Including the energy saving potential of self-driving cars into LCA of future passenger vehicles

In this analysis we include the potential energy savings of autonomous driving into life cycle assessment (LCA) of future electric cars. We model traffic smoothing improvements using exponential smoothing of established velocity versus time driving profiles and energy savings due to platooning by adapting the aerodynamic drag coefficient. We find that traffic smoothing and platooning could reduce vehicle energy demand by 10-25% and 10-20% respectively.

We use Monte Carlo analysis to examine uncertainty due to variation in input parameters. The mean result for a 2050 electric car charged with western European average electricity is 126 g CO_2eq/vkm with a standard deviation of 14 g CO_2eq. The minimum and maximum results were found to be 85 and 180 g CO_2eq/vkm respectively. Results are most sensitive to variations in vehicle size, range, battery energy density and lifetime distance travelled.

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Approach

Our current approach to model energy demand of vehicles is to assume standardized velocity versus time profiles [1] and back-calculate the energy to accelerate and overcome aerodynamic and rolling resistance as well as meet auxiliary energy demands such as lighting and heating.

We argue that energy-optimized autonomous cars can be modelled with similar driving cycles. However, they will try to minimize acceleration and may have knowledge of the road ahead, allowing for smoother driving patterns. We consider also the lowest bound for energy consumption, which is travelling at a constant speed.

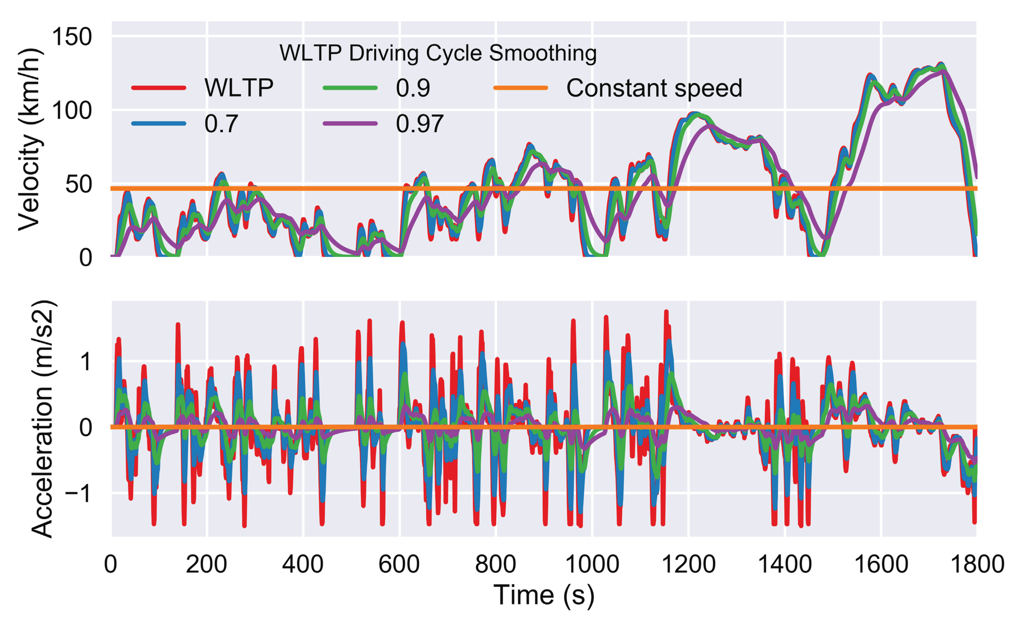
Furthermore, autonomous vehicles will be able to form platoons, reducing aerodynamic drag by up to 50% depending on platoon size and following distance [2].

Estimating traffic smoothing

We estimate autonomous driving cycles using exponential smoothing on existing driving cycles :

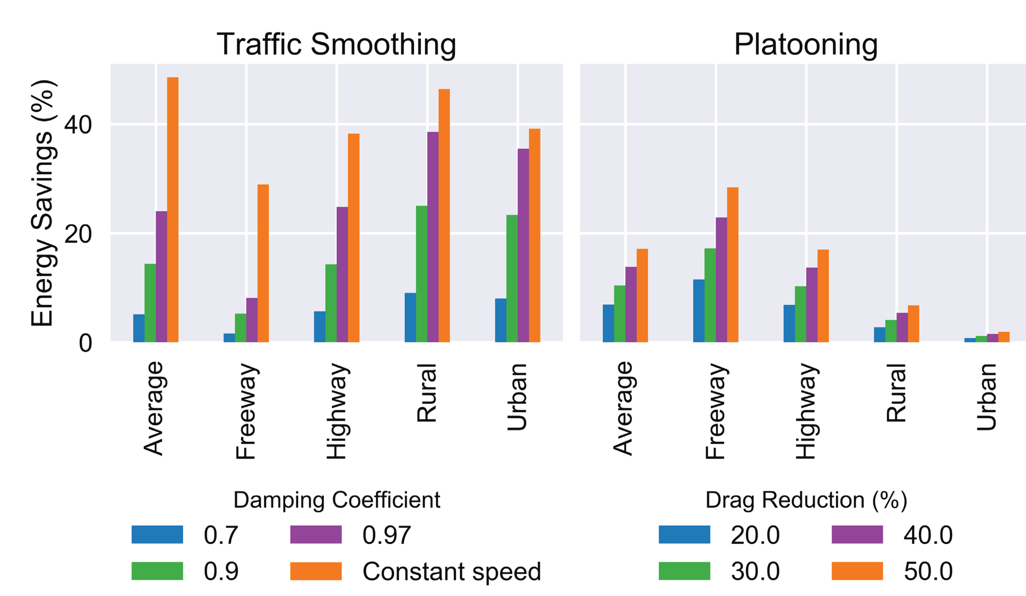
Damping coefficient — Target velocity — Actual velocity — Previous velocity

$$s_t = (1 - \alpha)x_t + \alpha s_{t-1}$$



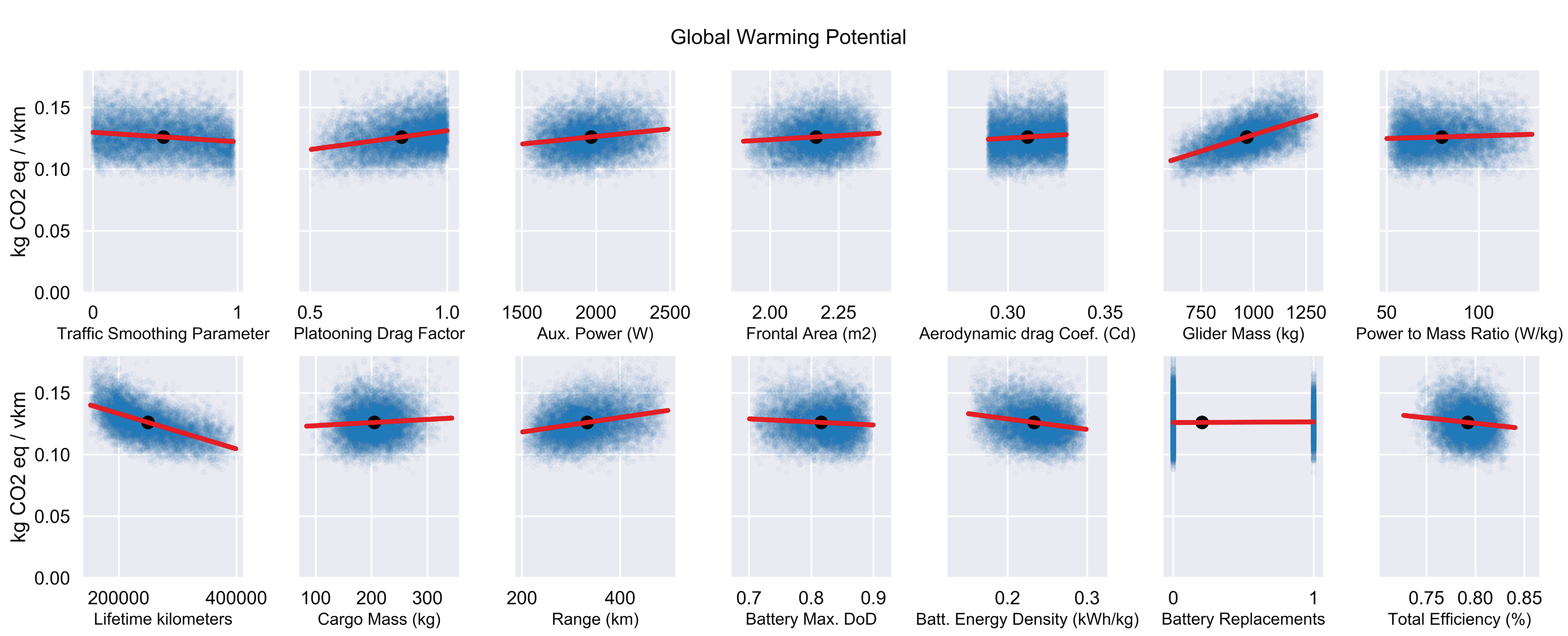
Autonomous driving energy savings

We show tank-to-wheel energy savings for average autonomous electric cars with different levels of exponential smoothing and drag reduction, separated for different driving conditions below. Traffic smoothing could save a maximum of 50% of vehicle energy, but this value is more likely 10-25%. Platooning will likely save 10-20%.



Life cycle assessment of future electric cars

We include our autonomous driving energy consumption model into a prospective life cycle assessment of future electric passenger cars . We use Monte Carlo analysis to include ranges for all input parameters based on reasonable boundaries for how electric cars are expected to perform in 2050 [3]. The background database is ecoinvent, modified using the business as usual scenario 2050 results (see other poster). The 2050 European average electricity mix is used for charging (390 g CO_2eq/kWh). Below we show the variation in global warming potential results for the most important input parameters. The black dot represents the mean result, while the red line is a linear regression result.



Conclusions

In this analysis we include the potential energy savings of autonomous driving into a life cycle assessment of future electric car performance.

We find that energy optimized autonomous cars could reduce traction energy demand compared to human drivers by 20 – 40% per vehicle kilometer due traffic smoothing, reduced acceleration demands and platooning.

We estimate the life cycle global warming impacts per passenger kilometer due to future autonomous electric vehicles to be 85 to 180 g CO2 eq / vkm , based on a business as usual scenario for 2050 electricity supply in Western Europe. The mean value is 126 g CO2 eq / vkm with a standard deviation of 14 g CO2 eq / vkm.

Results are found to be most sensitive to vehicle mass, lifetime distance travelled, efficiency, range, battery energy density, and benefits of autonomous driving.

References

[1] WLTP Worldwide harmonized Light vehicles Test Procedures. See: www.dieselnet.com/standards/cycles/wltp.php

[2] Zabat, Michael et al. 1995. The aerodynamic performance of platoons. University of Southern California.

[3] Hirschberg, Stefan et al. 2016. Opportunities and challenges for electric mobility: an interdisciplinary assessment of passenger vehicles. Final report of the THELMA project in co-operation with the Swiss Competence Center for Energy Research "Efficient technologies and systems for mobility". PSI, EMPA and ETHZ. Available at https://www.psi.ch/ta/thelma