ETH zürich

Synthetic renewable fuels: Future contributions to and consequences for the global energy system

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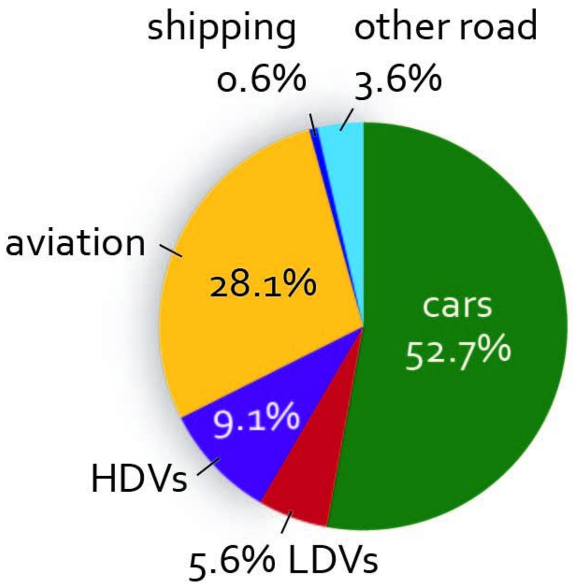
LAV ETHZ/SCCER Mobility

The Swiss transport system: Aviation is rapidly gaining importance

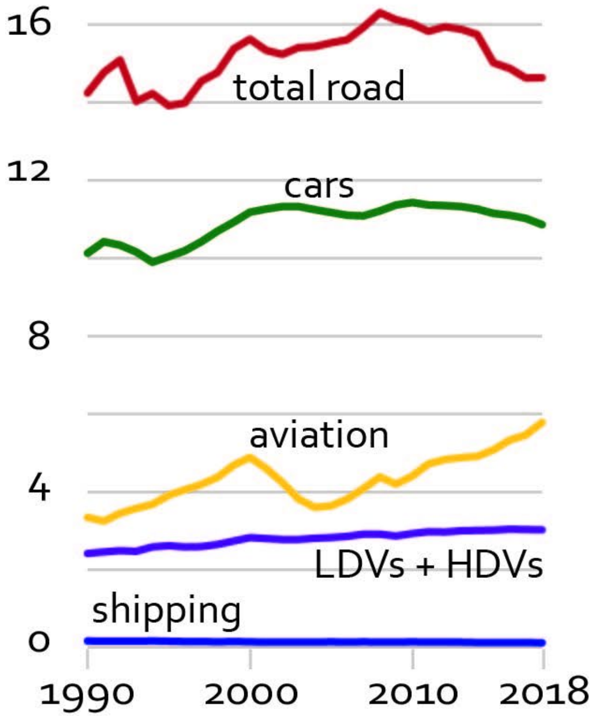
CO_2 emissions transport 2018 (48% of total Swiss emissions)



source: FOEN 2020

GHG emissions 1990-2018

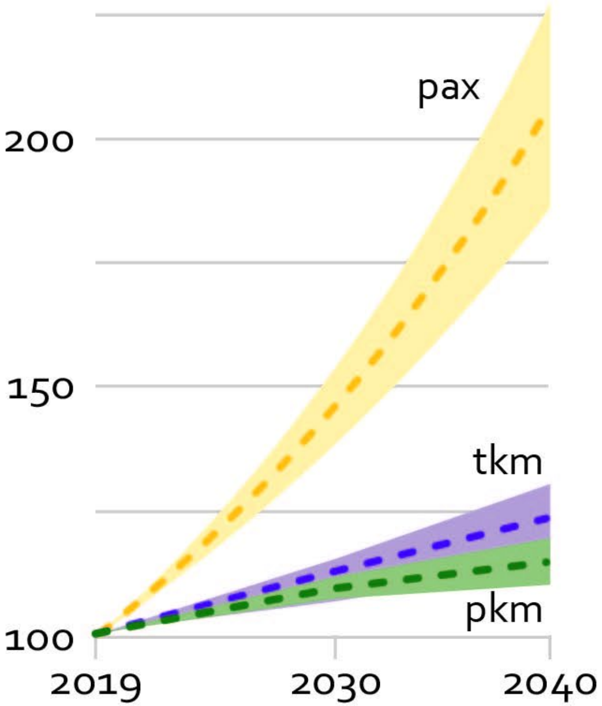
in Mt CO2-eq.



source: FOEN 2020

Transport demand projections

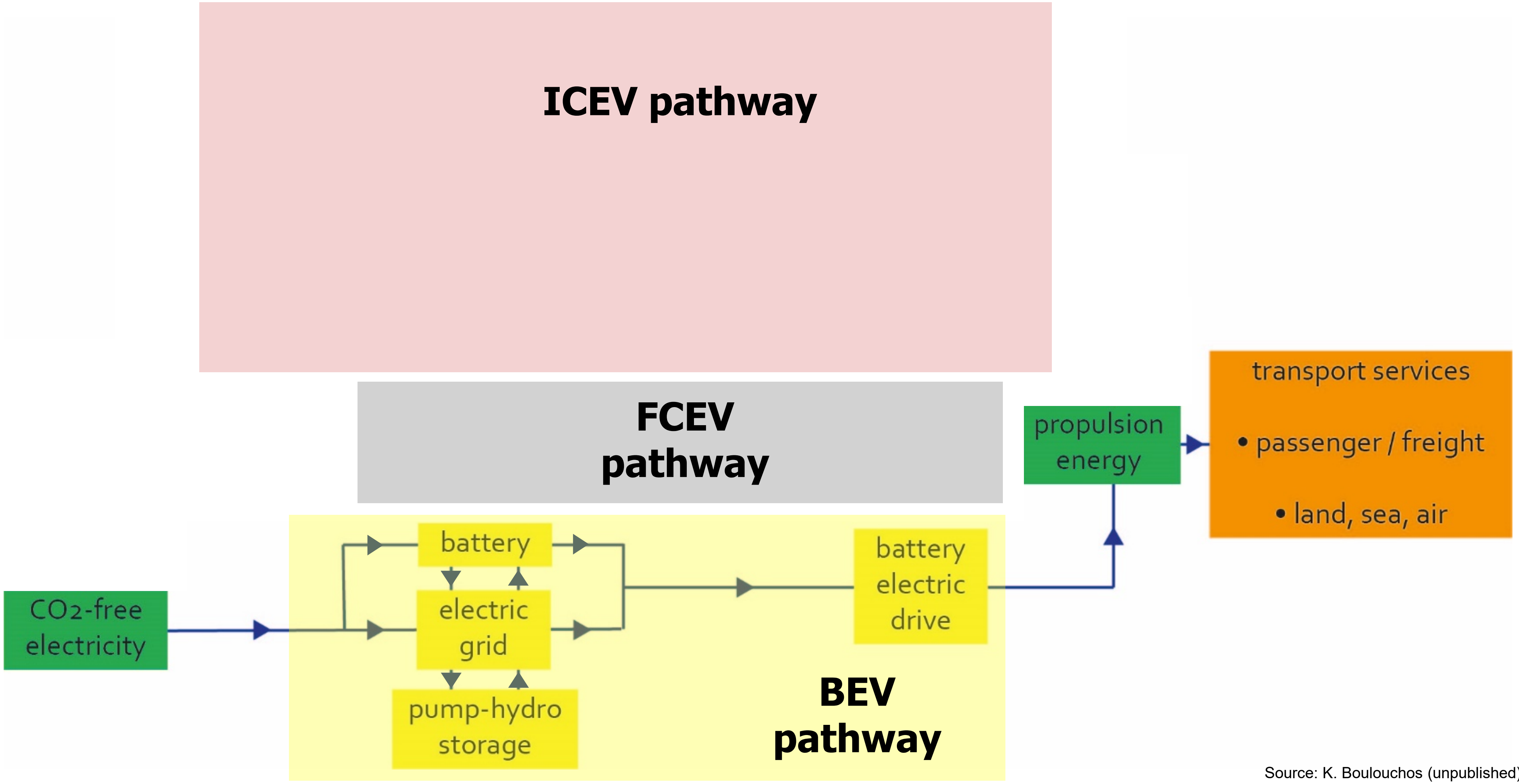
in %



sources: ARE 2016, Intraplan 2015

In the EU, CO_2 emissions from shipping are practically equal to the ones from aviation.

Sector coupling - energy carrier portfolio for mobility (2050)



Source: K. Boulouchos (unpublished)

Different e-fuels depending on application

- Compressed or liquified hydrogen
- Organic-bounded H2 and/or ammonia
- Synthetic methane
- Higher liquid hydrocarbons (w/o aromatic components)
- Methanol, DME, OEM…

- -> Costs of production, transmission, distribution but also issues of safety, security of supply etc. will be highly relevant.

Life Cycle Analysis of Powertrains for cars (meta-study of 80 publications)

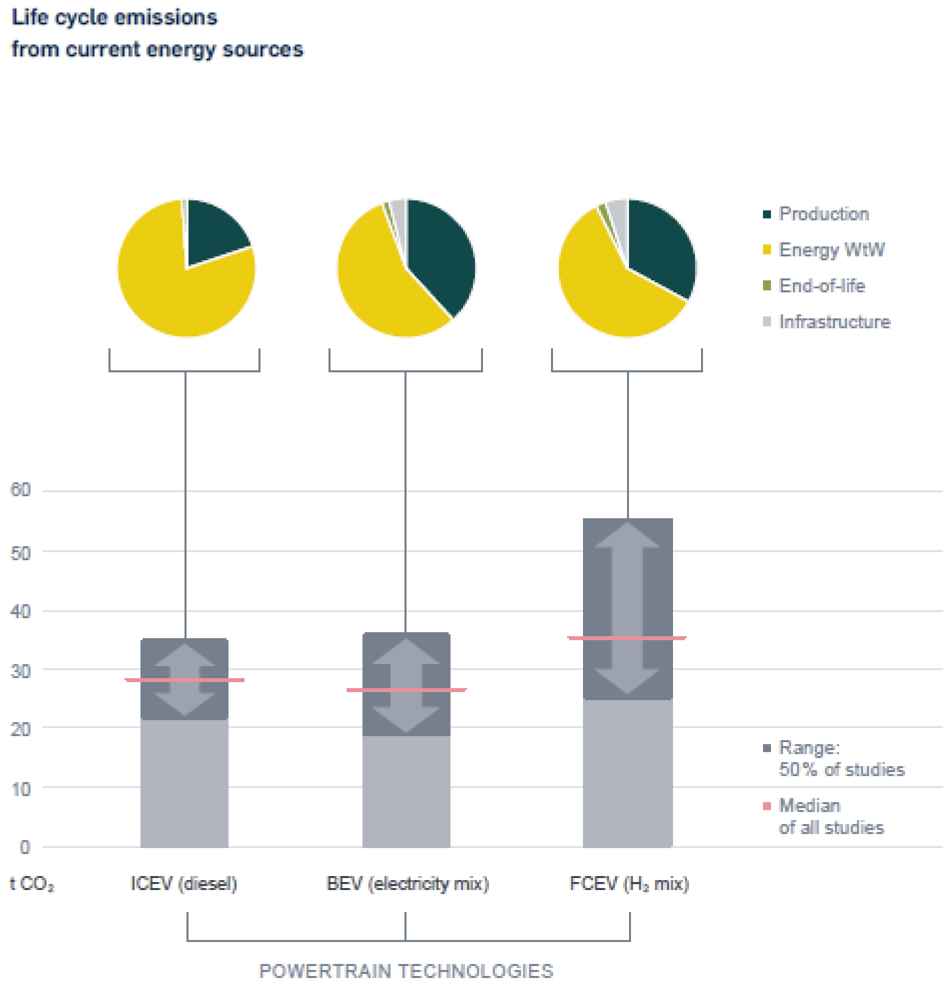


Figure 2-A: If cars are powered by fossil fuels, with electricity from the current energy mix or with conventionally generated hydrogen, battery electric vehicles and internal combustion engine vehicles have comparable life cycle emissions.

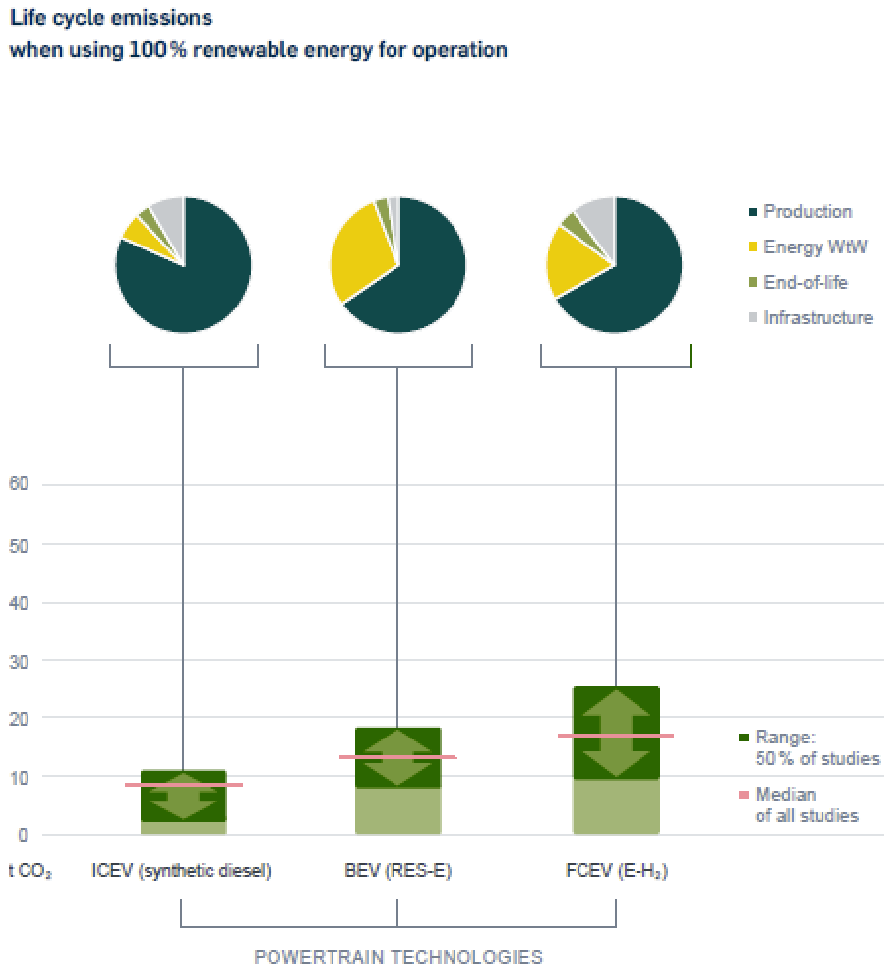
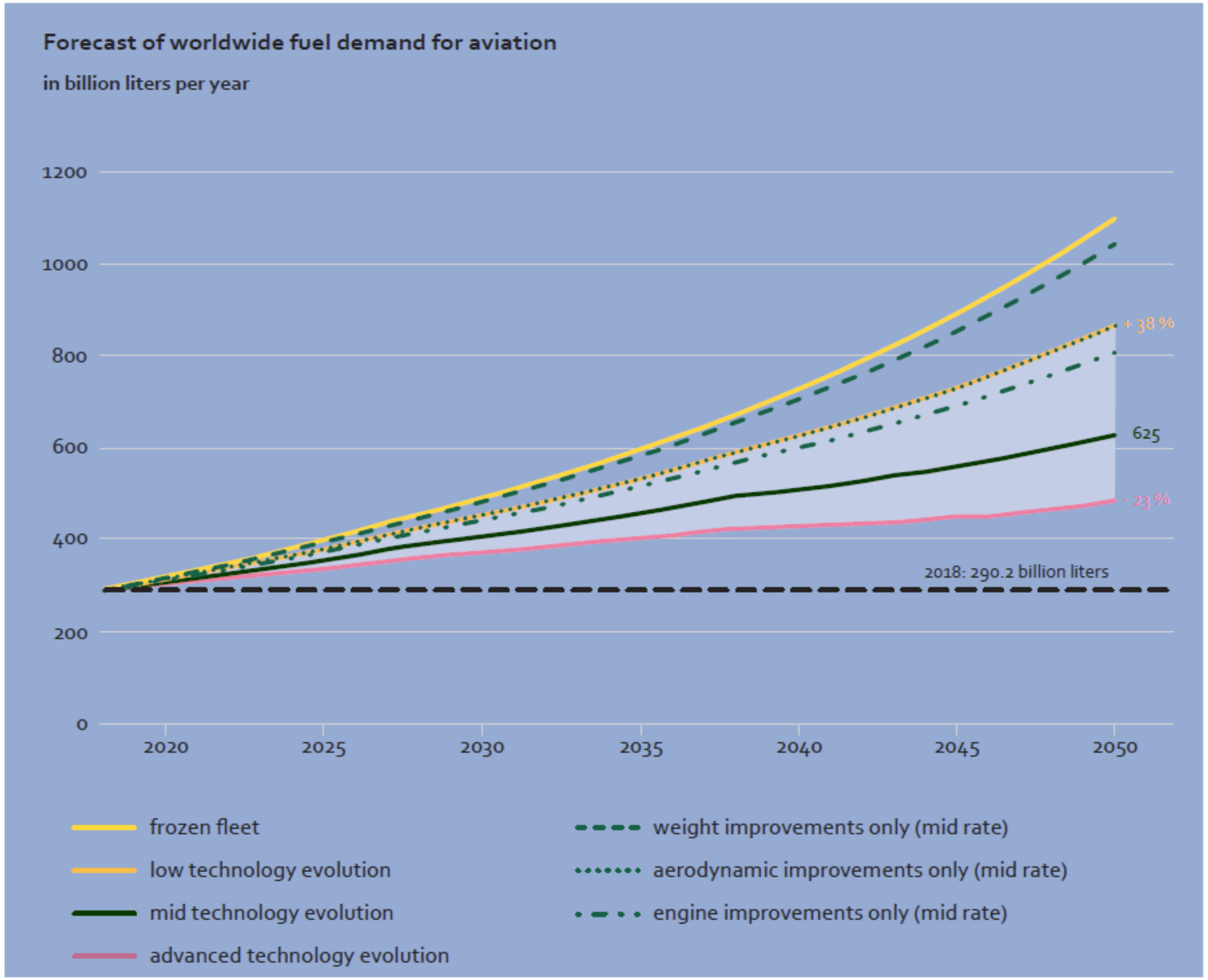


Figure 2-B: If only renewable energy carriers are used during operation, a vehicle powered by synthetic fuels may even have lower CO_2 emissions than a battery electric vehicle. There is still room for optimisation of the fuel cell.

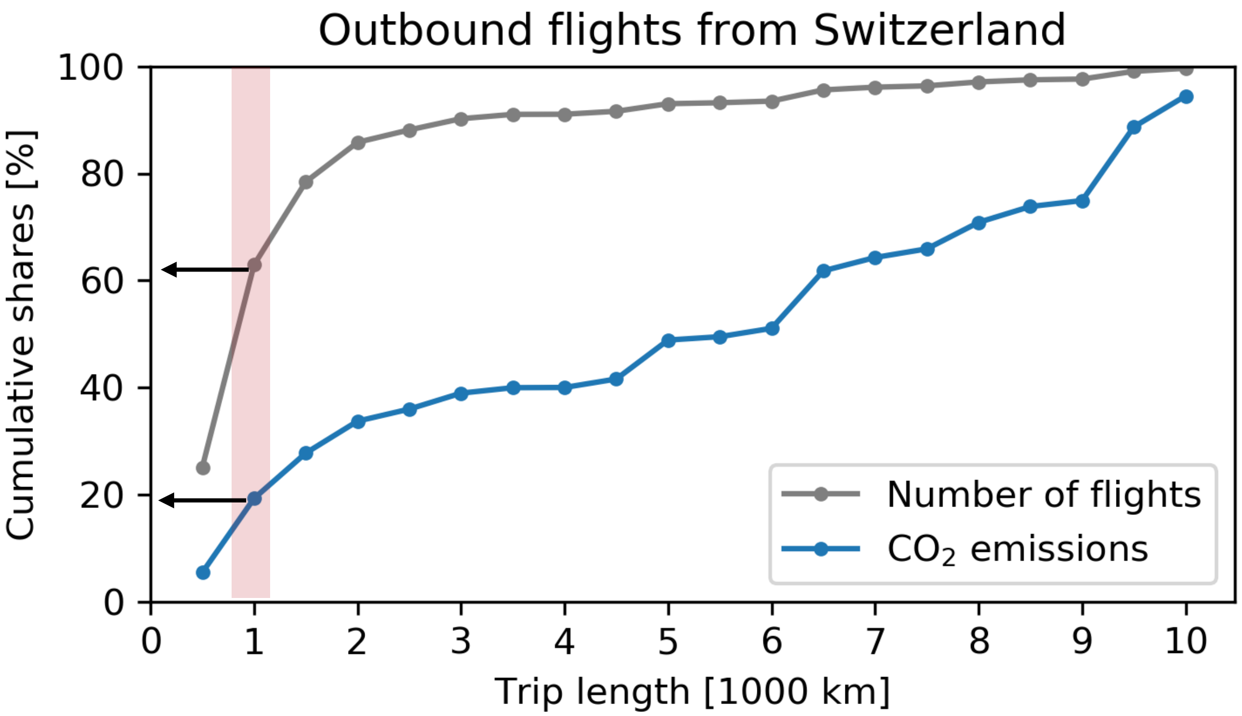
Source: FVV Prime Movers, 2020

Jet-fuel demand will increase substantially until 2050



Forecast of worldwide fuel demand for aviation depending on the implementation of different efficiency improvement technologies (Seymour et al., 2020)

Aviation: Reducing CO_2 emissions by short-haul electrification or shift to high-speed rail?

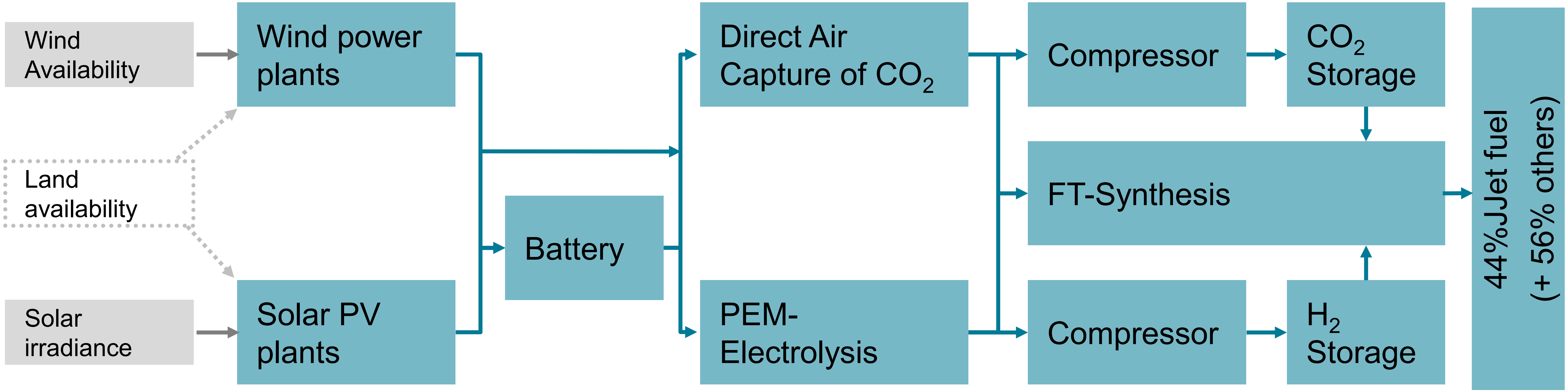


- 63% of all flights departing from Swiss airports are shorter than 1’000 km, corresponding to 19% of total Swiss CO_2 emissions from aviation.
- Estimates indicate that with a battery-pack energy density of 800 Wh/kg (expected around 2050), this could be covered by all-electric aircraft.
- However, assuming 7 flights a day, one year of continuous flight operation would already exceed 2’500 battery charging cycles.
- Therefore, shifting short-haul aviation to high-speed rail makes more sense and is in principal feasible in the near future.

Reference:

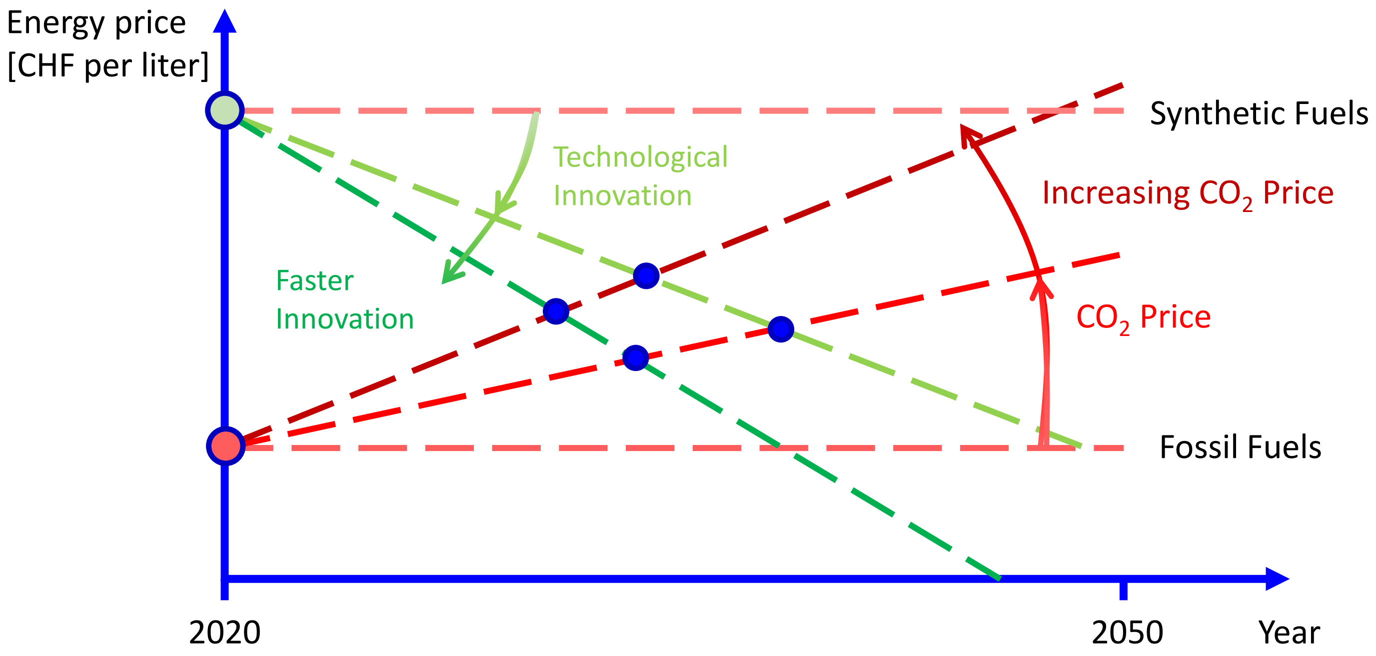
- Own calculation based on the methodology of: Seymour K., Held M., Georges G., Boulouchos K. (2020): "Fuel Estimation in Air Transportation: Modeling global fuel consumption for commercial aviation” in Transportation Research Part D: Transport and Environment, DOI: 10.1016/j.trd.2020.102528
- Schäfer A., et al. (2019): „Technological, economic and environmental prospects of all-electric aircraft” in Nature Energy, vol.4 (2), pp. 160-166

Synthetic renewable fuels: Methodological setup for finding the cost-optimal production sites in Europe



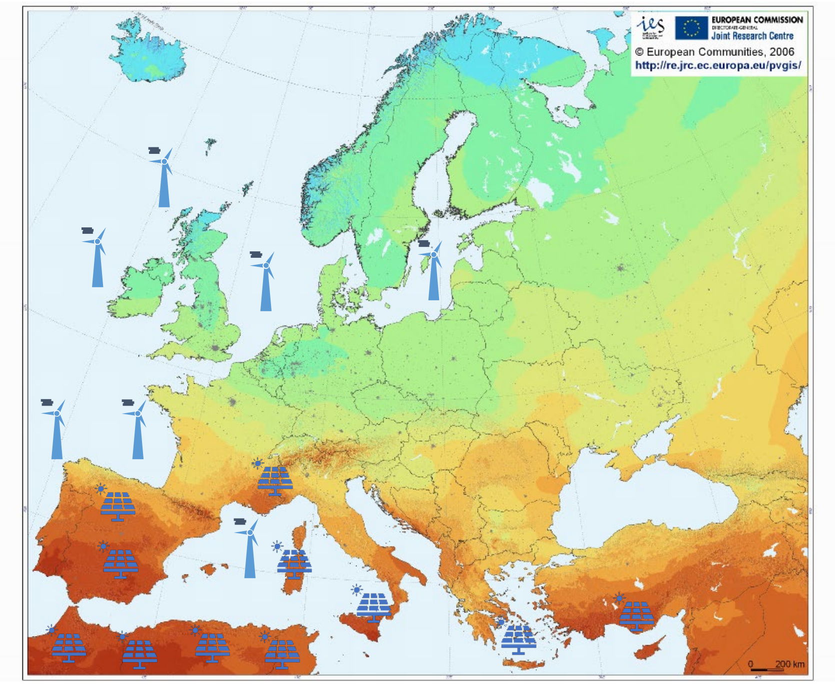
Source: Kyle Seymour, Maximilian Held, Saskia Adam, et. al. ETH Zurich, preliminary results, to be published in 2021

CO_2-Pricing & Technology innovation - We need both!



Source: K. Boulouchos (2020)

Where should renewable fuel come from? The case of Switzerland



- Electricity **requirements** for the production of renewable fuels abroad

→ for heavy-duty road freight: ~10 TWh_{el}

→ for e-jet-fuel (aviation): ~60 TWh_{el}

→ totally: **70 TWh_{el}**

- Why fuel from abroad:

→ Significantly lower electricity costs and much higher quantities can be realized

→ Required installed capacity of the electrolysers 2-3 times smaller than for generation in Switzerland

→ Transport/distribution infrastructure exists for the most part (no need for high-voltage lines)

Installed Power Generation and Electrolyzers Capacities (CH)

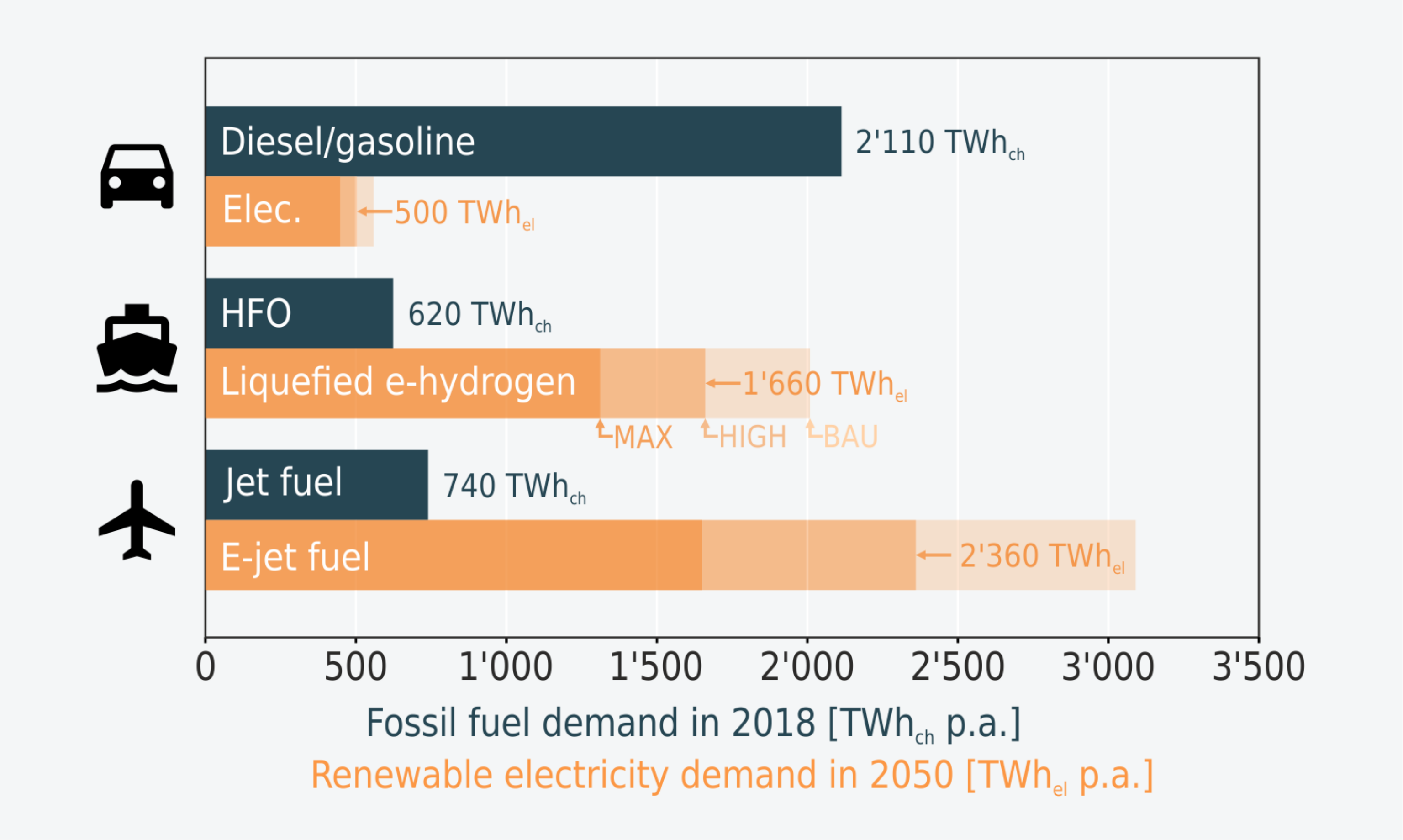
70 TWh renewable fuels for Swiss transportation for heavy-duty road freight and aviation via:

- Solar energy in CH: 1’000 full load hours (**70 GW**)
- Solar energy in best locations: 2’200 full load hours (**32 GW**)
- Wind energy in best locations: 4’600 full load hours (**15 GW**)

For comparison:
Installed current power generation capacity in CH
~20GW

Capacity must be buildt up rather fast so that exissting fleets (trucks, ships, airplanes) can take advantage of «zero»-CO2 fuels

The situation in Europe (EU 27)



For comparison:
Current electricity demand (EU 27) amounts to about 3'300 TWh!

Source: M. Held (ETH Zürich 2021)

Current (2018) annual demand for fossil fuels vs. future (2050) annual demand for renewable electricity for the automotive, the shipping, and the aviation sector. Renewable electricity is either used directly in BEVs, or used to produce liquid e-hydrogen and e-jet fuel.

Conclusions

- Synthetic renewable fuels will be imperative in order to achieve «zero»-CO_2 emissions from heavy-duty and long-haul transport as well as for industry processes
- A variety of options wrt chemical and physical properties w/o clear winner as of now
- Very large investments and huge amounts of additional renewable - or at least «zero»-CO_2 - electricity worldwide will be necessary around 2050
- However the required, installed power generation capacities appear feasible if best locations (mainly for utility-scale PV and on-/off-shore wind) are selected
- For achieving cost-parity with fossil fuels before 2050, steep technoeconomic learning curves <u>and</u> increasing CO_2 - prices for internalizing the climate externality will be indispensable

Aknowledgement

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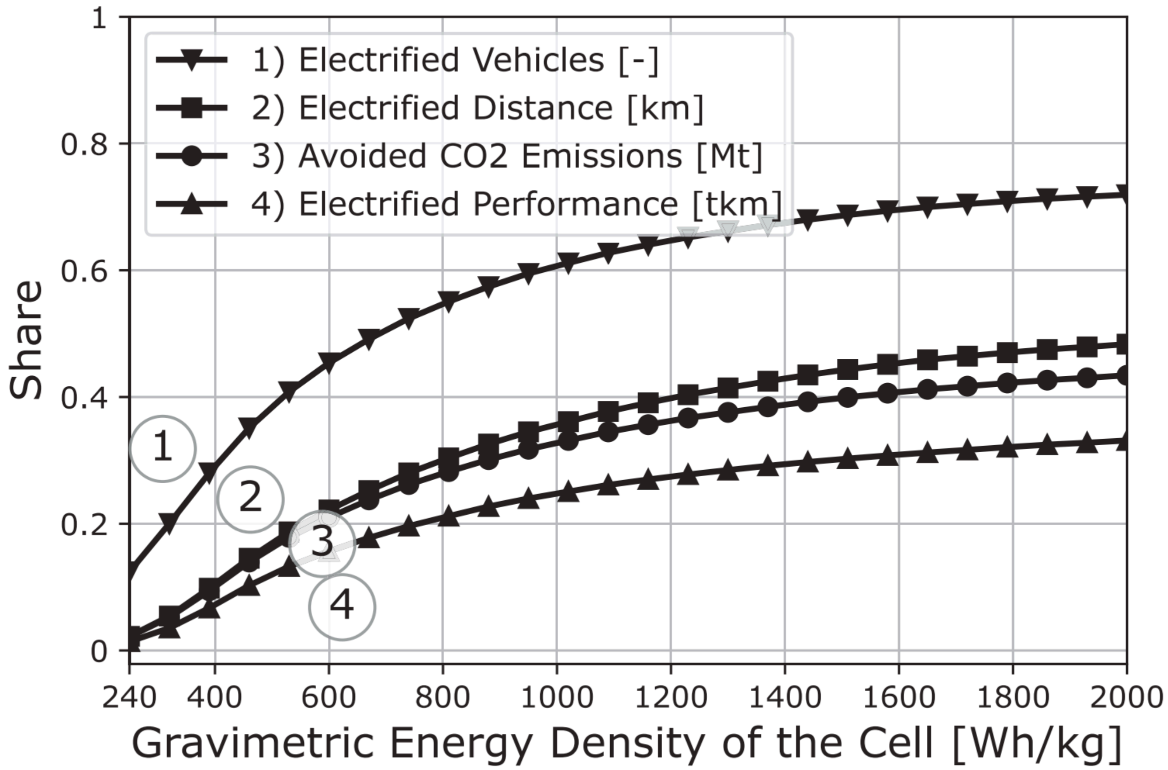
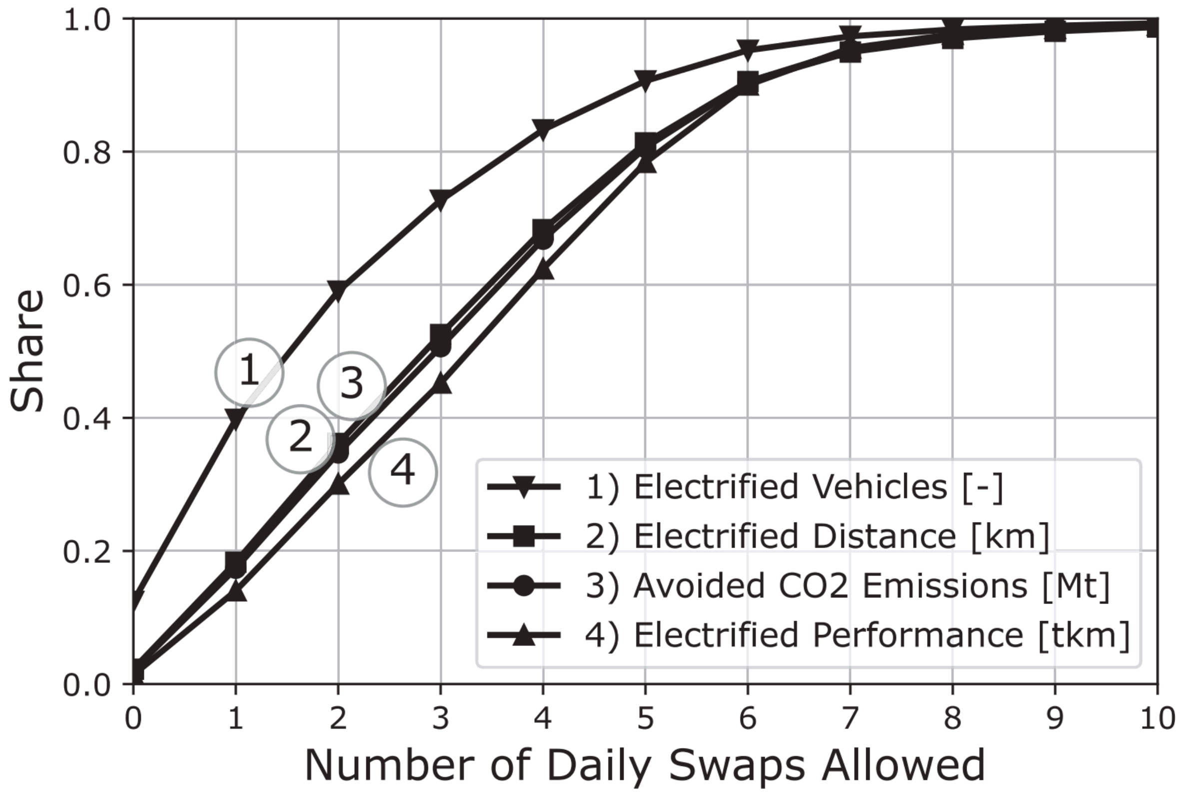
If interested, take a look at the White Paper of the SCCER Mobility (March 20, 2021)

- *"Pathways to a net zero CO_2 Swiss mobility system" - see following link*

Removing fossil fuels from road freight transport (I)
The potential of battery-electric propulsion for trucks in Switzerland.





Reference: Cabukoglu et al. (2018): «Battery electric propulsion: An option for heavy-duty vehicles? Results from a Swiss case-study" in *Transp. Research Part C: Emerging Technologies*, doi: 10.1016/J.TRC.2018.01.013