180	-80%	+100%	30.0



Table 10: Intermediate target levels and required EV shares in 2050 for scenarios d) to g), for the case of 40% biofuels in the fuel for ICEVs in 2050

40% biofuels in 2050				
Scenario	EVs share	TA CO <sub>2</sub> target (TTW)		
	2050	2025	2030	2035
[#]	[%]	[g/km]	[g/km]	[g/km]
d)	14%	83	72	60
e)	22%	82	68	55
f)	43%	77	58	40
g)	57%	73	52	30

## 5 Considerations on WTW CO<sub>2</sub> based metric and other alternative metrics

The assessments presented above are all based on the assumption that the CO<sub>2</sub> regulation for passenger cars will remain to be based on TTW CO<sub>2</sub> emissions. A TTW CO<sub>2</sub> based metric, however, has certain disadvantages.

First of all it does not provide control over the net WTW GHG emission impacts of the regulation. EVs and FCEVs count as zero-emission under a TTW based metric, but have finite WTW emissions due to upstream emissions in the production of electricity and hydrogen. If a target is met by given shares of ICEVs (with some level CO<sub>2</sub> reducing technologies applied) and LEVs, increasing the share of LEVs allows OEMs to produce ICEVs with higher CO<sub>2</sub> emissions. As a result of this, and because of the non-zero WTT emissions of LEVs, the average WTW emissions of new vehicles increase with an increasing share of LEVs under a TTW based metric. Under a WTW CO<sub>2</sub> based WTW emissions obviously do not depend on the mix of technologies that is used to meet the target.

In [3] it has been shown that the “CO<sub>2</sub> leakage” of a TTW CO<sub>2</sub> based metric is most pronounced in the short to medium term (up to 2030), when WTT emissions from electricity generation and hydrogen production (through steam reforming of natural gas) are still high. With increasing shares of renewables in the production of these energy carriers the effect is reduced.

A second disadvantage of a TTW CO<sub>2</sub> based metric is that it tends to over-incentivise the marketing of LEVs, in the sense that OEMs might be stimulated to market larger shares of

LEVs than the share that would be most cost effective from a societal point of view.

Besides a TTW and WTW CO<sub>2</sub> based metric, also TTW and WTW energy based metrics are conceivable. In [4] the alignment of cost optimal LEV shares from a manufacturer, and end-user and a societal perspective is analysed for a range of metrics. Comparing these metrics on a range of criteria shows a complex picture, and leads to the conclusion is that none of the alternative metrics score significantly better overall.

## 6 Conclusions

From the analysis of a wide range of scenarios it can be concluded that EVs and other low emission vehicles such as PHEVs and FCEVs can be expected to play a prominent role in achieving the long term CO<sub>2</sub> reduction goal for transport.

Without biofuels generally a LEV share of 40 to 70% is necessary in 2050 to reduce the direct emissions of the passenger car fleet by 60 to 80% compared to 1990. Assuming 40% biofuels a reduction of 60% between 1990 and 2050 is feasible with a limited share of LEVs and a 2030 target of 70 g/km. For higher reductions than 60% a lower 2035 target is needed, leading to a higher share of LEVs in 2050.

Under a lower assumption for the growth of the number of car kilometres and a higher assumption for the biofuel share a 60% target for passenger cars in 2050 is in principle feasible without LEVs. Nevertheless the most likely scenarios do require a significant share of LEVs to allow passenger cars to realize their required contribution to meeting the European Commission’s overall goal of reducing transport greenhouse gas emissions by 60% in 2050 relative to 1990.

Besides on the available share of biofuels in the fuel for ICEVs in 2050, the required intermediate target levels strongly depend on the assumed growth in vehicle kilometres between 1990 and 2050, and on the expected extent to which additional reductions in passenger cars are necessary to compensate for lower reductions than 60% in other subsectors. The sensitivity to the latter appears stronger than the impact of volume growth.

The analysis also seems to indicate that a 60% target for transport sector does not automatically put sufficient pressure on the system to reach other

goals of White Paper such as to “Halve the use of ‘conventionally-fuelled’ cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO<sub>2</sub>-free city logistics in major urban centres by 2030”. The combination of a 60% target level for transport and the sectoral target definition (according to IPCC) creates much more room for different ways of meeting the target than e.g. an 80% reduction based on WTW emissions.

EVs are currently in the early stage of market introduction, but the economic crisis and various other factors pose a significant risk of frustrating the further growth in market shares in coming years. Given that the EVs and other LEVs are to play a important role in achieving the climate goals for 2050, and knowing that the transition from early market formation to mass market volumes will take several decades, the proper choice of post-2020 targets under the CO<sub>2</sub> regulation for passenger cars can be a powerful instrument to support the transition. Sufficiently low post-2020 target can create a market pull and may help to avoid a “valley of death” for EVs. A continuous and stable increase in market share is necessary to support developments that lead to the cost reductions and product improvements that are necessary for enabling EVs to reach the large market shares needed by 2035 and beyond. A 2025 CO<sub>2</sub> target of at most 70 g/km, and a significantly lower target for 2030 to be announced as early as possible, will motivate manufacturers to continue their efforts in marketing and further development of EVs and other low emissions vehicles in the coming decade, in the knowledge that they will need to sell these vehicles in large quantities by 2025 and beyond.

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