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Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles – learnings for stakeholders

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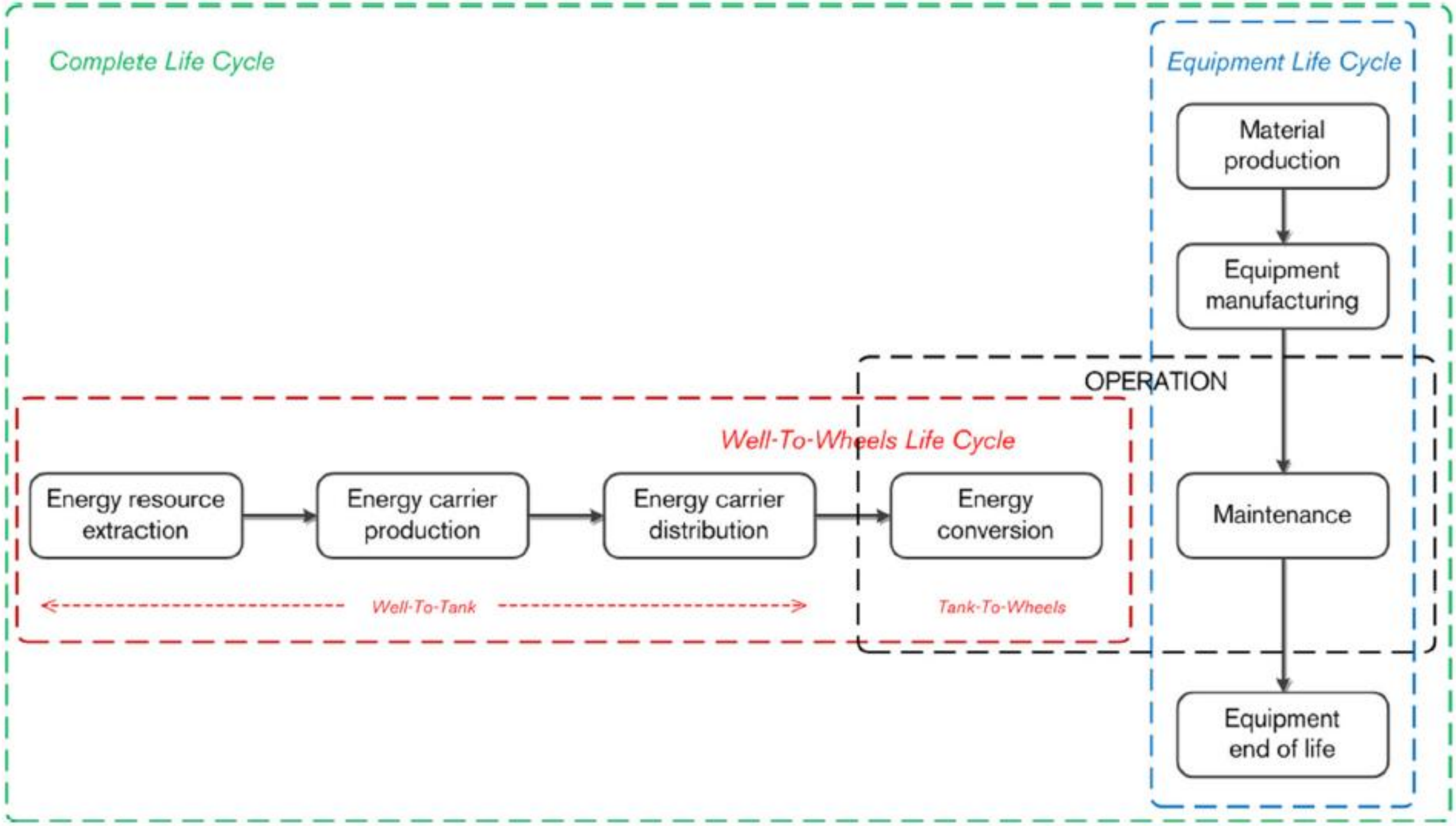


Fig. 1 Simplified view of the well-to-wheels and equipment flows (a more detailed view would include, for example, recycling options)

Well-To-Wheels life cycle

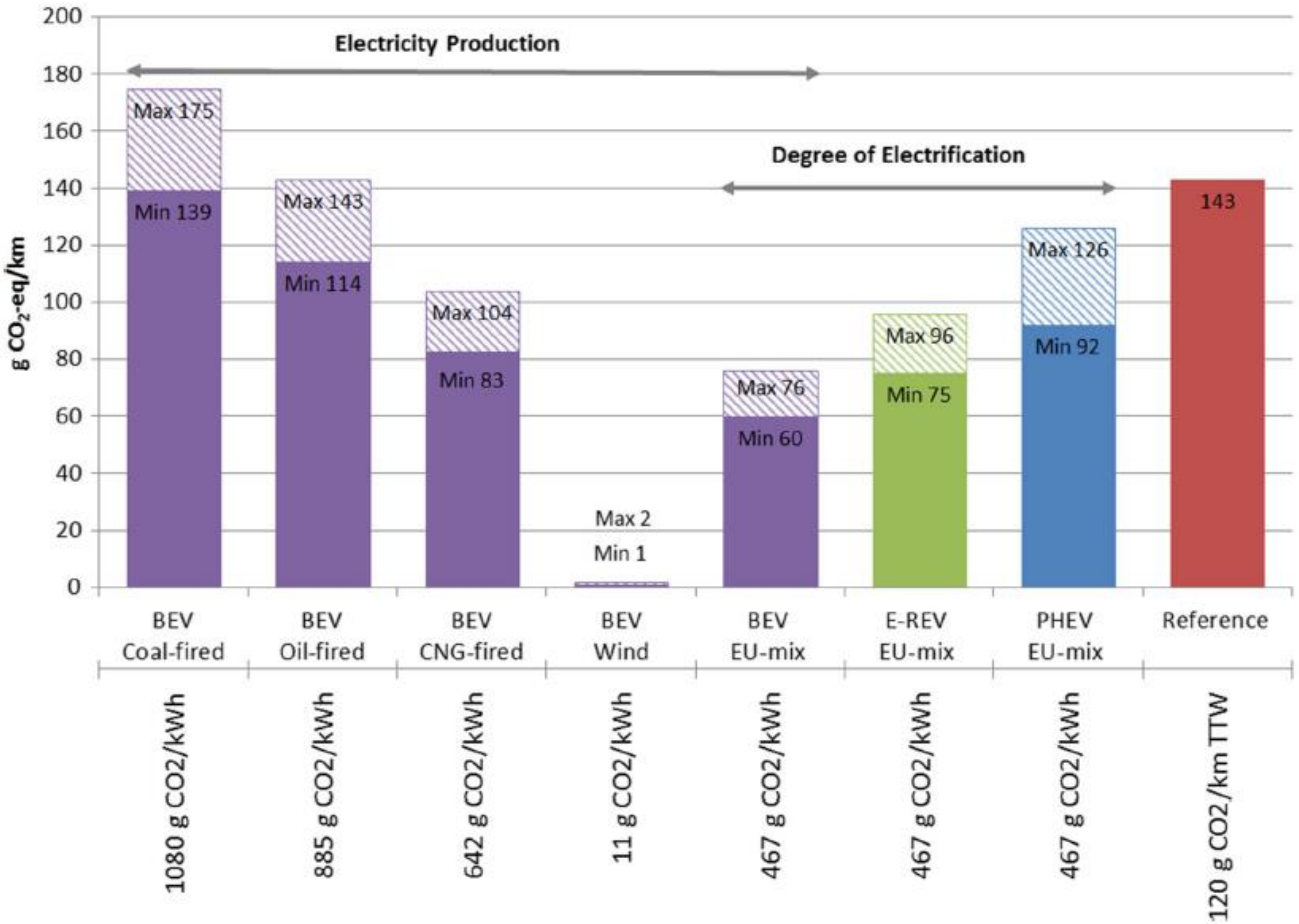


Fig. 2 WTW GHG emissions for different electricity production and degrees of electrification. To the *right*, BEV, E-REV, and PHEV values using the EU average electricity mix of 2008 (467 g CO2-eq./kWh), according to Edwards et al. (2011b). To the *left*, BEV data has been recalculated for different types of electricity production (Dones et al. 2007). The reference vehicle corresponds to the 2012 EU fleet target for tailpipe emissions of sold cars (European Parliament 2008). For detailed information, see Electronic Supplementary Material

Compete life cycle

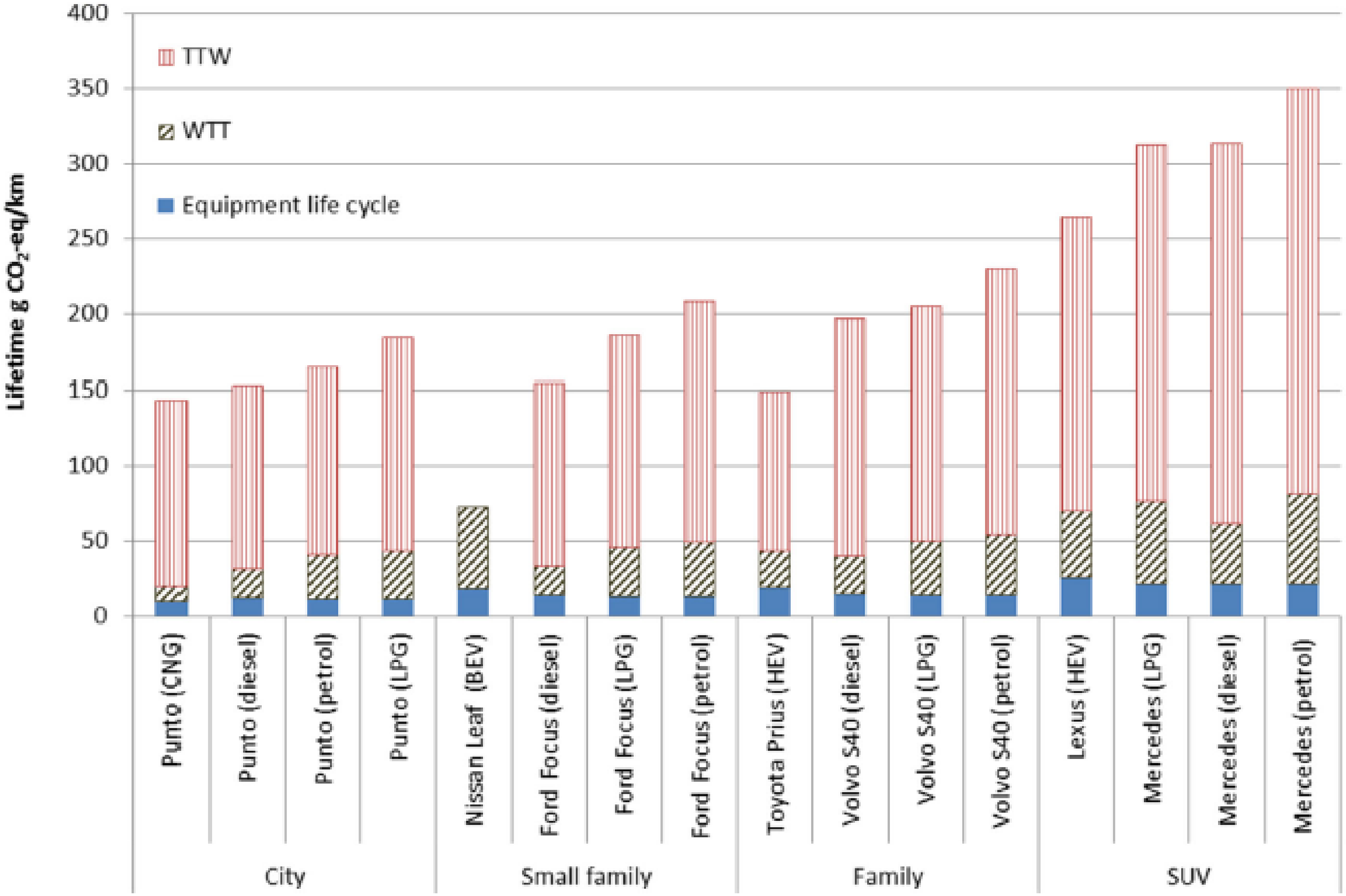


Fig. 4 Passenger cars divided into typical segments (Belgian Ecoscore classification) showing the general trend in CO_2-emissions for the complete life cycle divided into WTT, TTW, and equipment life cycle based on the CLEVER study (Van Mierlo et al. 2009). An average vehicle lifetime of 230,500 km corresponding to 13.7 years has been used, based on statistical data from the Belgian vehicle registration database. Fuel consumption is based on NEDC data. The Nissan Leaf BEV has been assumed to be charged with EU-mix electricity. For detailed information, see Electronic Supplementary Material

Broader impact assessment

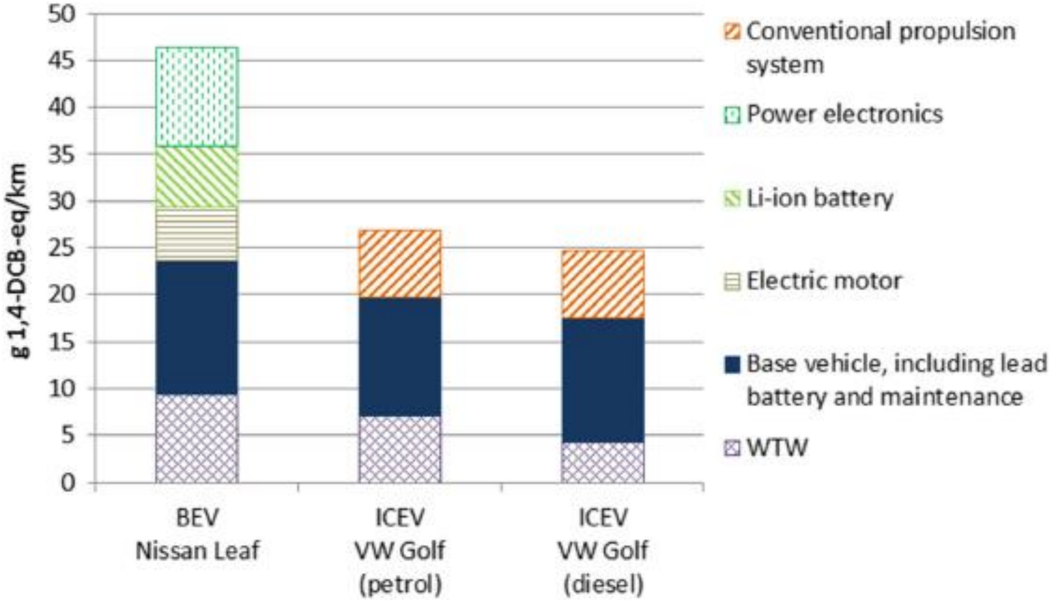
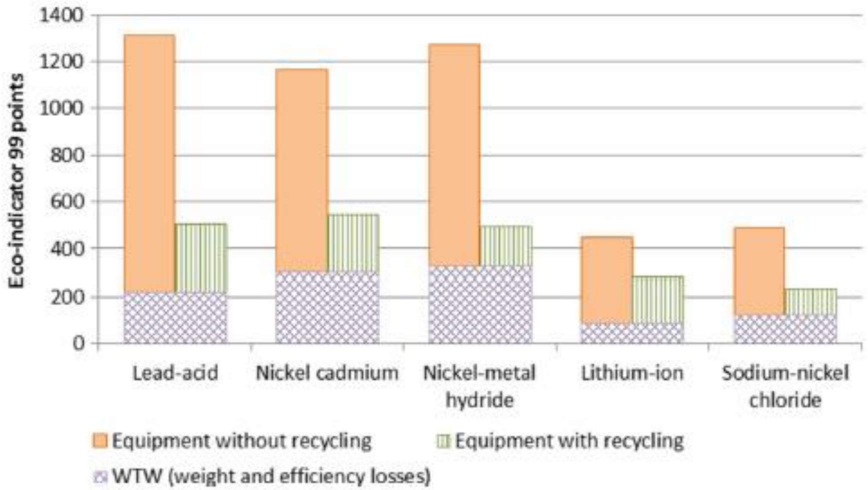


Fig. 6 Results for human toxicity potential comparing compact class vehicles for different powertrain options (Messagie 2013). For calculation of WTW life cycle values for the BEV, a vehicle life distance of 209,470 km charged with 2011 Belgian electricity mix has been assumed. All petrol and diesel are Euro 5 standard. For detailed information, see Electronic Supplementary Material

Fig. 7 Eco-indicator'99 results with and without highly efficient recycling for the environmental score of different battery types—all dimensioned to provide 60 km range at an 80 % depth of discharge for an 888 kg electric car (excluding the weight of the battery) and a vehicle life distance of 180 000 km with 3,000 charge–discharge cycles. The WTW stage corresponds to the amount of European mix electricity needed to cover internal losses and carry the weight of the battery itself (Van den Bossche et al. 2006). For detailed information, see Electronic Supplementary Material



Key conclusions

A large scale deployment of electric vehicles without making electricity production essentially free from emissions of fossil carbon, is insufficient to mitigate global warming as regards individual mobility.

- Many uncertainties relating to resource handling suggest that it will become targeted for improvements.
- Recycling may avoid future constraints on key resources and reduce production energy demand, but the realization of efficient recycling remains as a future challenge.

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MODERN INDIVIDUAL MOBILITY

Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles—what can we learn from life cycle assessment?

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Abstract

Purpose The purpose of this review article is to investigate the usefulness of different types of life cycle assessment (LCA) studies of electrified vehicles to provide robust and relevant stakeholder information. It presents synthesized conclusions based on 79 papers. Another objective is to search for explanations to divergence and "complexity" of results found by other overviewing papers in the research field, and to compile methodological learnings. The hypothesis was that such divergence could be explained by differences in goal and scope definitions of the reviewed LCA studies.

Methods The review has set special attention to the goal and scope formulation of all included studies. First, completeness and clarity have been assessed in view of the ISO standard's (ISO 2006a, b) recommendation for goal definition. Secondly, studies have been categorized based on technical and methodological scope, and searched for coherent conclusions.

Results and discussion Comprehensive goal formulation according to the ISO standard (ISO 2006a, b) is absent in most reviewed studies. Few give any account of the time scope, indicating the temporal validity of results and conclusions. Furthermore, most studies focus on today's electric vehicle technology, which is under strong development. Consequently, there is a lack of future time perspective, e.g., to advances in material processing, manufacturing of parts, and changes in electricity production. Nevertheless, robust assessment conclusions may still be identified. Most obvious is that electricity production is the main cause of environmental impact for externally chargeable vehicles. If, and only if, the charging electricity has very low emissions of fossil carbon, electric vehicles can reach their full potential in mitigating global warming. Consequently, it is surprising that almost no studies make this stipulation a main conclusion and try to convey it as a clear message to relevant stakeholders. Also, obtaining resources can be observed as a key area for future research. In mining, leakage of toxic substances from mine tailings has been highlighted. Efficient recycling, which is often assumed in LCA studies of electrified vehicles, may reduce demand for virgin resources and production energy. However, its realization remains a future challenge.

Conclusions LCA studies with clearly stated purposes and time scope are key to stakeholder lessons and guidance. It is also necessary for quality assurance. LCA practitioners studying hybrid and electric vehicles are strongly recommended to provide comprehensive and clear goal and scope formulation in line with the ISO standard (ISO 2006a, b).

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Questions?