Tipping points of competing battery and hydrogen fuel cell cars in Swiss energy transition

The goal of «Energy Economic Modelling» in the Capacity Area B2 is to carry out integrated analysis of the Swiss transportation system. This is achieved by implementation of ***whole energy system approach*** with high level of ***technology detail*** to identify future energy transition pathways. The focus of the first phase of SCCER Mobility was on car fleet. In Phase 2, we proceed with non-car fleet, including freight transportation. We continue to undertake what-if type ***scenarios analysis*** to understand long term transition of the Swiss mobility to meet the goals of the 2050 Swiss Energy Strategy.

Ramachandran Kannan, Stefan Hirschberg, Tom Kober
Energy Economics Group, Laboratory for Energy Systems Analysis, Energy Divisions
Paul Scherrer Institut, 5232 Villigen PSI, Switzerland
email: kannan.ramachandran@psi.ch

PAUL SCHERRER INSTITUT
PSI

Introduction

Switzerland is set to takeoff for energy transition, in which transportation is a key sector to reduce energy demand and CO_2 emissions. For future cars, a range of drivetrains and fuels are available and their penetration depends, among others, on expected technology learnings. A major area of uncertainty is the competition between battery electric vehicles (BEV) and hydrogen fuel cell (HFC) cars. The uncertainties are not merely in the technology per se but concern the entire energy supply chains. This requires a systemic analysis by considering the entire energy system. We generated insights on tipping points between these two competing technologies using the Swiss TIMES energy systems model (STEM) [1]. We analyzed the following set of scenarios.

Reference ***(Ref)*** scenario includes transport demands from the Swiss energy strategy (SES2050), nuclear phase out, full autarky in electricity supply, and a set of baseline car technology development [2]. Efficiency and cost of cars are shown in Figure 1.

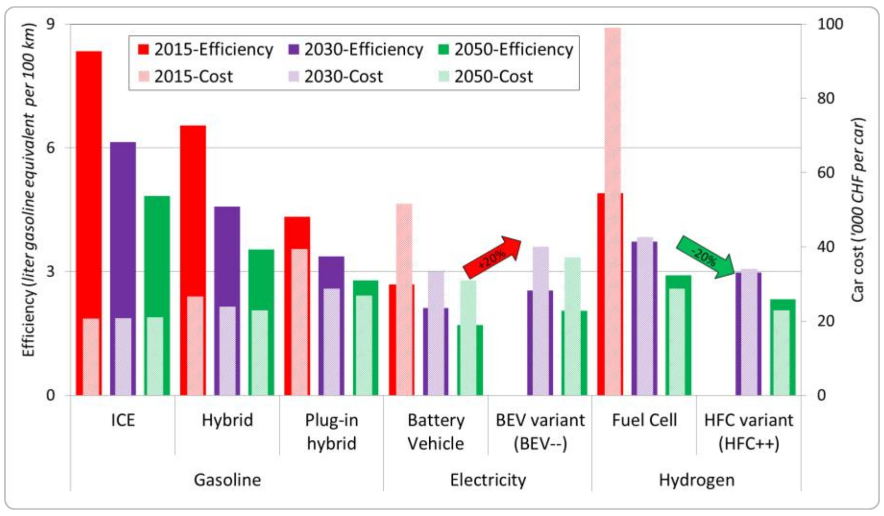

Figure 1: Baseline car technology developments [2]

A low carbon scenario ***(LC)*** similar to the NEP scenario of the SES2050 – a 60% reduction in CO_2 emissions across the whole energy system by 2050 relative to 2010. In a ***BEV––*** variant of *LC*, cost of BEV is 20% higher while efficiency is decreased by 20% compared to the baseline technology assumptions (see Fig.1). In ***HFC***$^{++}$ variant of *LC*, cost of HFC car is reduced by 20% and efficiency is increased by 20%.

Long term cars fleet and tipping points

In ***Ref*** scenario, gasoline hybrid vehicles dominate the car fleet in 2050 due to increasing energy price. To meet the CO_2 target (***LC*** in Fig. 2), small and medium size cars shift to BEV whereas large size cars adopt gas hybrid vehicles. The electricity in 2050 is largely produced from new renewables (27 TWh) and gas power plants (8 TWh). Given the high supply of electricity in summer, the plug-in hybrid cars are driven more on electric mode compared to winter season. The transport sector benefits also from natural gas blended with biogas delivered through the central gas network.

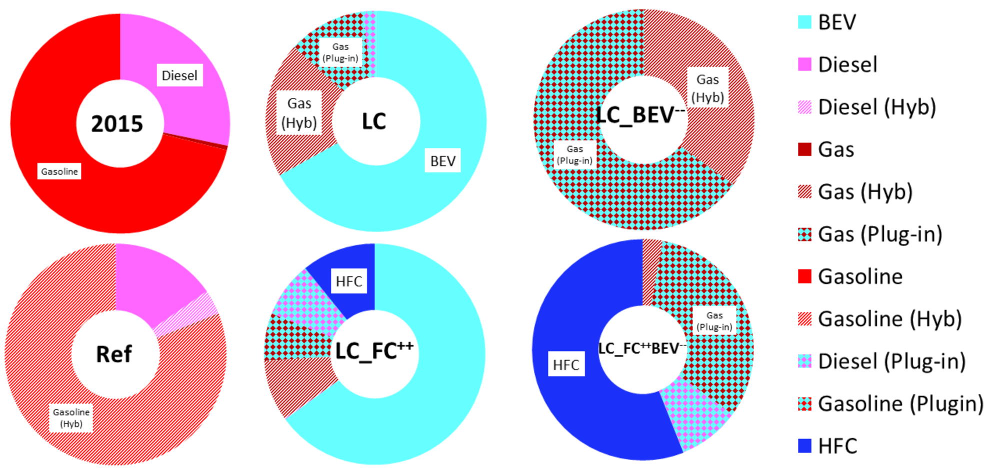

Figure 2: Car fleet in 2050

If the BEV fails to reach the baseline efficiency of 2.1 liter gasoline equivalent per 100 km (*l/100km)* by 20%, then the BEV in the *LC* scenario shift to gas plug-in hybrid (see LC_*BEV––* in Fig 2), i.e. HFC cars are not competitive under these conditions. The shift from BEV to gas hybrid reduces electricity demand by 5 TWh but gas used in cars increases direct CO_2 emission of the car fleet by 2.1 Mt-CO_2. (Fig. 3).

A 20% higher efficiency in HFC cars (3 *l/100-km* vs. 3.7 *l/100km* in baseline) enables to capture a share of gas hybrid and gas plug-in car markets (*LC_FC*$^{++}$). At the same time, BEV retains its own market share. The hydrogen is predominately produced from natural (and bio-) gas using steam methane reforming (SMR). Thus, some direct emissions from car fleet are shifted to conversion sectors (Fig 3).

From the transport sector perspective, gas is an important energy carrier in Swiss energy system. Gas is either used in cars directly or indirectly via hydrogen produced from SMR, but also through electricity partly produced from natural gas. The BEV are broadly deployed because of their high efficiency on primary energy to end use basis; and their flexibility to charge during times of excessive (and off-peak) power generation.

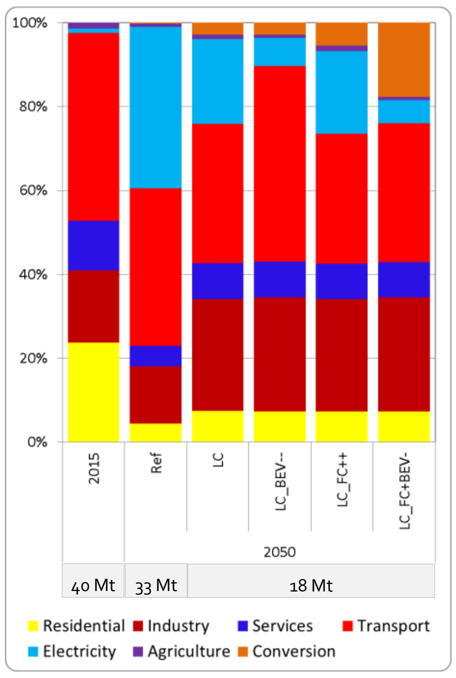

Fig 3: Sectoral CO_2 emissions

Transport fuel demand

Other than the car fleet, bus fleet is partly shifted to hydrogen. Nevertheless, the transport sector retains fossil fuels for freight transportation (LGV/HGV in Fig 4). Current efforts in SCCER mobility concerns other transportation modes.

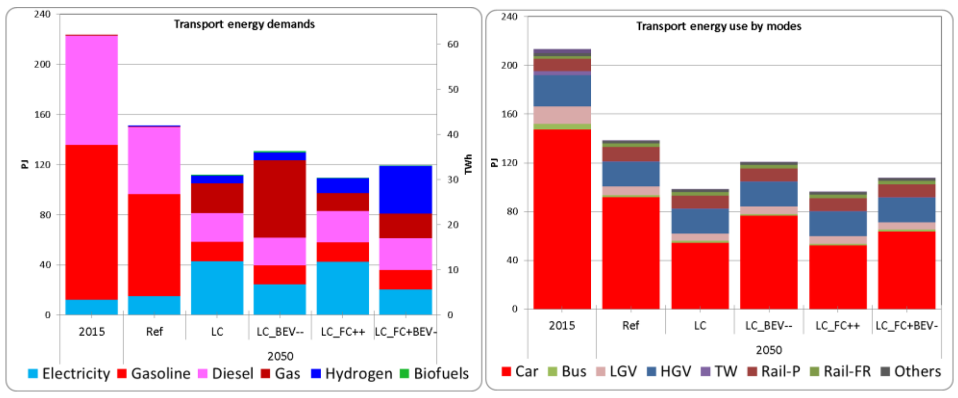

Fig 4: Transport fuel demand in 2015 and 2050 and their use by modes

Conclusions and outlook

Electricity and natural gas (with biogas) emerge as key fuels for car fleet to mitigate CO_2 emissions. The use of gas directly in cars or indirectly in BEV/HFC depends on the prospective technology progress. BEV and gas plug-in hybrid cars offer flexibility to the electricity system to integrate new renewables at reduced storage needs. HFC cars need highly accelerated learning to compete with BEV. However, non cost aspect of car technology (e.g. range, fueling/charging time) are not considered. So far the scenario focus has been on car fleets. The ongoing work on non-car fleet is expected to offer additional insights with relevance for energy transition.

Reference

[1] Kannan, R., Hirschberg S. 2016 Interplay between electricity and transport sectors – Integrating the Swiss car fleet and electricity system, Transportation Research Part A: Policy and Practice (94), pp. 514-531.
[2] Hirschberg, S 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