

The effect of ambient conditions and operating modes on the CO₂ emissions of plug-in hybrid vehicles

BACKGROUND

Recent studies show that there is a large gap between real-world and official type-approval CO₂ emissions from plug-in hybrid electric vehicles (PHEVs). The gap is due in part to the use of heating and air-conditioning systems, which are not assessed during type-approval. The use of these systems reduces the electric energy available for driving and contributes to a lower share of electric driving. A new study assesses, via testing of a representative PHEV, the effect of ambient temperature and use of air-conditioning on CO₂ emissions, electric energy consumption, and electric range. Furthermore, it analyzes how CO₂ emissions are affected by user-selectable operating modes, and how on-board fuel- and energy-consumption monitoring (OBFCM) data recorded by the vehicle can be used to assess the real-world usage of PHEVs.

KEY FINDINGS

- » When starting with a fully charged battery under an ambient temperature of 23 °C and at a temperature of 35 °C with the use of air conditioning, the tested vehicle first operates purely electric until the battery is almost depleted. This results in low CO₂ emissions during charge-depleting mode of 2 g/km and 10 g/km, respectively. When the test is started with an empty battery, therefore operating in charge-sustaining mode, the CO₂ emissions increase by 22%, from 155 g/km to 190 g/km, when tested at the same ambient conditions. The official CO₂ value, determined by weighting the charge-depleting and charge-sustaining CO₂ emissions by the distance share in these modes, increases from 43 g/km at 23 °C to 57 g/km at 35 °C, or by 34%.
- » When the vehicle was tested at a temperature of -5 °C while using cabin heating, the combustion engine was used intermittently from the start of the test, presumably to warm up the catalyst. In combination with the lower available electric energy for propulsion, this change in operating strategy results in charge-depleting CO₂ emissions of 94 g/km, or more than 40 times higher than at 23 °C. In combination with the CO₂ emissions increase of 30%, from 155 g/km to 201 g/km in charge-sustaining mode, the official weighted CO₂ emissions at -5 °C almost triples compared to 23 °C, from 43 g/km to 122 g/km. These results are based on the assumption of daily recharging; real-world CO₂ emissions can be even higher if charged less frequently.

- » Testing the vehicle in driver-selected charge-increasing mode showed the battery was primarily charged using the combustion engine. Consequently, the additional fuel consumed for generating the electric energy increased the CO₂ emissions by 60%, from 154 g/km to 246 g/km, compared to operation in charge-sustaining mode. By charging the vehicle battery in charge-increasing mode, 2.5 to 2.8 times more CO₂ is emitted than if charging with EU grid energy. Unexpectedly, the combustion engine was also used to charge the battery when sports vehicle- and transmission-mode was selected, even when charge-increasing mode was not engaged.
- » The analysis also showed that OBFCEM data recorded on the test vehicle can be used to derive parameters that characterize the real-world usage of a PHEV, which can be used to determine deviations from official type-approval values.

To achieve more realistic official PHEV CO₂ emission values, type-approval should address the effects of ambient temperatures and air-conditioning use on fuel and energy consumption as well as on electric range. As a short-term solution, the PHEV utility factor should be adapted to better reflect the real-world usage. In addition, charge-increasing modes using the combustion engine for recharging the battery should be prohibited and the effect of other user-selectable operating modes, such as sports mode, on CO₂ emissions should be considered during type-approval to better reflect real-world operation.

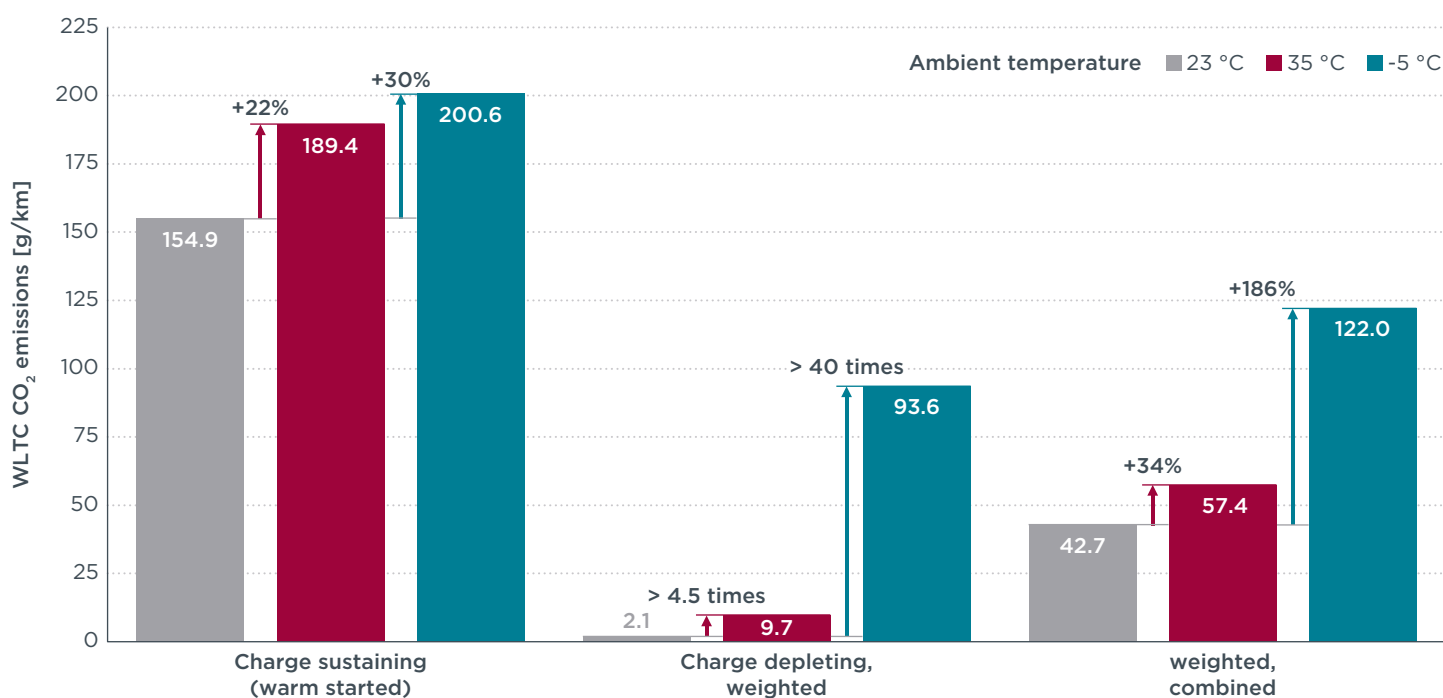


Figure. Effect of ambient temperature and use of air-conditioning on WLTC CO₂ emissions. The data shown uses the second WLTC of the charge-depleting sequence as transition cycle for all temperatures, and the utility factor is therefore 0.73.

PUBLICATION DETAILS

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