On the way to climate-neutral road traffic in Switzerland

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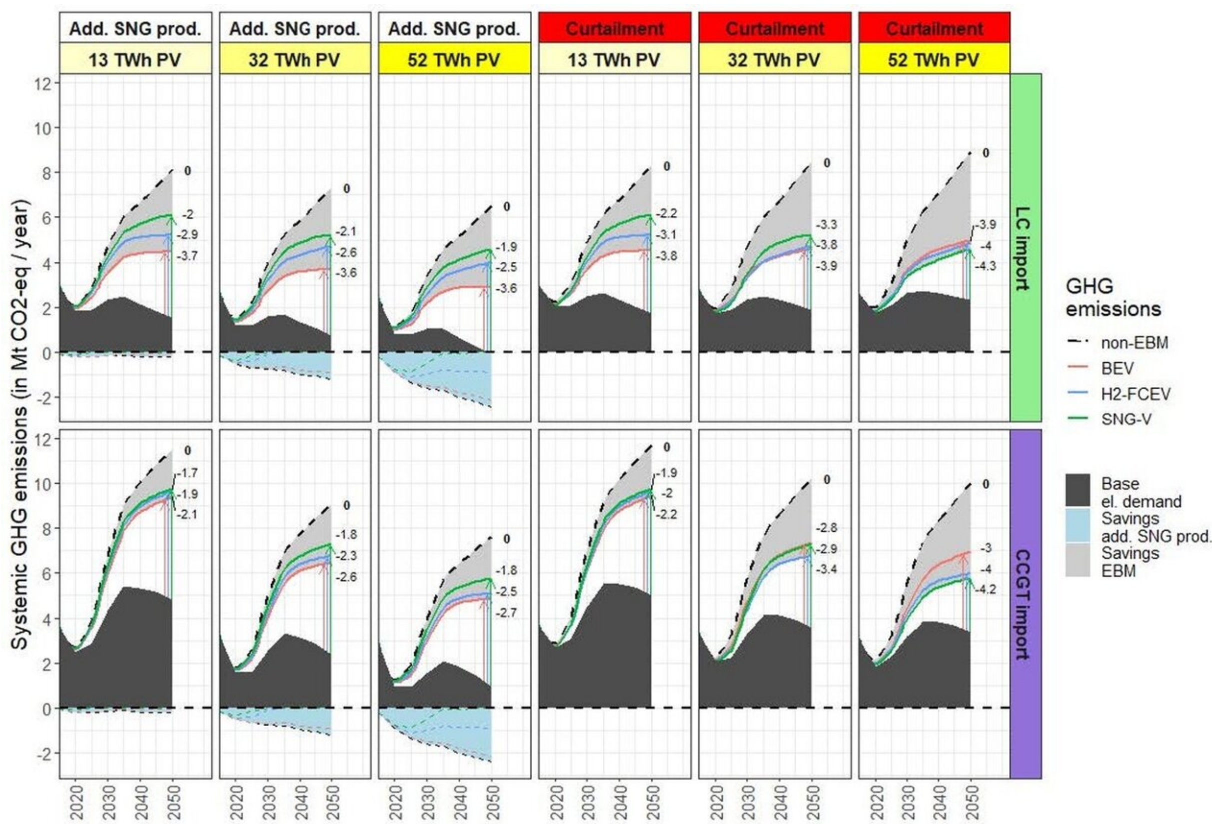

In four of the twelve scenarios, which have been calculated, there is an advantage for battery electric vehicles. In eight scenarios there are just minor differences be-tween the three propulsion systems. Credit: Empa

Road traffic is currently responsible for more than 30% of Switzerland's greenhouse gas emissions. Reducing these emissions is complex because the switch from fossil-based mobility to electricity-based mobility will only lead to substantial reduction in global GHG pollution if more renewable energy is integrated into the energy system at the same time.

Transforming the Swiss car fleet

In a study funded by the Competence Center for Energy and Mobility of the ETH Domain (CCEM) and recently published in the journal *Applied Energy*, researchers from Empa, the Paul Scherrer Institute (PSI), ETH Zurich and EPFL jointly investigated the potential of electricity-based mobility in terms of reducing climate change impact. This was done against the background of the changing Swiss energy system. Not only the direct domestic GHG emissions but also the indirect GHG emissions that are produced globally were taken into account. Indirect emissions arise, for example, in the production of vehicles and fuels or in the extraction of raw materials for batteries.

Using a model based primarily on CO_2 legislation for new vehicle registration, the impact on the total Swiss vehicle fleet was assessed. While it was assumed for the new car fleet, for example, that 60% of the gasoline- and diesel-powered passenger cars will be replaced by electricity-based vehicles by 2040, the impact on the overall fleet will only be gradual. Indeed, this means that a fleet ratio of 60% / 40% between electricity-based and fossil-based passenger cars will be reached only in 2050. The energy demand from this prospective model of future electricity-based mobility in Switzerland was determined on the basis of the foreseeable technological development and then included into a model of estimated future electricity demand.

Twelve energy system scenarios

The researchers created twelve different scenarios that explore the variation in different key aspects. Three different photovoltaic development paths of 13, 32, and 52 terawatt hours (TWh) were considered for the transformation of the electricity market. Two different electricity import scenarios were explored for winter supply: Import of majority renewable electricity or electricity from fossil gas-fired combined cycle power plants. Finally, the possibility of using surplus electricity was also investigated. The high domestic photovoltaic development paths showed large temporary electricity surpluses in summer. In the simulation models, these were either used for the production of synthetic methane, which can be used in the gas market, or they were "curtailed," i.e., solar power generation is disconnected from the network to avoid overloads.

Efficiency versus flexibility

Electricity-based vehicles differ greatly in their energy impacts: While electric vehicles are highly energy efficient, they have short-term flexibility to use electricity in their batteries and they can only be charged if electricity is being fed into the grid elsewhere at exactly the same time. The option of synthetic fuels provides an opposite solution that exhibits low efficiency, but long-term flexibility, which means that temporary electricity surpluses can be stored for months and used for mobility when needed. Hydrogen-powered vehicles are roughly in between in terms of efficiency and flexibility.

Framework conditions are crucial

The results of the simulations show that for eight of the twelve scenarios, the differences for GHG reduction between battery-powered vehicles, hydrogen-powered fuel cell vehicles and synthetic fuel-powered vehicles are small. The main reason for this is that, in these cases, efficiency and flexibility cancel each other out over the year. This is the case in the six scenarios that assume imported electricity from gas-fired combined cycle power plants when there is not enough production in Switzerland, as well as in two scenarios that are based on mostly importing renewable electricity. In the remaining four scenarios, the use of battery vehicles bring substantial reduction in GHG emissions when compared with the other electricity-based options because efficiency is more beneficial when a lot of renewable energy is available at any time of the year. This applies to the three scenarios in which surplus electricity can be converted as synthetic methane and used in other sectors (e.g. road freight transport, industry, heat/electricity coupling), as well as to the scenario with the lowest PV addition and the possibility of importing renewable electricity.

Overall, this means that the global GHG reduction when switching to electricity-based mobility depends significantly on the Swiss energy context that can be affected by PV addition, utilization of electricity surpluses and the possibility to import renewable electricity.

Intelligent charging stations

In addition to the energy calculations, the researchers studied the impact of electric vehicle charging on the local power grid. This is because a single average electric vehicle fully charged from a home-wall socket all night is roughly equivalent to four state-of-the-art electric stoves running at full power for six hours. It is therefore important to have intelligent charging systems that adapt the charging power of the vehicles to the grid capacities. This prevents the power grids from being overloaded and causing outages in extreme cases.

More information: Martin Rüdisüli et al, Prospective life-cycle assessment of greenhouse gas emissions of electricity-based mobility options, *Applied Energy* (2021). DOI: 10.1016/j.apenergy.2021.118065

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