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Environmental impact of passenger cars with different powertrain types

Present (2021) and future scenarios (to 2050).

Summary of the expert report by the Federal Office for the Environment (FOEN)

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Summary

The most important facts in brief:

The report compares the environmental impacts of differently powered passenger cars over their entire life cycle. The calculations are based on life cycle inventory data updated by the Paul Scherrer Institute in 2022.

Battery-electric passenger cars cause fewer greenhouse gas emissions, a lower total environmental impact and lower cumulative energy consumption than comparable passenger cars powered by petrol, diesel, natural gas or hydrogen from non-renewable energy. Only fuel cell vehicles powered by hydrogen from renewable energy have a similarly low environmental impact as battery-electric vehicles.

Regardless of the powertrain type, small and light passenger cars have a lower impact on the environment than large and heavy ones.

The future scenarios based on the federal government's Energy Perspectives 2050+ show that battery electric vehicles offer the greatest potential for reducing greenhouse gas emissions and the overall environmental impact between 2030 and 2050 compared to other powertrain types.

This expert report compares the environmental impact of using passenger cars with different drive systems over their entire life cycle. The study is based on life cycle inventories that were updated and, in part, newly compiled in 2021/22.

The report describes the life cycle assessment methodology, the underlying data used, the procedure followed, and the assumptions made when compiling these inventories. The main section presents the results of the inventories, classifies them and supplements the results with sensitivity analyses. The report ends with a description of the development potential for two future scenarios and conclusions for reducing the environmental impact of passenger cars.

The **results in Figure A1** show a comparison of the environmental impact of mid-size vehicles with different drive systems, broken down into vehicle manufacture, operation, maintenance and disposal, as well as the provision of energy and the road infrastructure. The lowest environmental impact is observed with the battery electric vehicle (BEV) powered by renewable electricity. Compared to a petrol vehicle, its greenhouse gas emissions (GHG) are 65% lower. It has a 44% lower overall environmental impact and 32% lower cumulative energy demand.

If a BEV is operated with the consumer electricity mix, it also has a lower environmental impact than an internal combustion engine, although the difference is less significant. It produces 55% less greenhouse gas emissions, has a 23% lower total environmental impact and an 5% lower cumulative energy demand than the petrol vehicle.

A fuel cell vehicle (FCEV) powered by hydrogen from renewable sources has comparable environmental impacts to the BEV powered by renewable electricity.. On the other hand, an FCEV with hydrogen produced with the consumer electricity mix causes significantly more greenhouse gas emissions than the BEV.

The highest level of greenhouse gas emissions is caused by the petrol vehicle, while the highest total environmental impact and the highest cumulative energy demand result from the fuel cell vehicle powered by hydrogen with the consumer electricity mix. The total environmental impact of this vehicle is 17% higher than that of the petrol vehicle, and the cumulative energy demand is 77% higher than that of the petrol vehicle. Diesel and LPG vehicles are slightly below petrol vehicles in all indicators. For petrol vehicles, a hybrid system can reduce greenhouse gas emissions by between 7% (hybrid) and 16% (plug-in hybrid, PHEV), although for PHEVs the reduction

depends to a large extent on the charging behaviour. When the overall environmental impact of hybrid vehicles is considered, the reduction is lower than for greenhouse gases. The cumulative energy demand decreases by 6% with hybrids; for the PHEV, the cumulative energy demand increases marginally compared to the petrol vehicle.

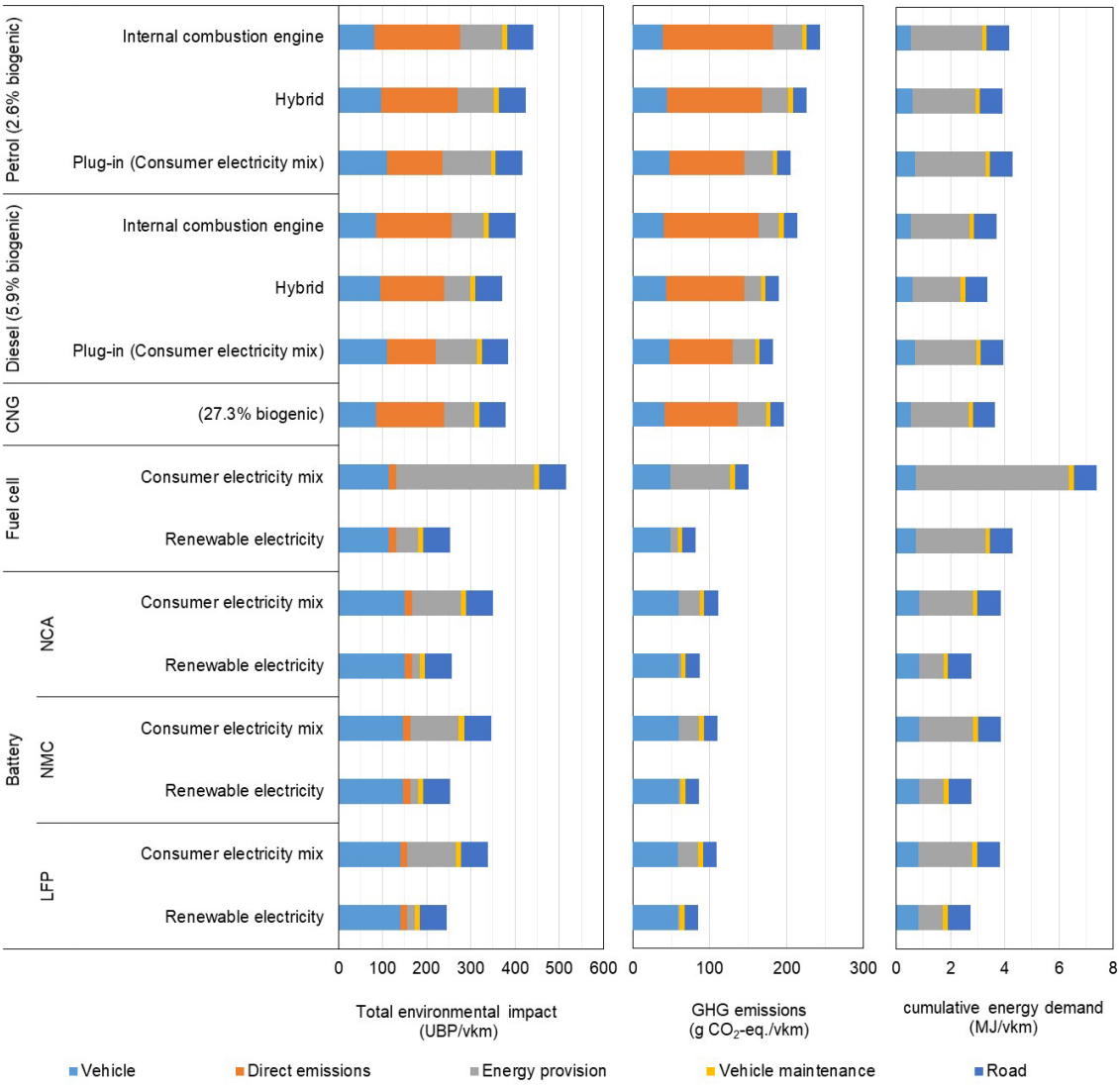

Figure A1: Influence of the different powertrain types on the total environmental impact (UBP), the level of greenhouse gas emissions (g CO_2-eq.) and the cumulative energy demand (MJ) per vehicle kilometre (vkm) of a mid-size passenger car (1,250–1,750kg).
Consumer electricity mix in 2018 (35% hydropower, 40% nuclear, 10.7% new renewable, 14.3% other. Total imports 45%)
Renewable electricity (96% hydropower, 4% other renewable).
Note: The environmental impact of certain vehicles and an individual electricity mix can be estimated by entering the key figures in the Excel table at www.mobitool.ch.
NCA: Lithium-ion battery with an anode of lithium nickel cobalt aluminium oxide
NMC: Lithium-ion battery with an anode of lithium nickel manganese cobalt oxide
LFP: Lithium-ion battery with an anode of lithium iron phosphate ($LiFePO_4$)

Comparing the **different size classes of passenger cars** with each other, it can be seen that smaller and lighter vehicles pollute less than larger and heavier ones for all types of powertrain types. The range of vehicles analysed shows a potential reduction of 75% in greenhouse gas emissions between the largest petrol vehicle (luxury SUV) and the compact BEV with the consumer electricity mix.

Compared to public transport and journeys made by bicycle, passenger cars produce the highest levels of greenhouse gas emissions by far and have the greatest environmental impact. Over a distance of 5km, a mid-range petrol vehicle causes about twelve times more greenhouse gas emissions and a battery electric vehicle about six times more greenhouse gas emissions than the average public transport vehicle.[1] Compared to a bicycle, a petrol vehicle emits about 26 times more greenhouse gases, a battery electric vehicle about 12 times more.

The two **future scenarios** considered – a 'business as usual scenario' and the basic 'net zero emissions' scenario (ZERO) – are, as far as possible, based on the federal government's Energy Perspectives 2050+ and have been supplemented with assumptions on the technological development of vehicles. An evaluation of these scenarios shows that battery electric vehicles offer the greatest potential for reducing greenhouse gas emissions between 2030 and 2050. The use of hydrogen or electricity-based synthetic fuels produced in 2030–2050 with the electricity mix projected for this period does not lead to any further reduction in greenhouse gas emissions and overall environmental impact compared to the respective BEVs. In the scenarios considered, their use also does not lead to a reduction of greenhouse gases compared to today's BEV. If only renewable drive energy is used, BEVs cause the lowest greenhouse gas emissions and the lowest total environmental impact of all examined powertrain types.

The additional reduction potential of battery electric vehicles is mainly achieved by a higher **lifetime mileage** of the vehicle and **lighter batteries**. In comparison, battery reuse (**second life**) and increased battery **recycling** offer less reduction potential in terms of greenhouse gases and the environmental impact, although the availability of raw materials also plays a role in addition to the environmental impact of raw material provision. This aspect of raw material availability cannot be considered in depth in this report, but existing recycling processes have been taken into account.

Based on the findings, the **possibilities for reducing the environmental impact** are as follows. The greatest potential lies in the choice of transport mode: as the comparison shows, public transport and cycling have a much lower environmental impact. Furthermore, with a battery electric vehicle, the environmental impact per kilometre can be kept significantly lower than with other powertrain types. Renewable electricity and a low vehicle weight play an essential role in this. The environmental impact can be further reduced by frequent charging of plug-in hybrids, with a long lifetime mileage of battery electric vehicles and by using recycled materials in the battery.

The **updated life cycle inventories** for passenger cars presented in this report lay the foundation for further work in the field of life cycle assessments. The inventories are documented and available for further studies.

[1] See Excel table at www.mobitool.ch