Capacity Area A3 Topic 3.2 Milestone 2

Publication of design strategies and new designs available

Energy Systems Group, LAV, ETH Zurich: Lukas Küng, Gil Georges

In the context of the BFE project "ESMOBIL-RED" and the SCCER Mobility Capacity Area A3, we developed a simulation methodology to compute the energy demand of any passenger cars using and any common powertrain technology (conventional combustion, battery-electric, fuel cell electric or hybrids resp. plug-in hybrids thereof). This modelling framework has been published in Applied Energy (doi: 10.1016/j.apenergy.2019.113948) in September 2019.

The model does not depend on the powertrain technology itself, except for the weight the powertrain adds to the curb weight. This allows to plug in the properties of other vehicles, say that of a different vehicle class or a light-weighted vehicle.

Based on this model, an additional publication is currently under preparation. We intend to submit that in Q4/2020. This study assesses the role of minimizing the vehicular energy demand (E/vkm) vs. the role of alternative powertrain-energy carrier-tuples (CO_2/E) for Switzerland. Preliminary results can be expected by the end of August.

Quantification of the role of vehicular energy demand minimizations for the decarbonization of the Swiss passenger car fleet

The following work has been performed and the paper "Strategies to contain cars within the 1.5°C carbon budget: the roles of CO_2 emission limits, alternative technologies and synthetic fuels" by Lukas Küng, Maximilian Held, Giacomo Pareschi, Michele Bolla, Gil Georges, and Konstantinos Boulouchos, is in preparation for submission to Climate Policy

In this study, we analyze the overall contribution of improvements in the vehicle's weight (-15%), its aerodynamic drag (-20%), and its rolling resistance (-15%) to the decarbonization of the Swiss passenger car fleet. Combining all three CO_2 reduction measures, the specific real-world CO_2 emissions of conventional diesel/gasoline ICEVs can be reduced by 20-25 gCO_2/km. For CNG HEVs, the reduction ranges between 15-20 gCO_2/km.

Furthermore, we assessed different fleet substitution scenarios until 2065. In the central scenario, the global carbon budget for limiting global warming to 1.5°C has been broken down to the Swiss car sector: ~110 Mt CO_2 from the beginning of 2020. We translated this carbon budget to a linear decrease in the fleet's CO_2 emissions, reaching zero emissions by 2029, and compared it to real-world tank-to-wheel emissions which are decisive for current legislation. We assumed two ramp-up scenarios of electric vehicles: a fast market diffusion similar to that observed for Norway (31.2% of new registrations in 2018, extrapolation yields 100% EV sales in 2043), and a medium diffusion extrapolated from historic market shares by an S-shaped curve up to 100%. It reaches 100% EV sales after 2065.

We fixed these EV ramp-ups and analyzed which non-EV technologies are suited to comply with the 1.5°C-related carbon budgets. If conventional vehicle technologies (ICEVs, HEVs and CNG-HEVs – all of them in their basic and their improved vehicle design) were not sufficient to comply with the given carbon budget, we assumed drop-in e-fuels to do the trick. Produced from renewable electricity and CO2 captured from air, ICEVS and HEVs are assumed to be accounted as zero-emission vehicles when powered by an e-fuel. The different cumulative demand in e-fuels between the basic and the improved vehicle design scenario is another indicator for the benefit of the vehicle improvements described above. Assuming gradual adoption of those improvements over seven years (until the full potential is reached), can save between 1/5 and 1/4 of the cumulative demand for e-fuels between 2020 and 2065. However, the difference in the high and medium EV scenario has a way higher impact on the cumulative e-fuel demand, cutting the e-fuel demand by up to 80%.

In summary, vehicle improvements (light-weighting, aerodynamics improvements, and rolling resistance reductions) can contribute to the decarbonization of the Swiss passenger car fleet, but their importance diminishes in faster EV ramp-up scenarios. This is aggravated by the fact that particularly light-weighting has a drastically lower positive impact on the CO_2 emissions for EVs than for conventional vehicles. Whether such vehicle improvements will play a part under real market conditions de-pends heavily on their CO_2 abatement costs compared to those of other CO_2 reduction measures (like the direct electrification of vehicles) and their time-to-market, i.e. until they could reach a large-scale market adoption.