Environmental and cost comparison of personal transportation powertrains

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Introduction

In Switzerland, the personal road transportation fleet:
- consumes 19% of national final energy
- produces 22% of national GHG emissions
- is expected to grow by 23-32% by 2050

Technology alternatives such as hybrid cars, battery electric cars, fuel cell cars, or plug-in hybrid cars may be able to reduce transportation related energy consumption and environmental burdens compared to conventional cars, but a transparent analysis of costs and environmental impacts is required for informed decision making.

Aim

Examine costs and environmental impacts of a mid-sized car under consistent conditions for different powertrains and energy supply chains with current technology levels.

Research question:
What are the costs and environmental burdens of travelling with different personal transportation technologies and where do they come from?

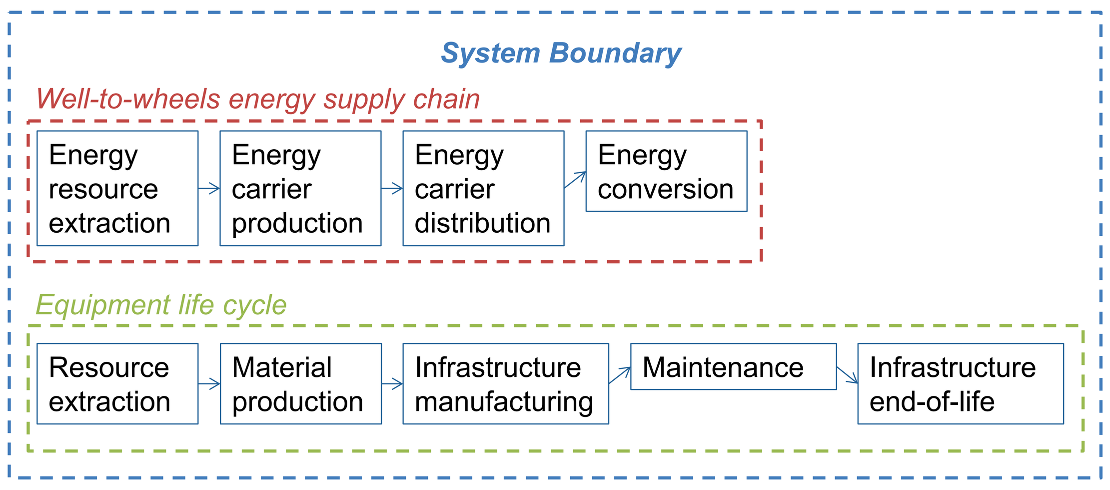
Methodology

- Vehicle assumed to be driven 15 000 km per year for 10 year lifetime based on WLTP* driving cycle
- Costs and environmental impacts from each component are accounted for separately to allow transparent comparison
- The same glider, performance requirements, and driving cycle are used for all compared technologies

* World-Harmonized Light-Duty Vehicles Test Procedure

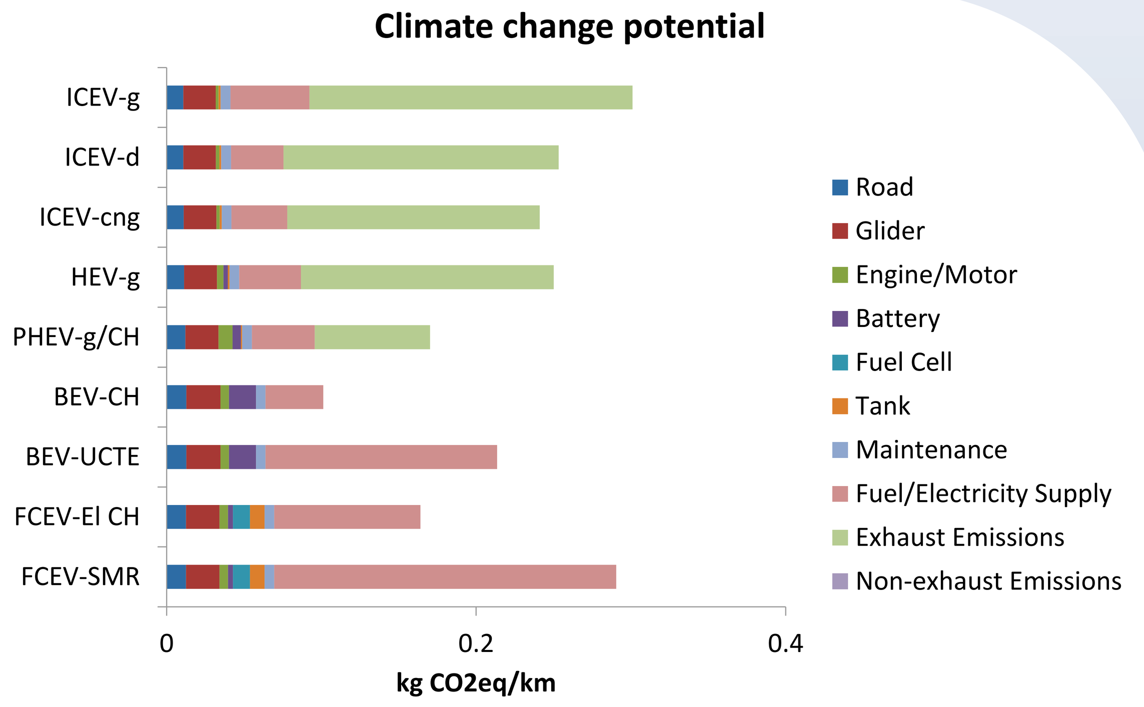
Environmental impacts

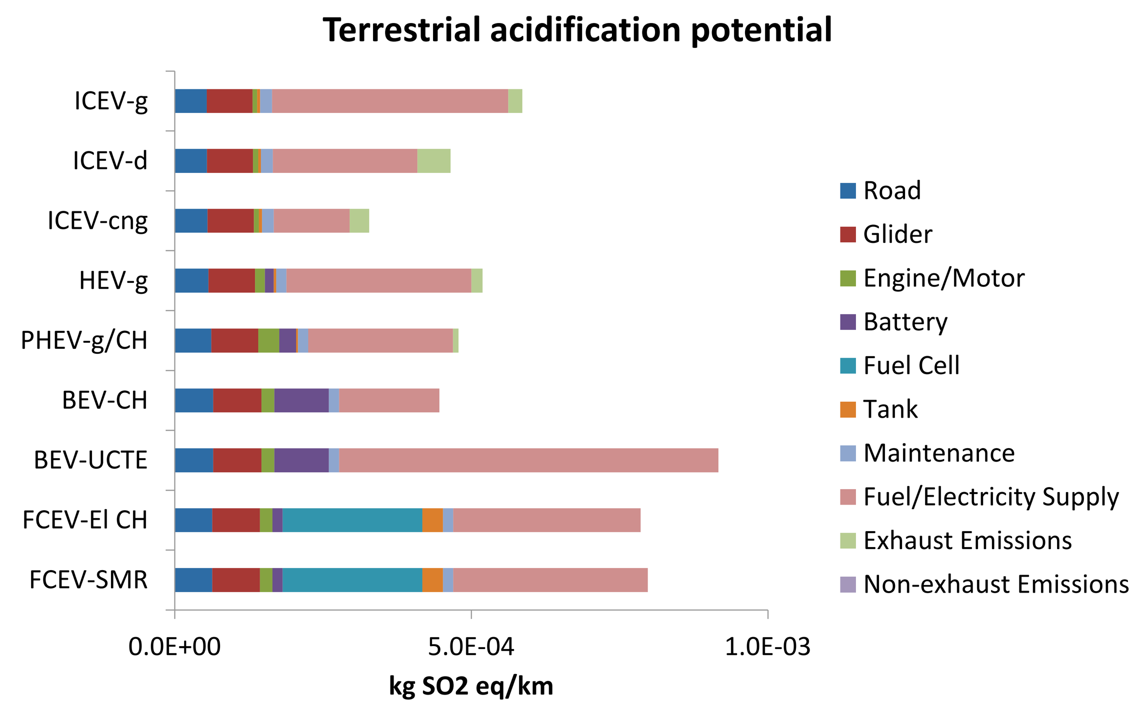
- Life Cycle Assessment (LCA) methodology used
- Ecoinvent LCA database used with SimaPro software
- Functional unit is “1 km driven”
- All life cycle phases are considered, including the complete equipment life cycle and the well-to-wheels energy supply chain

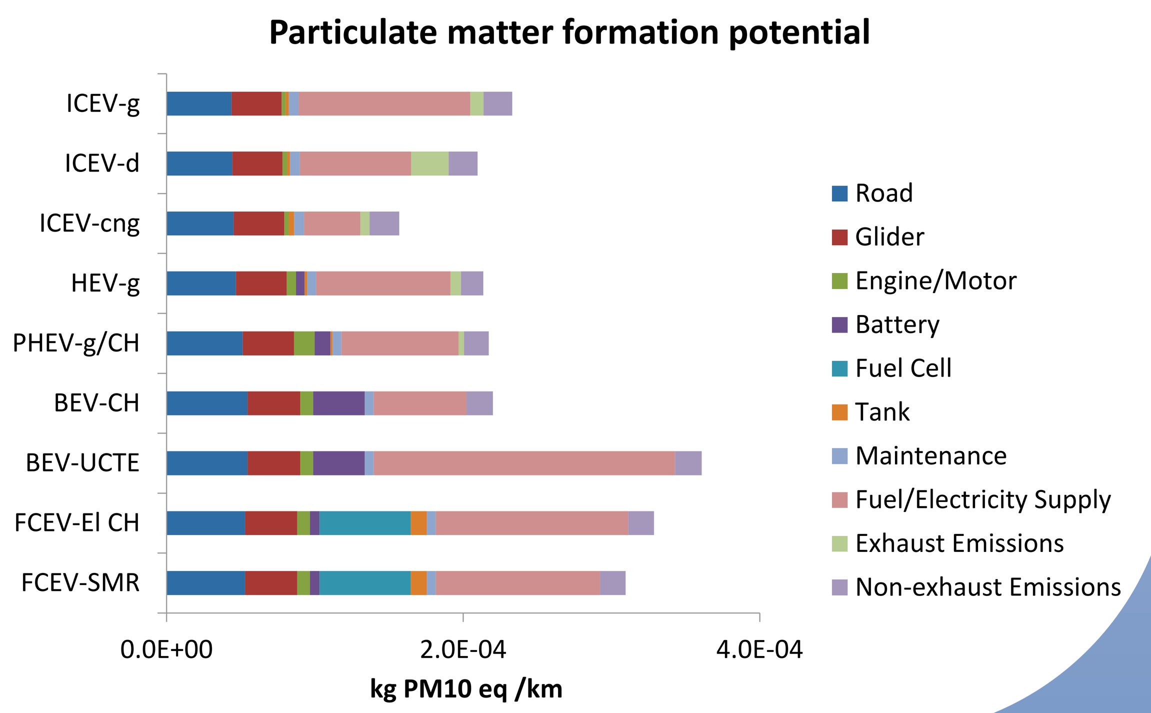


ReCiPe midpoints (hierarchist perspective) used to quantify environmental burdens:
- Climate change potential includes all greenhouse gases according to IPCC GWP 100a
- Terrestrial acidification includes SO_2 and NO_x emissions
- Particulate matter includes primary formation as well as secondary formation due to NO_x, SO_2 and ammonia emissions

ICEV-g	Internal combustion engine – gasoline
ICEV-d	Internal combustion engine – diesel
ICEV-cng	Internal combustion engine – compressed natural gas
HEV-g	Hybrid electric vehicle – gasoline
PHEV-g/ CH	Plug-in hybrid electric vehicle – gasoline and Swiss electricity
BEV-CH	Battery electric vehicle – Swiss electricity
BEV-UCTE	Battery electric vehicle – European electricity
FCEV-El CH	Fuel cell electric vehicle – hydrogen from Swiss electricity
FCEV-SMR	Fuel cell electric vehicle – hydrogen from steam methane reforming

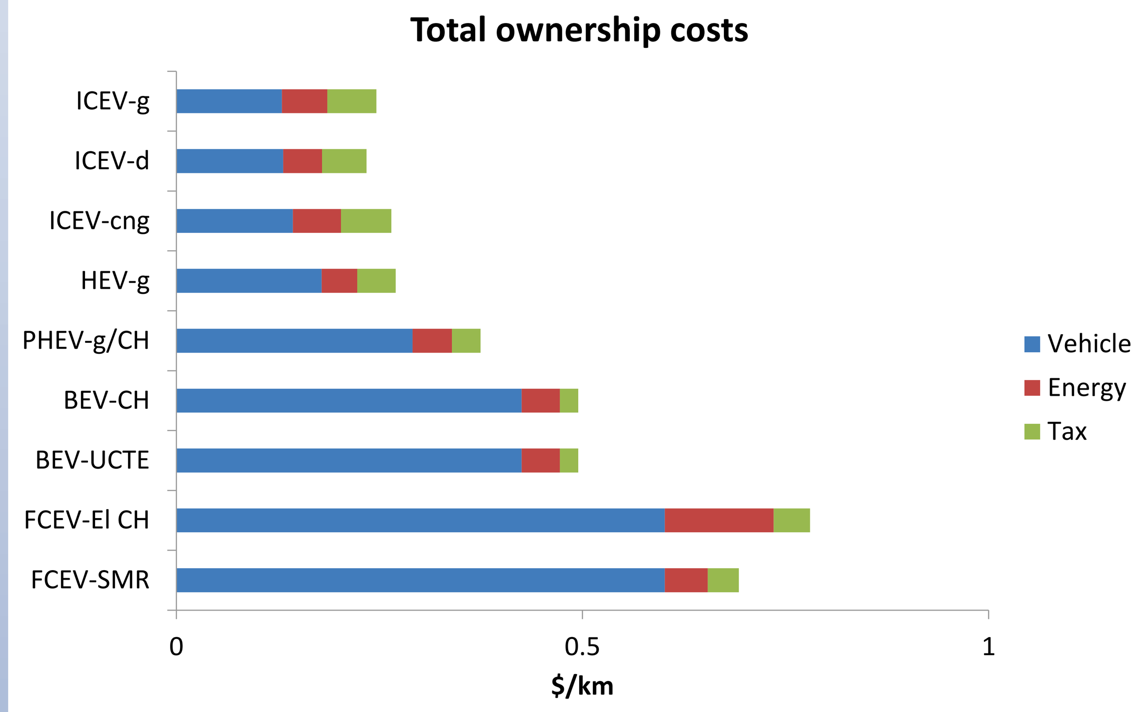






Total ownership costs

- Total ownership costs refer to costs seen by owner (do not include public infrastructure or external costs)
- Vehicle costs are manufacturing costs plus profit margins
- Energy costs are the cost of fuel and/or electricity
- For consistent comparison, energy taxes are added to all energy sources based on 2013 Swiss gasoline tax 24.1 $/GJ + 8% VAT



Outlook

PSI is developing consistent high quality data for the environmental burdens and costs of transportation for current and 2050 technology levels.

Future work will include:
- extending existing data coverage to all transportation modes including road, rail, water and air for both personal and freight transportation for current and future technology levels
- implementing more advanced models using state of the art LCA techniques such as consequential LCA or regionalized LCA
- extending analysis to include other sustainability indicators such as noise, accident risk, etc.

Conclusions

- Methodology presented allows a consistent comparison of different powertrain types and energy supply chains for current, mid-size passenger vehicles
- Accounting for future technology developments is necessary to demonstrate the full potential of advanced technologies (work in progress)
- Technologies such as hybridization and electric powertrains have the potential to reduce GHG emissions, if powered by low carbon sources
- It is important to consider environmental impact categories other than only GHG emissions when comparing different technologies
- Fuel switching from gasoline to diesel to natural gas offers improvements in all environmental impact categories examined, with marginal impacts on cost.
- Hybrid powertrains are economically competitive and offer benefits compared to pure fossil fuel powertrains

Acknowledgements

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About the author

Brian Cox is a PhD student in the Technology Assessment group of the Laboratory for Energy Systems Analysis at the Paul Scherrer Institut in Switzerland. His research focus is on analysing the economics and environmental burdens of the Swiss transport sector and how they are expected to develop until 2050.

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