CO_2 emission regulation for passenger cars

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Analysis and recommendation for the implementation of a CO_2 emission legislation with optimized environmental impact

IASTEC
international association of sustainable drivetrain and vehicle technology research

Executive Summary

The current CO_2 emission legislation[1] for passenger cars is leading to significantly increased real CO_2 emissions in comparison with the legislation limit (EUR-Lex, 2019). Real emissions including production and operation of the new vehicles will often be more than 3 times higher than the actual legislation limit in the year 2030 of e.g. 49 g_{CO2}/km.

As a consequence, the current legislation does not support an efficient further reduction of green-house gas emissions. The effects of the legislation therefore contradict the ambitious goals of the Paris climate protection agreement (EUR-Lex, 2016), (EUR-Lex, 2016), (Dröge S., 2015), which indispensably requests a cradle-to-cradle green house gas balancing.

For this reason, the CO_2 emission legislation must be comprehensively revised and developed on the basis of a correct physical balancing.

[1] The correct formulation is CO_2e (CO_2 equivalent emissions) including for instance N_2O or CH_4, which must be considered according to their greenhouse gas potential. For reasons of simplifications, CO_2 is always used instead of CO_2e in this report.

Boundary conditions of CO_2 regulation

The effective reduction of CO_2 emissions is the driving ambition to enable sustainable and environmentally friendly drivetrains of the future for transport applications including passenger cars. However, the current framework conditions lead to unsatisfactory economic, environmental and social consequences.

This paper therefore focuses on the effects of current CO_2 emission legislation and outlines proposed solutions for the development of a regulation with an improved environmental benefit.

The CO_2 legislation for passenger cars regulates a variety of technical solutions, including MHEV, HEV, PHEV[2] and classic internal combustion engine drivetrains besides BEV[3] applications. The complexity of technical solutions has continuously increased in recent years as technical progress has been transformed into new developments.

However, the synthetic legislation does not take real CO_2 emissions into account. The following introduction explains the current situation with a focus on the 2030 regulation (EUR-Lex, 2019). This report demonstrates the results of current legislation which is leading to unsatisfactory real emissions and falls far short of the envisaged target value based on the Paris Climate agreement! The ttw[4] approach only considers CO_2 emissions of Non-BEV[5] vehicles and neglects important impacts of BEV vehicles.

First of all, the influence of the legislation on the resulting fleet targets of the manufacturers is decisive.

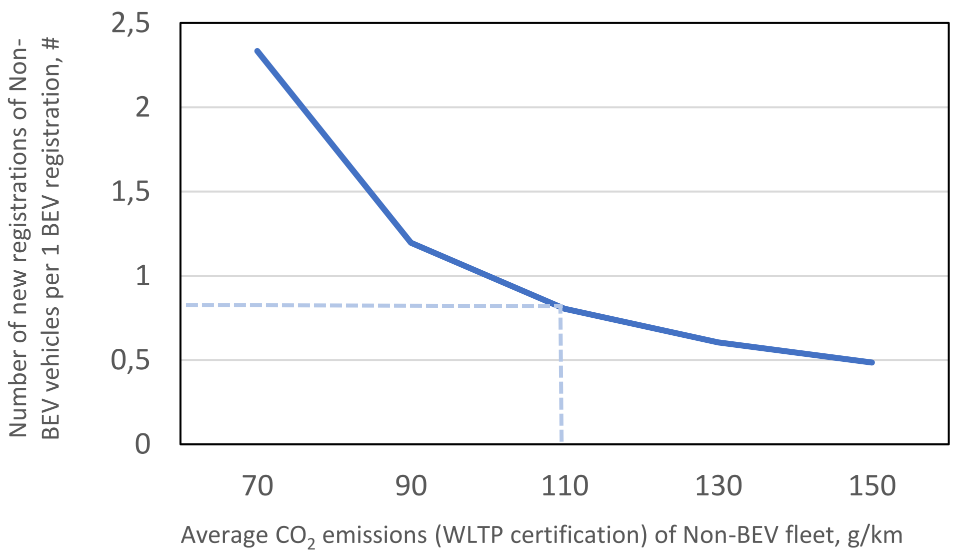

Figure 1:
Year 2030: Number of new registrations of Non-BEV vehicles per 1 new BEV registration WLTP
Further assumptions:
no CO_2-penalties assumed,
no certificate influence on sales strategy,
no additional super-credits,
fixed fleet CO_2-limit of e.g. 49 g_{CO2}/km with no detailed influence of vehicle weight

[2] MHEV: mild hybrid electric vehicle, HEV: hybrid electric vehicle, PHEV: plugin hybrid electric vehicle,
[3] BEV: battery electric vehicle, also known as „electric car“
[4] ttw: tank-to-wheel legislation only considers the CO_2 emissions of the vehicle itself and does not consider the impact of infrastructure, production, energy delivery and recycling.
[5] Non-BEV vehicle: MHEV, HEV, PHEV, gasoline and diesel drivetrains

It is depicted in Figure 1, that the registration of one new BEV in the year 2030 enables the additional registration of e.g. 0.8 Non-BEV vehicles with an average CO_2 registration value of 110 g_{CO2}/km. In other words, it is necessary to place 1.24 BEV vehicles on the market for every Non-BEV vehicle under these boundary conditions[6].

As a consequence, this proportion between BEV and NON-BEV vehicles will significantly determine for instance:

- the dependence on important raw materials including foreign processes especially for battery production,
- the necessity of further tax subsidies in order to stimulate consumer behavior etc.,
- significant infrastructure efforts with partly undefined environmental influence,
- the value creation (profit margin) and the economic situation of important suppliers (TIER) including the manufacturer (OEM),
- significant direct and indirect impact on GDP via cost of transportation,
- unknown impact on society due to significant influence on the industrial sector.

In addition to the serious impact on economic and social issues, the question of the real CO_2 emissions of the future vehicle fleet must be clarified (IASTEC, 2021).

Analysis of the total CO_2 emissions resulting from the current CO_2 emission legislation

The fleet CO_2 limit of e.g. 49 g_{CO2}/km is based on the tailpipe emissions. This limit value represents the maximum permitted average CO_2 emissions of a manufacturer´s entire new vehicle fleet in the year 2030, with BEV vehicles weighted at 0 g_{CO2}/km. The BEV contribution is therefore not considered, even it can often be significantly higher than 100-150 g_{CO2}/km. A significant increase of real CO_2 emissions in comparison with the synthetic limit value remains an unsatisfying consequence of current legislation e.g. due to the impact of vehicle production, the CO_2 emissions of the electricity sector including the various power plants, infrastructure and additional issues.

Figure 2 illustrates the total CO_2 emissions after a lifetime of 210.000 km of a BEV for a wide range of different electricity generation systems. As discussed in a couple of publications (Holland S., 2022) (VDI, 2023) (IASTEC, 2022), the often utilized mean electric CO_2 footprint calculation significantly underestimates the CO_2 emissions of additional electrical energy requirement. The resulting CO_2 emissions roughly double the averaged mean value published. Considering a variety of impacts like CO_2 impact of infrastructure construction, significant request for load reserve for modern power plant applications, thermomanagement of BEV vehicles etc. on the one hand and ETS[7] system influence with a complex cap and trade impact on the other hand a factor of 1,5, considering the real interaction of additional electrical consumers on CO_2 emissions, acts as a compromise, although the real CO_2 emissions of electrical consumers are significantly higher.

Please note that overall CO_2 emissions of e.g. 33 tons after 210.000 km are equivalent to 157 g_{CO2}/km, even though the limit is 49 g_{CO2}/km!

[6] This important ratio is defined by the average fleet certification value, which is assumed to be 49 g_{CO2}/km for WLTP and remains constant for the analysis of this report. In addition, the weight influence, allowing higher CO_2 emissions with increasing vehicle weight, is not part of the discussion of this document.
[7] The European Trading System ETS is a cap and trade system to minimize emissions via a carbon market.

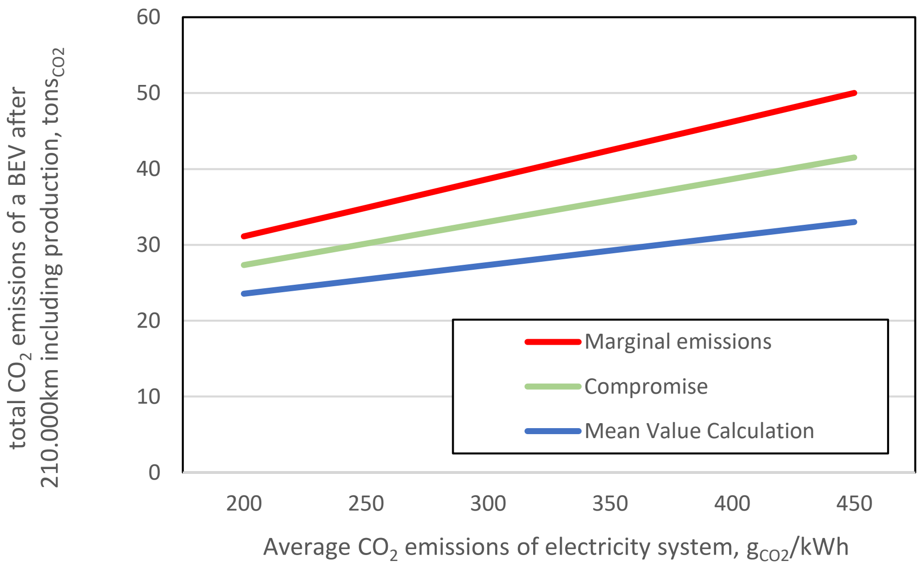

Figure 2:
Total CO_2 emissions of a BEV after 210.000 km as a function of the footprint of the electric energy system including production
Further assumptions:
Energy request of BEV: 18 kWh/100 km
Production of BEV drivetrain (65kWh): 16 $tons_{CO2}$
Compromise (green graph) scales the electricity system CO_2 footprint mean value by a factor of 1.5

The resulting analysis is a consequence of the previous two figures. As explained above Figure 1 shows the direct correlation between BEV vehicles to be sold according to the CO_2 legislation in the year 2030 and resultant sales of Non-BEV vehicles made possible. Figure 2 shows the CO_2 emissions of a BEV vehicle over its operating duration as a function of the electricity system, whereby in reality the CO_2 footprint of electricity systems typically decreases over the years due to the continuous improvements of various power plants.

As a consequence of these results Figure 3 illustrates the averaged CO_2 emissions from the resulting fleet mix of BEV and Non-BEV vehicles in the year 2030. This CO_2 emission analysis of the new car fleet is a function of the CO_2 emissions of the Non-BEV vehicle on the one hand (according to figure 1) and the footprint of the electricity system on the other (according to figure 2). Figure 3 also contains the influence of the drivetrain production leading to an impact of 76 g_{CO2}/km (BEV with a production impact of 16 $tons_{CO2}$ related to the distance of 210.000 km) and 38 g_{CO2}/km (Non-BEV with a production impact of 8 $tons_{CO2}$ related to 210.000 km) (VDI, 2023).

Assuming an ambitious average electric footprint over the years of 300 g_{CO2}/kWh, the real average CO_2 emissions of a new car fleet in the year 2030 easily exceed 150 g_{CO2}/km, although a fleet value of 49 g_{CO2}/km has been defined and Non-BEV vehicle are operated with e.g. 110 g_{CO2}/km, according to the WLTP result. The effects of the legislation therefore contradict the goals of the Paris climate protection agreement to effectively reduce greenhouse gas emissions.

The current legislation shows a significant parallel to the NEDC based NO_x emission legislation in 2007 for EURO5 and EURO6 certification, which also had been leading to intensive amount of additional NO_x emissions. This has also been well known from the beginning and has finally caused misleading technology developments (WKM, 2024).

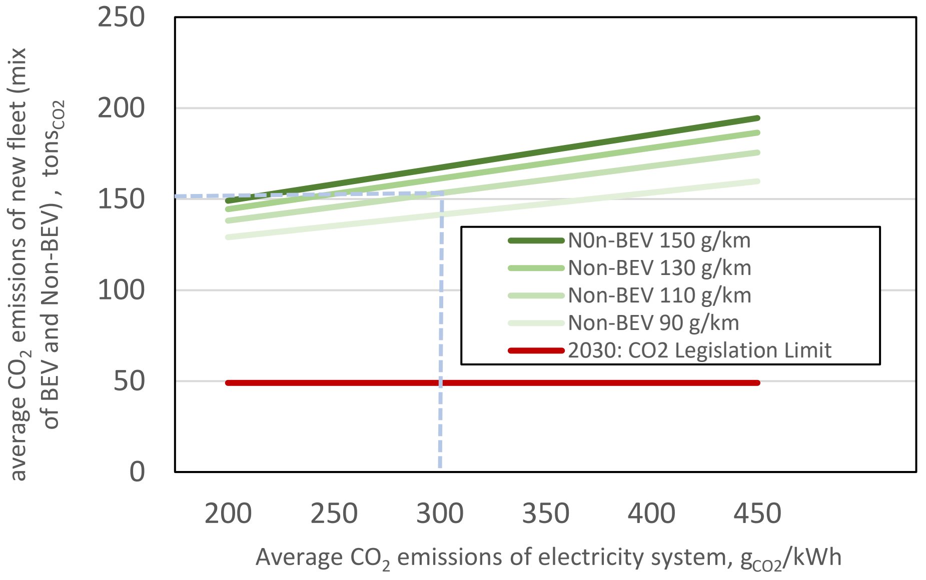

Figure 3:
Average CO_2 emissions of a new fleet after lifetime with a BEV / Non-BEV share in the year 2030 according to Figure 1
Further assumptions:
Energy request of BEV: 18 kWh/100 km
a compromise approach is applied again, scaling the electricity system CO_2 footprint mean value by a factor of 1.5
Production of BEV drivetrain: 16 $tons_{CO2}$
Production of Non-BEV drivetrain: 8 $tons_{CO2}$
No vehicle weight influence considered
No additional CO_2 benefit credits

Summary and recommendation for improved emission legislation leading to reduced overall CO_2 emissions for passenger cars

The following core statements can be derived from the analysis:

- The current ttw based legislation significantly underestimates the real CO_2 emissions of the new vehicle fleet of the future, especially in the year 2030. The lack of a physical basis of the legislation leads to significantly increased real CO_2 emissions in comparison with the emission limit.
- The legislation already has been leading to an undesirable development and strategies of the automotive industry, some of which even contradict the sustainability goals while at the same time fulfilling the legal framework conditions! Real emissions of the complete fleet of the new vehicles including production can be more than 3 times higher than the legislation limit of e.g. 49 g_{CO2}/km (assumption: average CO_2 emissions of electricity system: 300 g_{CO2}/kWh).
- The important influence of infrastructure construction has not been considered in this analysis.
- The contribution of PHEV vehicles has not been in the focus of this analysis as the market share is rather small. Instead, the CO_2 contribution of PHEVs is calculated in accordance with the specifications of the Non-BEV class, e.g. 110 g_{CO2}/km.
- The 2030 legislation in particular leads to a one-sided orientation of the automotive strategy. Rather, the legislation only partially leads to an improvement in the important reduction of CO_2 emissions.
- Due to the CO_2 pricing, the significantly increased real CO_2 emissions in comparison with the emission limit finally lead to considerable additional burden for EU citizens and the EU economy.

The significant legislative intervention in economies of scale is also having a considerable impact on the European supplier and automotive industry including further branches, with further measures such as taxonomy influence triggering additional adverse effects!

A rapid and comprehensive revision of CO_2 emissions legislation is urgently recommended, in particular due to the partially opposing environmental impact! It would probably take several years to develop a comprehensive, physically based cradle-to-cradle legislation that would comprehensively cover infrastructure construction as well as the production, operation and recycling of vehicles.

Therefore, the introduction of a new CO_2 emissions regulation is mandatory, which must be valid until 2030 at the latest. This new legislation should be characterized by the following contents if it is to provide the best possible benefit for environmental protection.

- A compatibility with the long-term goal of completely sustainable drivetrains and the goals of the Paris climate protection agreement is indispensable.
- In particular, a significant tightening of the CO_2 targets in comparison with the expected real emissions based on current legislation (Figure 3) is expressly recommended!
- At the same time, the limit values must be based on physical balance principles and provide a benefit for the development of highly efficient drivetrains.
- The current synthetic limit values correlate with implausible fuel consumption values, e.g. 1.8 l/100 km in the year 2030 and must be revised.
- Due to the complexity of the ctc[8] legislation and the requirements of the Paris climate protection agreement, at least a wtw[9] based analysis must be implemented with a simplified impact of production.
- This extended well-to-wheel based analysis requires the reimplementation of a Carbon correction factor in order to correctly map the real environmental impact of the energy carrier and to optimize the overall CO_2 emissions of a complex holistic system.
- The far-reaching consequences of a reorientation of the CO_2 emission legislation and the interaction with the complex development, production and supplier processes must be considered.
- With a new, intelligent CO_2 emissions legislation, Europe could take the lead in global technology again and set important automotive standards.

[8] ctc: cradle-to-cradle legislation considers production and recycling over lifetime including the use phase, which is typically modelled acording to a wtw approach.
[9] wtw: well-to-wheel legislation also considers the CO_2 footprint of the energy carrier (fuel production including transport) to the tank of the vehicle in addition to the ttw analysis.

Abbreviations

BEV	battery electric vehicle, also known as electric car
ctc	cradle-to-cradle analysis considers production, recycling and wtw analysis of use phase
ETS	European Trading system ETS is a cap and trade system to minimize emissions via a carbon market
GDP	gross domestic product represents the value of goods and services produced during a given period
HEV	hybrid electric vehicle has an additional battery and at least one additional electric motor
NEDC	new European driving cycle has been defined in the late 1980s and early 1990s and served since then as an emission test cycle with partly limited transferability to real emission behavior
MHEV	mild hybrid electric vehicle typically operates with a voltage of 48 Volt and a maximum electric power in the range of 5-25 kW
OEM	original equipment manufacturer often called automotive manufacturer
PHEV	plugin hybrid electric vehicle offers the possibility to charge the battery with external energy from the electricity sector
TIER	automobile supplier
ttw	tank-to-wheel analysis basically only considers the fuel consumption and typically neglects a comprehensive consideration of fuel production and transport
WLTP	worldwide harmonized light vehicles test procedure has been introduced in Europe in September 2017
wtw	well-to-wheel legislation also considers the CO_2 footprint of the energy carrier including transport (fuel production including transport) to the tank of the vehicle in addition to the ttw analysis

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