SCCER Mobility Mission Report (19 Dec. 2019)

Important topics for transport research in Switzerland post 2020

Context and scope

Herewith we want to derive strategic goals for energy research post 2020 for the mobility sector in accordance with the Swiss Energy Strategy 2050 by reviewing the original aim and achieved progress in Phase 1 and Phase 2 of SCCER Mobility. In addition, we consider international trends and insights from similar initiatives and studies abroad, as well as further developments that became relevant in the last few years.

Review of challenges, international boundary conditions and new developments

The set of challenges as formulated in 2013 remains relevant and several key performance indicators (KPI) for a sustainable transport system continue to serve as guidance (see Swiss Energy Strategy 2050). However, the Paris Agreement and climate change mitigation have become the dominant drivers. In 2015, most nations of the world signed the Paris Agreement and committed to reducing emissions to limit global warming. To meet the set 2-degree goal (with a 66% probability) in practical terms means that from 2015 onwards no more than approximately 800 Gt of carbon dioxide (CO_2) should be emitted worldwide (this burden shrinks significantly if a 1.5°C-target is set). Distributed equally per capita results in a remaining budget of ~900 Mt CO_2 for Switzerland (IEA/IRENA 2017). Assuming a share across all energy sectors that reflects their current CO_2 output and a linear decrease of CO_2 emissions overtime means that by the year 2060, the Swiss transport sector should be practically GHG-emission free (Figure 1). This is a very tight timeline to achieve nearly complete decarbonization[1].

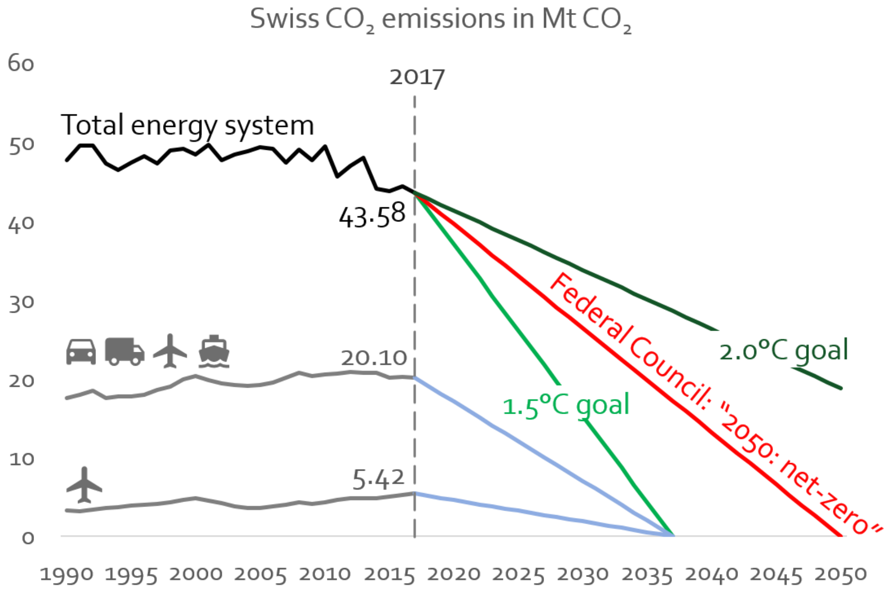

Figure 1. Current greenhouse gas emissions from the transport sector in Switzerland compared to the total CO_2 emissions (BAFU 2019) along with reduction trends needed to remain within the CO_2 budget to reach the international climate goals (IPCC 2018). All data include international aviation and shipping (without IPCC subsectors 4 (LULUCF) and 6 (Others)).

[1] For convenience we use here the established term "decarbonization", although "defossilization" would be more accurate.

In addition, greenhouse gas (GHG, in particular CO_2) emission targets also encompass energy related goals, usually convergent with local/regional environmental resilience and reduction of dependence on fossil (imported) energy carriers.

Furthermore, increased care has to be taken of the heavy-duty, long-haul transport sectors (freight on the road, maritime shipping, aviation, etc.), while in the period 2014-2019 of SCCER Mobility most efforts (though not all) were focused on motorized individual mobility and transport in the urban environment. In addition, the dependence of Switzerland on European policy and overall development trends (EASAC 2019) must receive more intense consideration when formulating national pathways. Concrete research efforts must also be directed towards the transitional phases on the road to a sustainable mobility system, since lifetime of assets and lock-in-effects become increasingly important. Finally, sector coupling necessary for decarbonization leads to important interfaces between the mobility sector and the energy supply system as well the manufacturing industry.

Framework of analysis

In view of the above observations the conceptual framework for analyzing/assessing the current state and designing desired future evolution scenarios is still valid and useful. A Kaya-type decomposition has proven instrumental in guiding research priorities, targeting both the demand and the supply side as well as their mutual interactions. However, this concept must be not only continued but also expanded in the future in order to put more emphasis on:

- Different sectors (passenger/freight, surface/sea/air, urban/interurban, etc.)
- Additional indicators besides CO_2 (ideally covering the set Sustainable Development Goals)
- A consideration of relevant time scales as the GHG emission **budget** is THE relevant indicator. Therefore, the pace of decarbonization within the next 3-4 decades will be decisive for meeting the overarching decarbonization goals

The concept for the decomposition of key indicators depending on relevant drivers is illustrated below through this Kaya-type relationship, here exemplary for CO_2 emissions from motorized individual transportation. It is important to notice however that individual factors on the right hand side of the Kaya-equation may depend on each other (for example due to rebound effects).

$$m_{CO2}|_a = (popul) \cdot \frac{GDP}{popul} \cdot \frac{pkm}{GDP} \cdot \frac{vkm}{pkm} \cdot \frac{E_N}{vkm} \cdot \frac{E_{end}}{E_N} \left[\frac{E_{prim}}{E_{end}} \cdot \frac{m_{CO2}}{E_{prim}} + \frac{E_{invest}}{n \cdot E_{end}} \cdot \frac{m_{CO2}}{E_{invest}} \right]$$

(A) (B) (C) (D) (E) (F) (G) (H) (I) (J) (K)

$m_{CO2}|_a$= annual emissions of CO_2
E_N = useful energy (at the wheel)
E_{end} = final energy (tank)
E_{prim} = primary energy
E_{invest} = embedded/grey energy in components and infrastructure
n= life-time of hardware / infrastructure
(B), (C): exogenous drivers
(D), (E): demography, urban planning, and pricing policies
(F): vehicle technology
(G): powertrain technology

(H), (I): energy/electricity infrastructure, technology innovation, and policy
(J), (K): technology innovation, policy/legislation.

Here it is important to notice that the CO_2 budget concept implies that it is the cumulative CO_2 output of the mobility sector as it evolves over time that is crucial for meeting the goals of the Paris Agreement, rather than the undisputable final goal of "net-zero" CO_2 emissions at some time in the future. The latter is simply derived from the mentioned budget and the corresponding CO_2 reduction trajectory.

A systemic research portfolio

According to this expanded framework of analysis and still taking CO_2 emissions as the lead indicator, future research work must encompass all relevant drivers of the right-hand side of the above Kaya decomposition. In addition, estimates of future evolution of these parameters over time must be included and roadmaps to assess progress and guide short-, mid- and long-term research priorities must be developed. These should take into account not only the innovation/pace of introduction of new technologies into the market but also the time scales necessary to replace fleets and other assets. In the following we discuss R&D areas of priority according to the Kaya terms above (Figure 2), while a more in-depth analysis is reserved for the final systemic White Paper of SCCER Mobility, due in the year 2020.

a) Demand and modal choice for mobility services for all transport sectors and its influencing factors: habits, social norms and standard practices, urban/spatial planning including lock-in effects of existing and investments in new infrastructure, considering the trade-off between demand containment and relevant needs of the economy. Behavioral aspects on both the consumer and the investor side are therefore important.
b) Particular consideration of the impact of digitalization (in terms of available information enabling optimal multi-modal travelling, sharing rides and means of transport, energy logistics and autonomous interconnected vehicles), but also with regard to smart systems integration (efficient sector-coupling), including therefore not only the end-users but also operational issues and innovative business models from the supply side. Of specific interest in this context are rebound effects (due to changes in costs, comfort and sprawl trends) that may (over-)compensate efficiency increases stemming from digital technologies. In addition cyber-risks associated with digitalization and in particular autonomous driving must be considered as well
c) Further improvements in vehicle design, shifts in real-world driving habits and efficiency increase of incumbent propulsion technologies. Though progress in these fields alone cannot lead to full decarbonization, such efforts are important for extending the period of time during which the available GHG (mainly CO_2 for the transportation sector) budget must be exhausted. Although disruptive developments must be supported from the very beginning, one should not ignore the potential of better incumbent technologies (not every car will be electric tomorrow morning).
d) Step-change developments of powertrains and associated energy carriers. Here three major directions must be pursued in parallel, but with due prioritization for the individual sectors. More concretely, direct electrification (battery electric vehicles) appears most promising for short-, H_2 with fuel cell electric vehicles for medium- and synthetic renewable hydrocarbons in combustion engines for long-range applications. Of course this categorization leaves room for major overlaps depending on local/regional conditions and cost competition at the interfaces of different range categories.

e) Since new energy carriers of different kinds will be indispensable for a climate-compatible transformation of the mobility sector, research and implementation must include significant efforts in the following areas:

> - Supply of adequate energy carriers for mobility through a very large expansion of zero-CO2 (preferable renewable) electricity generation capacity, with specific consideration of synthetic fuels for medium- to long-haul transport modes (indicatively for Switzerland, incl. international aviation an amount of 60-80 TWh electricity may be necessary for full decarbonization of the transport sector). Long-term storage and internationally coordinated harvesting of renewable energy are therefore crucial elements in order to accomplish this formidable task.
> - Securing long-term funding for energy supply infrastructure (conversion, storage, logistics) for a yet unknown share of different renewable energy carriers in the whole portfolio. In order to minimize corresponding costs one should consider the evolution of investment patterns and of the regulatory framework, in which new potential actors/stakeholders actively participate in different revenue streams.
> - Advanced materials and manufacturing technologies, which together with low GHG emissions of the energy supply sectors in the relevant countries, allow to reduce the climate-related and overall environmental footprint of new assets (batteries, fuel cells, electrolyzes, "green refineries" etc.). In this context the concept of the "circular economy", incl. reduction of amounts of rare materials through recycling is important, while in addition ethical aspects of mining processes and working conditions must be considered.

f) Finally issues of market design and overall policy at the interface of energy and mobility will be crucial for fulfilling the ambitious carbonization goals. Of particular importance here is the international dimension as markets and innovation processes are global.

The above three major new research thrusts are all related to the emerging sector-coupling. The term implies on one hand the rapid direct and indirect electrification of end-use sectors, and on the other hand new links among the electricity and the chemicals/fuels sector. These will ultimately lead to a two-way-coupling depending on spatio-temporal patterns of available primary renewable energy supply and of demand for specific energy services.

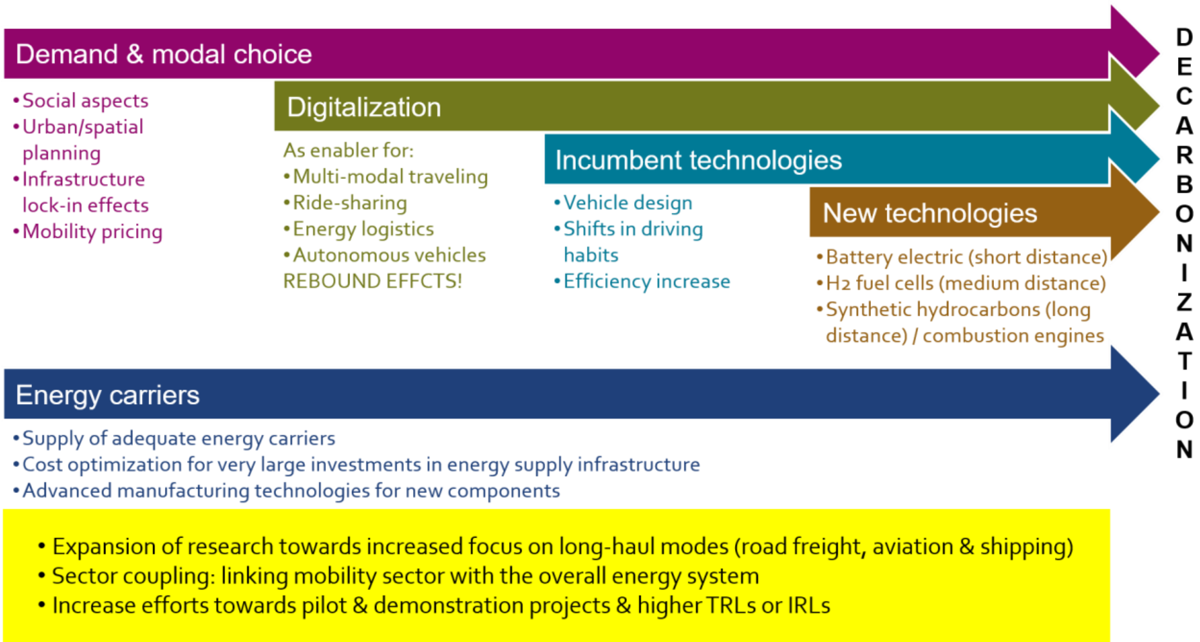

Figure 2. Conceptual illustration depicting areas of priority for future research in mobility according to the Kaya terms.

Ideas for the organization of a future research program in sustainable mobility

Based on experiences obtained so far from Phase I and Phase 2 of the SCCER Mobility we envisage (and propose) the following key elements of a possible future research program in this area, that are of outmost importance for Switzerland (Figure 3):

a) A systemic approach that provides a decision making basis for prioritization across technology fields, policy instruments and distribution of efforts and resources among different TRLs depending on the sector under consideration and other actual developments

b) A close interaction and embedment of socioeconomic and technology research within the same project, in order to ensure alignment with a common goal and to avoid disciplinary silos.

c) A long-term orientation (around 10 years) with coherent strategic level steering processes

d) Sufficient flexibility for the academic leadership (Executive Committee or similar) to propose and implement upon approval a redirection of resources depending on unforeseen developments and emerging opportunities.

e) A “built-in” platform for exchange and flexible cooperation between the mobility program and all other stakeholders, which may (and should) deal with “upstream” processes of energy carriers generation, storage and distribution.

The ultimate responsibility for funding future national programs in energy and mobility research programs lies of course with the Swiss Parliament. In preparation for this decision, expected in (late) 2020 several initiatives have submitted ideas and conceptual proposals. The leadership of SCCER Mobility actively participates in this process through work and membership in relevant institutions (CORE, Energy Committee of Academies of Sciences, etc.).

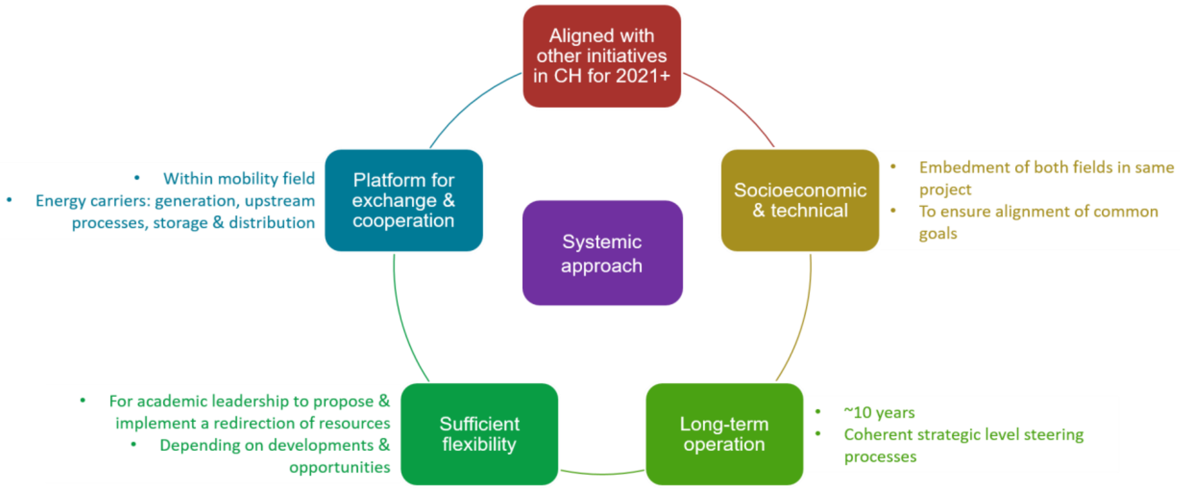

Figure 3. Key elements of a potential future research program in the field of mobility based on the experience from SCCER Mobility.

References

Bundesamt für Umwelt (BAFU). 2019. Greenhouse gas emissions of Switzerland 1990-2017. https://www.bafu.admin.ch/dam/bafu/en/dokumente/klima/fachinfo-daten/THG_Inventar_Daten.xlsx.download.xlsx/Evolution_GHG_since_1990.xlsx

Boulouchos K, Cellina F, Ciari F, Cox B, Georges G, Hirschberg S, Hoppe M, Jonietz D, Kannan R, Kovacs N, Küng L, Michl T, Raubal M, Rudel R & Schenler W. 2017. Towards an Energy Efficient and Climate Compatible Future Swiss Transportation System. Boulouchos K, Hirschberg S & Romera G [eds.]. SCCER Mobility. ETHZ, PSI, SUPSI & ZHAW. https://www.sccer-mobility.ch/export/sites/sccer-mobility/capacity-areas/dwn_capacity_areas/TowardsAnEnergyEfficientSwissTransportationSystem_Ver1.2.pdf

European Academies' Science Advisory Council (EASAC). 2019. Decarbonisation of transport: options and challenges. https://easac.eu/fileadmin/PDF_s/reports_statements/Decarbonisation_of_Tansport/EASAC_Decarbonisation_of_Transport_FINAL_March_2019.pdf

International Energy Agency (IEA) / International Renewable Energy Agency (IRENA). 2017. Perspectives for the energy transition. https://www.irena.org/publications/2017/Mar/Perspectives-for-the-energy-transition-Investment-needs-for-a-low-carbon-energy-system

Intergovernmental Panel on Climate Change (IPCC). 2018. Global warming of 1.5°C. https://www.ipcc.ch/sr15/