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Energy savings by light-weighting - 2016 Update

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Executive Summary

Current political targets and societal voices call for a substantial reduction in energy consumption and greenhouse gas emissions from the transport sector. The reduction of the weight of transport vehicles is one way to reduce the energy consumption and thus CO_2 emissions caused by transport vehicles and associated upstream processes. Several studies have already been carried out by ifeu to investigate potential energy savings by light-weighting (see [ifeu, 2004a], [ifeu, 2004b], [ifeu, 2005]). Since the previous studies were conducted more than ten years ago and modelling capacities for more differentiated and better comparable results have advanced, an update of reference values of specific energy savings by light weighting has been undertaken. Also corresponding use cases for life-time energy and CO_2 savings have been calculated. The means by which the weight of vehicles is reduced (e.g. material choices, specifics of component design, etc.) have not been considered in this study.

The modelling approach followed in this study delivers consistent energy saving reference values for a range of drive cycles. These include data on hybrid and electric vehicles, which have been underrepresented in previous studies. The following conclusions for light-duty vehicles can be drawn from the results:

- As expected, direct fuel savings are highest for dynamic applications at low speed (e.g. WLTP Urban, FTP-75 and JP10-15 cycle) and lower for highway driving (e.g. WLTP Highway). A sensitivity analysis for road conditions has also been undertaken for light duty vehicles as part of this update. The results show that fuel savings from driving in poor road conditions can be about 20 % higher compared to good paved roads.
- The modelling results for light duty vehicles also show a potential of secondary effects (i.e. maintaining the original power-to-weight-ratio) of light weighting, which increases the specific fuel savings, but to a lesser extent than as stated in the literature ([Casadei, / Broda, 2008; Delogu, et al., 2016; Ika, 2014; Kim, et al., 2016; Kim, / Wallington, 2016]).
- Modelled fuel saving values by primary mass reduction on the other hand, are mostly higher than those stated in the aforementioned literature. Specific total fuel savings for light-duty vehicles with conventional combustion engines are in most cases slightly lower than previously assessed, which can be attributed to generally lower fuel consumption level.
- The modelling results for hybrid passenger cars vary significantly by vehicle model and driving cycle. On average, however, fuel savings for gasoline hybrid passenger cars are about 20 % lower compared to conventional gasoline vehicles due to the generally lower fuel consumption level. Due to the high sensitivity of fuel savings the derivation of a single reference value, however, is not meaningful.
- Electric light-duty vehicles generally show less sensitivity to the driving cycle due to the generally high engine efficiency and potential for regenerative breaking. Electricity savings are mostly stable in the range of 0.6 kWh/ (100 km*100 kg).

Results for specific fuel savings for heavy duty vehicles are mostly comparable to previous reference values and literature data, too. Here, results produced by the ifeu vehicle simulator VEHMOD have also been checked for compatibility with results produced by VECTO, the designated official tool to play a crucial role in the European type approval procedure. From the result differences below 2 % a good compatibility between VEHMOD and VECTO can be concluded. As part of this study a more detailed sensitivity to various driving cycles has been undertaken with VEHMOD:

- As expected, fuel savings are highest in urban cycles and lowest for highway cycles. The highest primary CO_2 savings are found for the city bus with almost 0.2 kg l / (100 km*100 kg) in an urban cycle, while the lowest values are found for heavy trucks (mostly below 0.1 kg l / (100 km*100 kg)).
- Potentially three times higher fuel savings for trucks can be realised in case of weight limited cargo, because less vehicle-km are needed to transport the same amount of goods over a given distance. For fully load heavy trucks, fuel savings would be about 0.16 l/100 km and 100 kg in the WHVC and thus considerably higher than for volume limited cargo.
- Again hybrid and electric versions have been additionally analysed for city buses and light trucks. Differences between the driving cycles for the electric version appear to be higher as for passenger cars. The absolute energy savings level, however, is likewise in the range of 0.6 kWh/ (100 km*100 kg).

While for road vehicles a wealth of recent literature is available (see above), few such reference values for weight reduced trains exist or have been published. The available recent studies, as well as an additional modelling of a high speed train, however, show very stable values for energy savings by light-weighting of trains. Differences are rather found in the specific use cases, also being determined by lifetime distance.

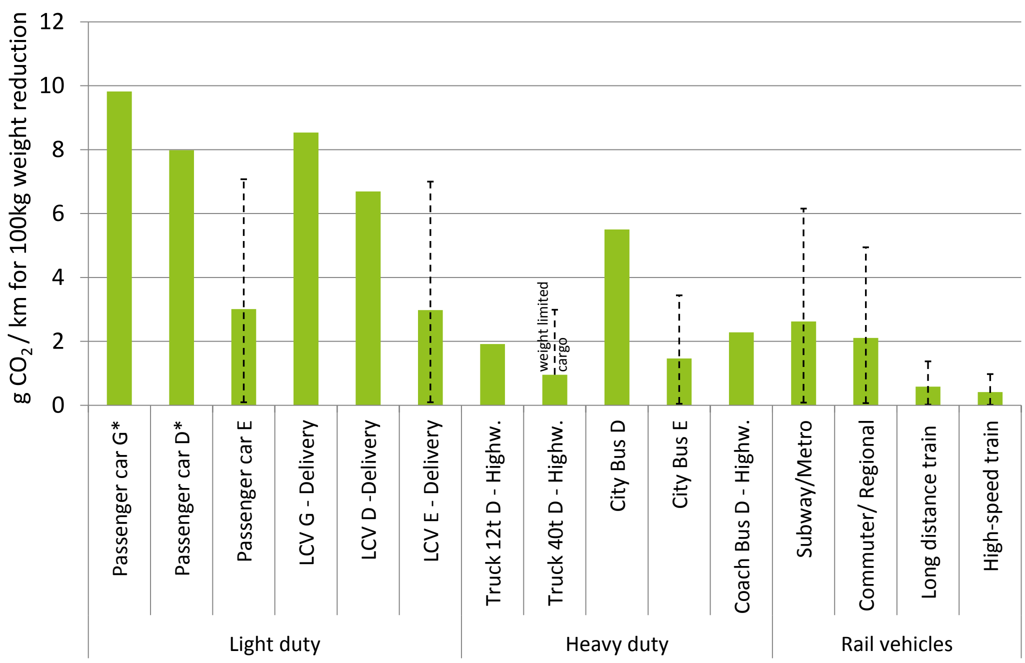

Figure 1: Specific primary CO_2 savings per km for a 100 kg weight reduction for selected vehicle use cases (EU28 electricity, electric vehicles range between energy supply in China (upper value) and Norway (lower value), reference year 2013)
* for passenger cars secondary effects by maintaining the power-to-weight ratio of the vehicle are considered

Specific primary CO_2 savings per km (including upstream processes) can now be calculated for a 100 kg weight reduction based on the specific fuel saving reference values (see selected use cases in Figure 1). For electricity generation, large country specific differences can be found which are displayed as error ranges representing China and Norway (reference year 2013). Specific CO_2 savings are highest for conventional passenger cars if secondary effects are included, but also light-commercial delivery vehicles and city buses show high specific savings, while long-distance vehicles have generally lower specific CO_2 savings.

A comparison of the lifetime CO_2 savings potential for a 100 kg weight reduction for selected use cases (see Figure 2), on the other hand, shows by far the highest savings potential for rail vehicles, due to the high life-time distance travelled. Among rail vehicles, however, the savings potential is higher for subways and regional trains than for long distance and high speed trains, despite the lower lifetime distance travelled. Further installation of low carbon electricity capacities over the lifetime of the vehicles, however, would decrease this potential. A detailed country specific analysis of such scenarios is beyond the scope of this study.

Among road vehicles, city buses and long distance coaches have the highest lifetime savings potential. For the electric versions, life-time primary CO_2 savings depend largely on the electricity split (see ranges in Figure 2) and can be significantly higher than for conventional cars (e.g. in China), but also lower (e.g. in Norway).

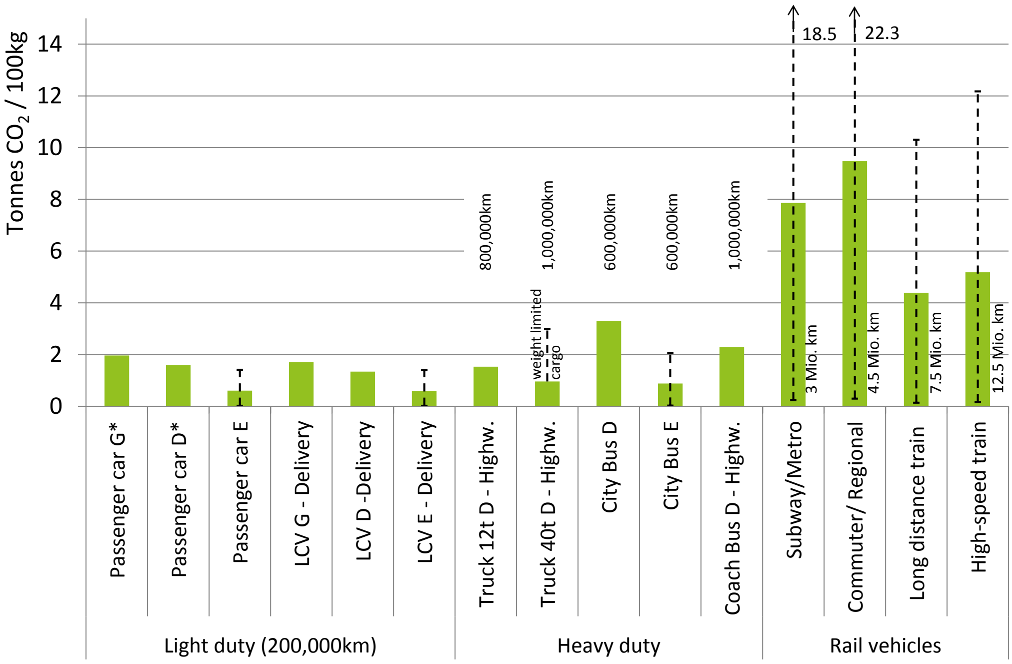

Figure 2: Life-time CO_2 savings by a 100 kg weight reduction for selected vehicle use cases (constant lifetime electricity split 2013 with EU28 electricity, electric vehicles range between energy supply in China (upper value) and Norway (lower value))
* for passenger cars secondary effects by maintaining the power-to-weight ratio of the vehicle are considered