Reviewing comparative LCAs for battery electric vs. internal combustion engine vehicles for passenger cars

Beitrag beim enerday 2022, TU Dresden

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DLR Projektträger

Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

Literature shows varying results for the Life Cycle Assessment (LCA) of BEVs in comparison with ICEVs


Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Total CO_2-equivalent life-cycle emissions from commercially available passenger cars

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"It can be seen that the CO_2-emissions of the electric motor are [...] a good quarter higher in the unfavorable case [than those of the diesel engine]."
– (translated from German), Buchal, Karl & Sinn, 2019

"increasing electrification led to increasing benefits versus conventional liquid"
– Hill et al. 2020

Due to the high ecological backpack in battery production, there is a requirement to significantly reduce this backpack in the future.
– (translated from German) Wietschel et al., 2022

Research questions

I. What **findings** do recent **comparative LCA** studies for **BEV**[1] and **ICEV**[2] have?

II. What are the **main drivers** for **differences**?

Aim of the work

I. Identification of **reasons** for **differing results**

II. Provision of **guidelines** for LCA interpretation

[1]Battery Electric Vehicle
[2]Internal Combustion Engine Vehicle

Four step methodology to identify main drivers of the environmental impact

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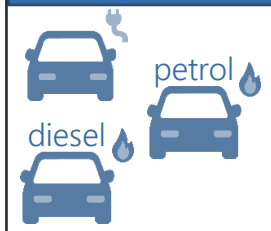
I. Meta study of recent Life Cycle Assessment studies with focus on Germany

Raw Materials → Production → Distribution → Use → Recycling

II. Identifying parameters and assumptions that lead to different results

- Car classes
- Total mileage over the entire lifecycle
- Specific consumption
- Electricity mix used for charging
- Share of urban driving

III. Dynamic Life Cycle Assessment with identified parameters



- Battery electric vehicle (BEV)
- Internal combustion engine vehicle petrol (ICEV_p)
- Internal combustion engine vehicle diesel (ICEV_d)
- Fuel cell electric vehicle (FCEV)
- Plug-in hybrid electric vehicles (PHEV)
- Small car
- Compact car
- Family car
- Executive car

IV. Sensitivity analysis for identified parameters

10% variation of parameters

Broad range of resulting footprints for BEVs and conventional cars in literature

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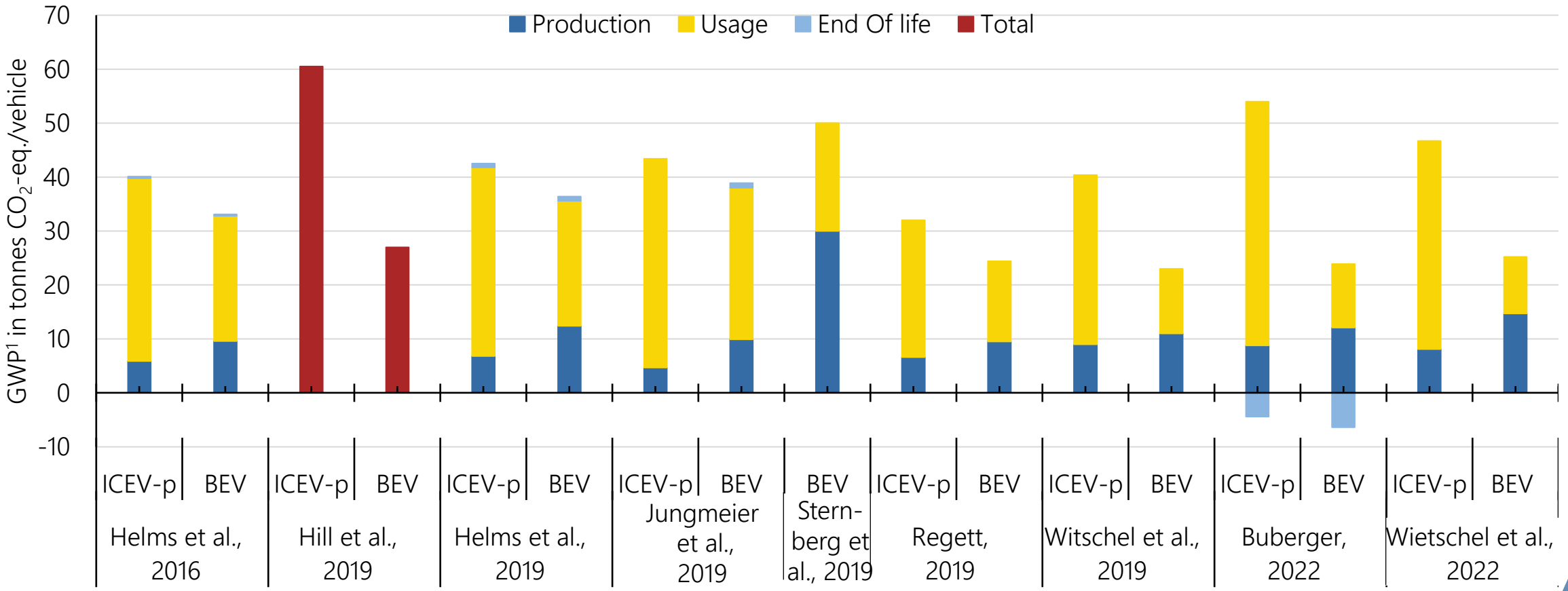
LCA-results within literature on BEVs vs. ICEVs, German case studies



Higher impact of production of BEVs is offset by the lower carbon emissions during the use phase

[1]Global warming potential

Parameter based Life Cycle Assessment in a Jupyter Notebook

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Parameters

1.1 Definition of goal and scope

In the first phase, you define the goal and scope of your LCA.
per year and how high the share of urban driving is.

- Lifespan
- Mileage
- **Share of urban driving**

  What share is driven in urban areas? The rest is allocated to d

  Share of urban driving [%]
- Consumption

Life cycle inventory

1.2 Life cycle inventory

In the second phase, the life cycle inventory (LCI) with all relevant processes
with all the in- and output flows has already been conducted. You only have t
use and the end of life stage of the observed life cycle.

Production stage | Use stage | End of life stage

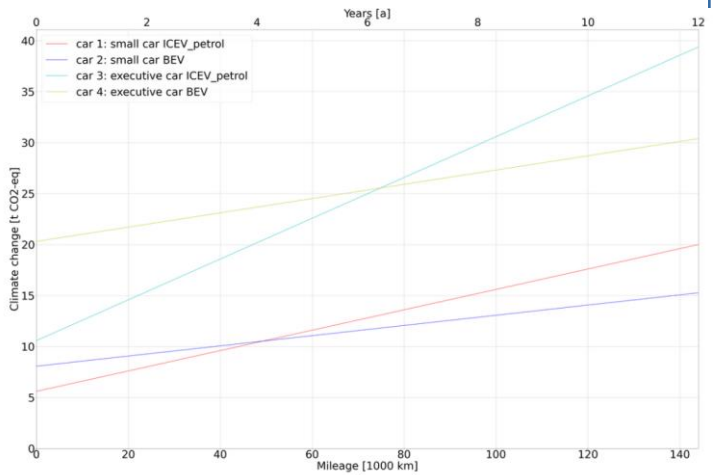
Electricity generation

How is the electricity for the production processes of the batteries, fuel c

Electricity used for production:

- (•) Status quo
- ( ) From renewable energy sources
- ( ) Fossil fuel based

Results



Possibility to calculate own LCA **with different parameters** for comparison

Parameter based Life Cycle Assessment in a Jupyter Notebook

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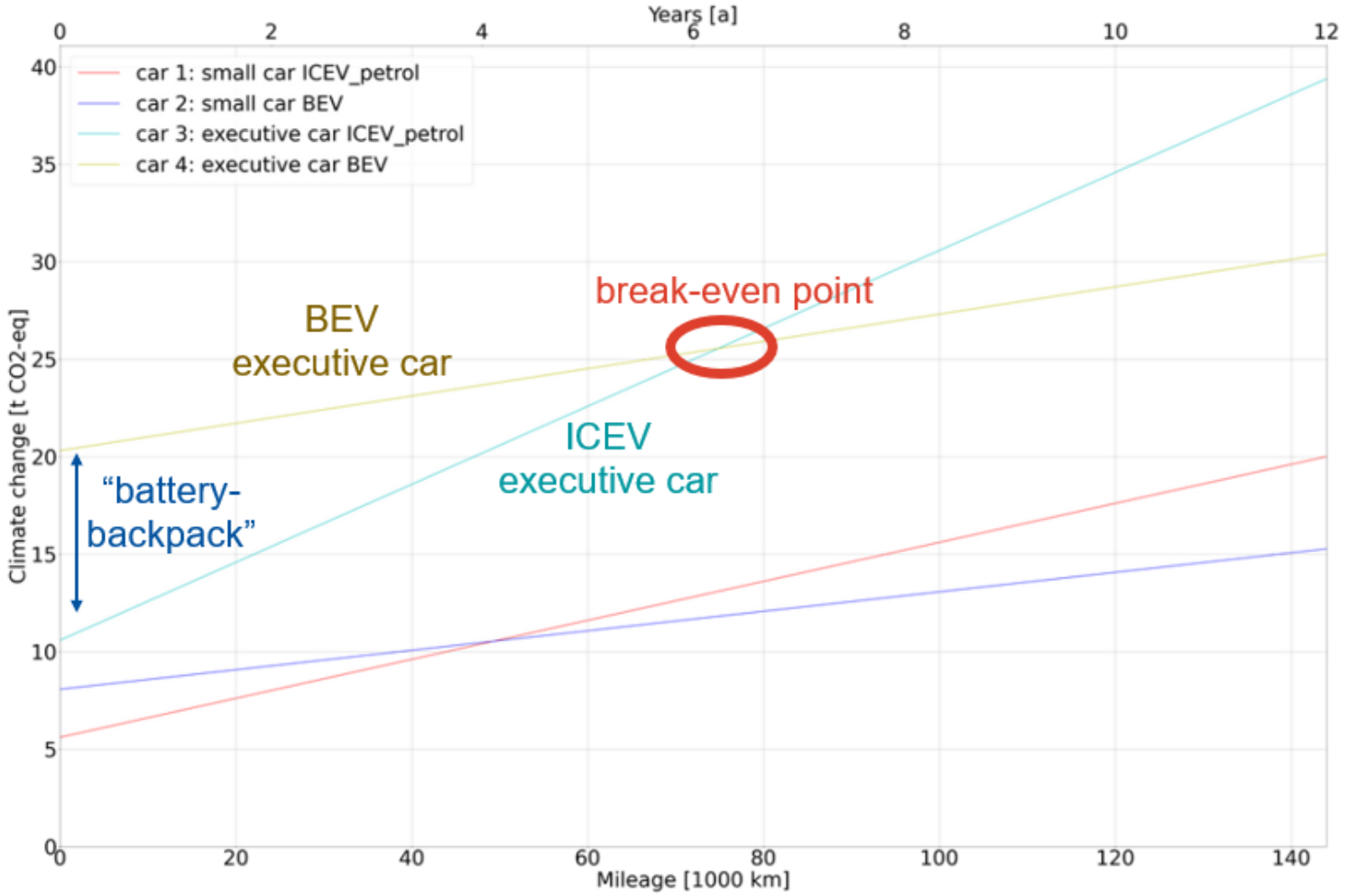

Results provide information on the **break-even point** for different vehicle classes

Sensitivity analysis of 10% shows deviation of GWP for different car classes

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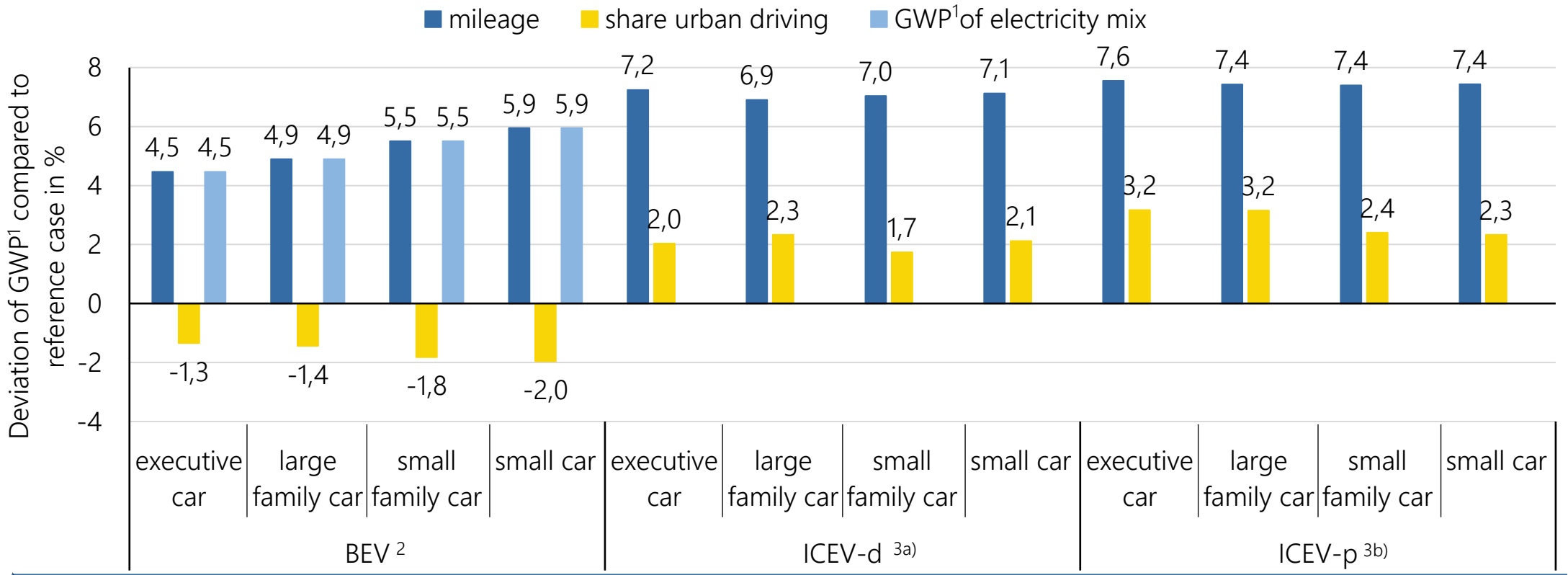
Influence on the LCA by variation of sensitivity parameters by +10%



Variations of use phase parameters for smaller BEVs are more sensitive on the total GWP

[1] Global warming potential, [2] Battery electric vehicle, [3] Internal combustion engine vehicle: a) diesel, b) petrol

Environmental "break-even point" between BEV and ICEV strongly depends on parameter choice

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Sensitivity analysis of parameters (+10%) in use phase compared to reference scenario

Parameter for sensitivity analysis (variation by +10%)	Average deviation of GWP compared to the reference scenario		
	BEV	ICEV-p petrol	ICEV-d diesel
Mileage	~+5.2%	~+7.5%	~+7.0%
Consumption	~+5.2%	~+7.5%	~+7.0%
GWP of electricity mix for charging	~+5.2%	0%	0%
Share of urban driving	~ -1,6%	~+2.0%	~ +2.8%

Conclusion	Reaching of break-even point with ICEV
BEV	
Bigger impact on ICEV than BEV	equal[1]
Bigger impact on ICEV than BEV	earlier
Only impact for BEV	later
Environmental benefits for BEV and disadvantages for ICEV	earlier

[1]The break-even point is reached at the same mileage, yet the GWP increases at a higher rate with continued driving distance for the ICEV (due to the higher impact of the operation phase).

Guidelines for LCA interpretation and further research in current projects

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Conclusions

- Choice of parameters can strongly impact the results of LCA studies
- Guidelines for LCA interpretation:
  - Due to the **energy-intensive battery production**, BEV show a comparatively **higher footprint at the production-phase**, that can be compensated during the operation phase
  - The **higher the specific consumption** in the use phase per technology, the **shorter the ecological payback time** of BEVs
  - The **higher the share of trips in urban traffic**, the **lower the impact of BEVs** and the **higher the impact of ICEV**
  - Since the **GWP of the electricity mix** is decisive for the impact of battery production and the operation phase of the BEV, **future developments** need consideration through a **prospective LCA-approach**

Further research

- Environmental impact of different smart charging use cases

  in the project unIT-e² (FfE)

- Environmental impact of DC infrastructure

  in the project IDEAL (RWTH Aachen)

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Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag