The environmental performance of passenger vehicles: today and tomorrow

This is an update of the Life Cycle Assessment (LCA) of passenger vehicles from last year [1-3]. Latest research [4] is adapted to Swiss conditions. The update mainly reflects the quick development of alternative drivetrain technologies, especially for Battery Electric Vehicles (BEV) – battery production capacities worldwide are growing and mass production shows a positive effect on associated environmental impacts. In addition, new empirical data on vehicle performance and modeling results of hydrogen production for Fuel Cell Electric Vehicles (FCEV) were included. Improved battery performance and lower impacts from production results in reduced life-cycle burdens of BEV – charged with clean electricity, they allow for a substantial reduction of Greenhouse Gas (GHG) emissions already today.

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Introduction

Passenger vehicles are important contributors to climate change and local air pollution. Clean alternatives to diesel and petrol vehicles are required to mitigate these environmental issues.

Despite of zero exhaust emissions, battery and fuel cell electric vehicles (BEV and FCEV) cause environmental burdens due to their production and the energy supply chains. These overall burdens are quantified applying Life Cycle Assessment (LCA).

BEV and FCEV are relatively new technologies and substantial technology development can be expected for the next decades. Therefore, their environmental performance must be evaluated not only from the current, but also from a future perspective. Different scenarios for the development of global electricity supply are taken into account in prospective LCA, eîther compatible with a 2°C target and largely based on renewables, or not. This has a considerable impact on LCA results and is visualized with error bars in the results for 2040.

Key parameters and assumptions

In this poster, the environmental performance of modern lower mid-sized passenger vehicles (e.g. VW Golf) is compared. Basic vehicle parameters are listed in the table below.

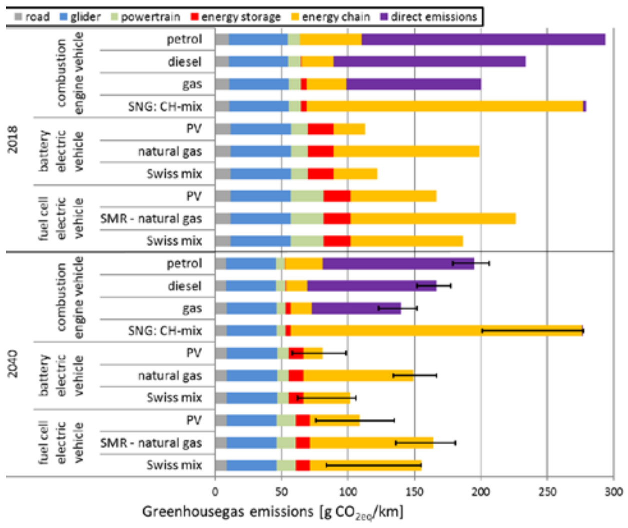
			Lifetime	Vehicle mass	Fuel consumption (real operation)		Range	Efficiency "tank-to-wheel"	Emission standard for pollutants
			km	kg	l petrol-eq per 100km	per 100km	km	%	
2018	ICEV	petrol	200'000	1318	7.6	7.6 l	492	21	EURO 6
		diesel		1342	6.9	6.3 l	615	23	EURO 6
		gas		1391	8.1	5.5 kg	494	20	EURO 6
	BEV			1509	2.2	19.3 kWh	186	64	
	FCEV			1470	4.0	1.05 kg	476	34	
2040	ICEV	petrol	200'000	1231	4.8	4.8 l	550	27	EURO 6 -50%
		diesel		1252	4.6	4.3 l	637	28	EURO 6 -50%
		gas		1290	4.9	3.3 kg	578	27	EURO 6 -50%
	BEV			1334	1.7	15.4 kWh	354	68	
	FCEV			1294	3.0	0.8 kg	509	38	

The LCA is based on a modeling approach. The model builds upon a list of vehicle parameters, e.g. efficiencies of drivetrain components, aerodynamics, rolling resistance, etc. These are used to quantify energy consumption for driving applying official driving cycles. Auxiliaries are added. The model is calibrated using data from the entire European vehicle fleet. Prosepctive LCA represents the expected mid-term future vehicle development.

GHG emissions

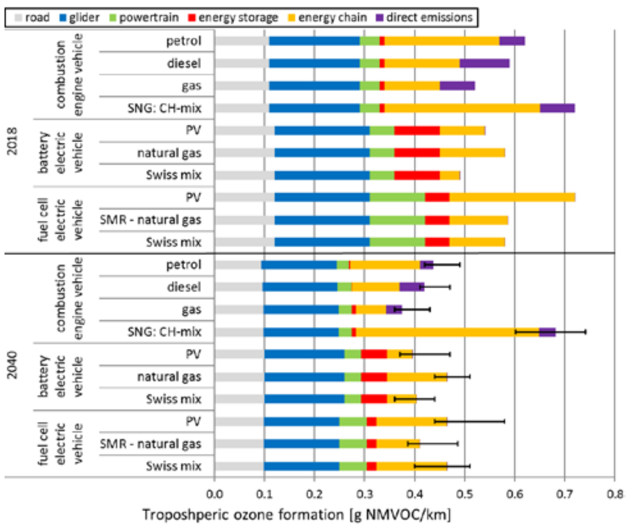
BEV charged with low-carbon electricity allow for a reduction of life-cycle GHG emissions of around two thirds, compared to petrol cars today. This relative reduction potential will remain about the same in mid-term future.

FCEV exhibit a lower reduction potential, as they are less efficient, both regarding powertrain and fuel supply.



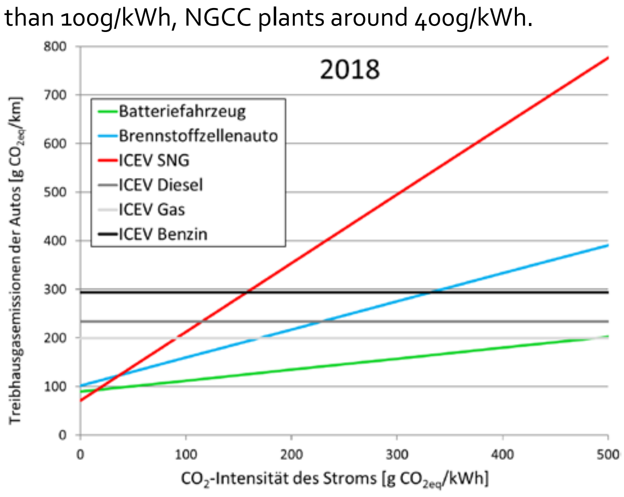
Air pollutants

BEV and FCEV do not cause tailpipe emissions. They improve local air quality, especially if they replace old diesel cars. However, life cycle air pollutant emissions – here represented by those causing summer smog (mainly NO_x and hydrocarbons) – are similar to those of modern ICEV. Some of those emissions are shifted from our city centers to industrial areas in other regions.



GHG intensity of electricity

Life-cycle GHG emissions of BEV (and FCEV with H2 from electrolysis) mainly depend on the carbon intensity of electricity used for BEV charging (and H2 production). Due to highest overall efficiency of BEV, they currently cause lower life-cycle GHG emissions than diesel cars up to a CO2-intensity of around 500g/kWh, while this break-even point is around only 200g/kWh for FCEV with H2 from electrolysis. Renewables usually cause less than 100g/kWh, NGCC plants around 400g/kWh.



Discussion and conclusions

- Since electric vehicles only reduce GHG emissions substantially, if supplied with low-carbon electricity, introduction of BEV must go along with expansion of renewable power generation.
- BEV are most effective among alternative fuels and drivetrains in reducing environmental burdens.
- Electric passenger cars are far from being equivalent to «zero emission» and will still be in the mid-term future. Therefore, just switching to e-mobility will not be sufficient and alternative mobility concepts are required.

Abbreviations

BEV	Battery Electric Vehicle
CH/Swiss-mix	Average Swiss electricity supply mix
CNG	Compressed Natural Gas
CO2eq	Carbon dioxide equivalents
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
ICEV	Internal Combustion Engine Vehicle
LCA	Life Cycle Assessment
NGCC	Natural Gas Combined Cycle
NMVOC	Non-methane volatile organic compounds
PV	Photovoltaics
SMR	Steam Methane Reforming
SNG	Synthetic Natural Gas

References

[1] Cox, B. and Bauer, C. (2018) The environmental burdens of passenger cars: today and tomorrow – fact sheet. Paul Scherrer Institut, Villigen PSI, Switzerland.

[2] Cox, B. and Bauer, C. (2018) The environmental burdens of passenger cars: today and tomorrow – background report. Paul Scherrer Institut, Villigen PSI, Switzerland.

[3] Cox, B., Mutel, C., Bauer, C., Mendoza Beltran, A. and van Vuuren, D. (2018) The uncertain environmental footprint of current and future battery electric vehicles. Environmental Science & Technology, doi:10.1021/acs.est.8b00261

[4] Cox, B., Bauer, C., Mendoza Beltran, A., van Vuuren, D. and Mutel, C. (2019) Life cycle environmental and cost comparison of current and future passenger cars under different energy scenarios. Submitted to Applied Energy.

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