Karlsruhe Institute of Technology

IFKM

Automatized LCA of Parametrizable Passenger Car Glider Models

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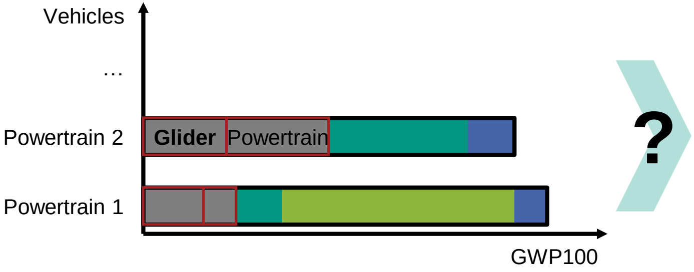
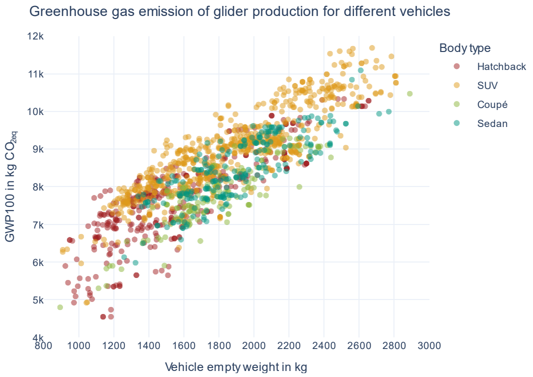
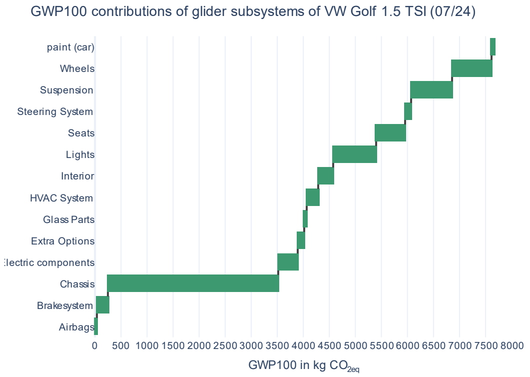
openLCA.conf, April 16 2024





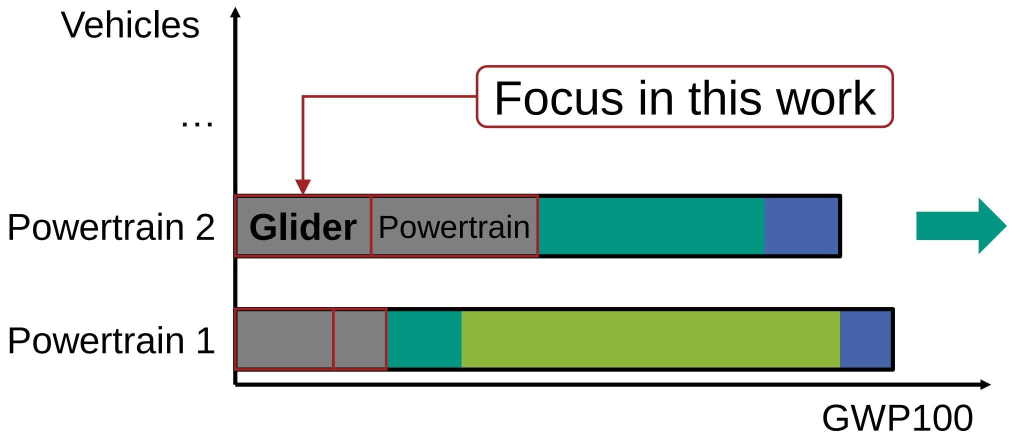


Agenda

- Motivation and Requirements
- Approach
- Results
- Conclusion

Motivation & Requirements
Common passenger car LCA studies vs. vehicle variety

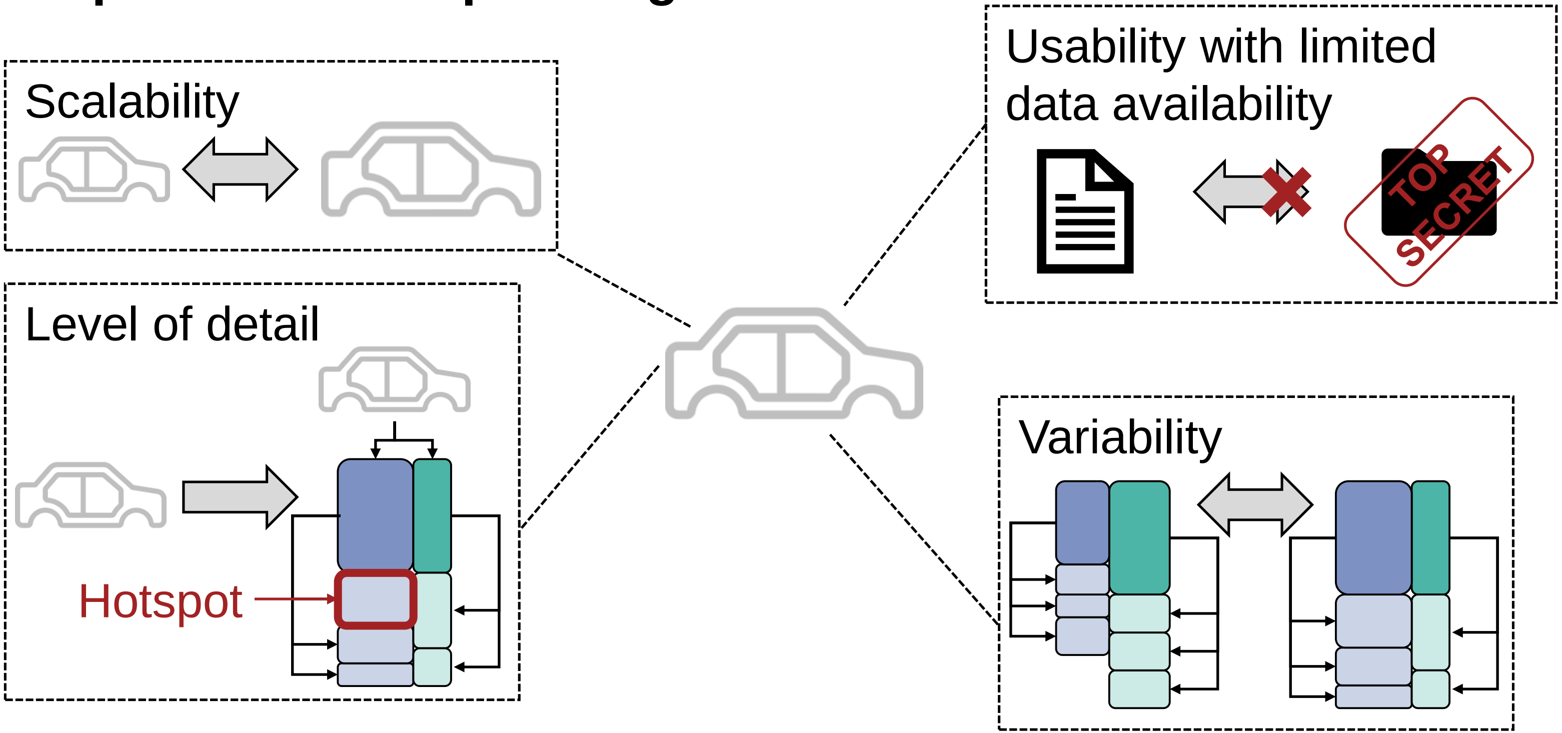
- Comparison of vehicles different powertrains regarding GWP100
- Life cycle stages **vehicle production**, **energy provision**, **usage** and **disposal**
  - Possible further subdivision



➔ Only valid for one specifc vehicle with numerous boundary conditions

➔ What about vehicles with different dimensions, components, materials, etc.?

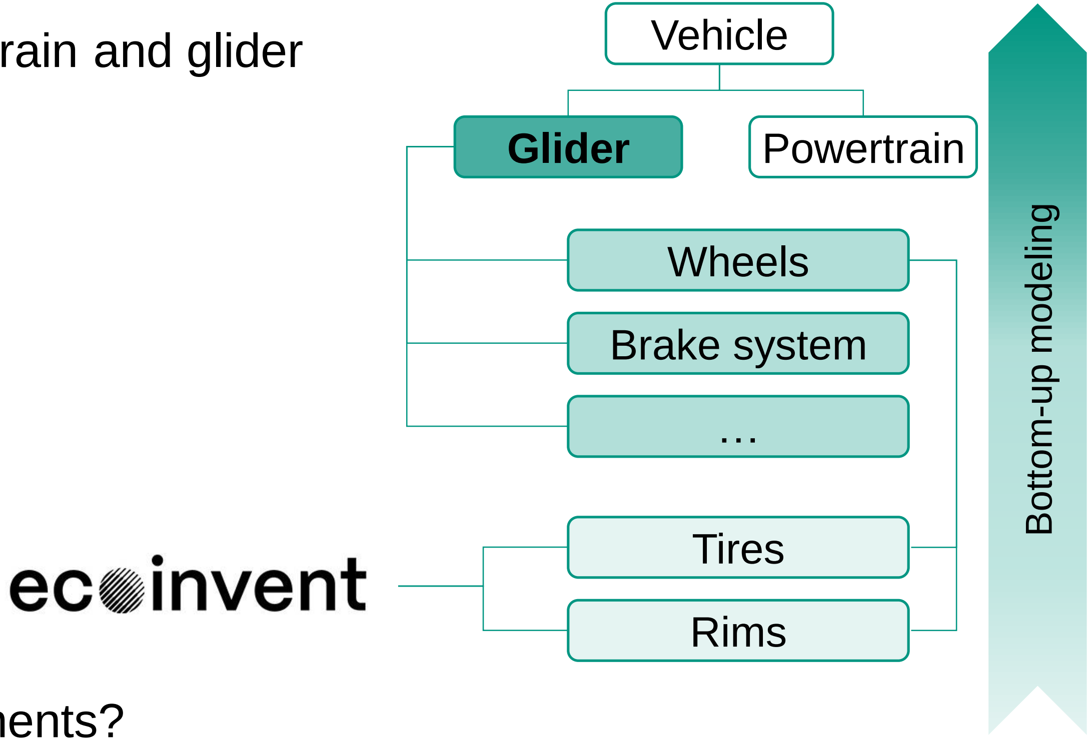
Motivation & Requirements
Requirements for passenger car LCI and LCA



➡ Parametrizable multi-level mass, material and energy information required

Approach
Glider definition and bottom-up modeling

- Breakdown of vehicle into powertrain and glider
- Further subsystem levels down to component level
- Connection with background database at the bottom
- Bottom-up joining of components up to top level

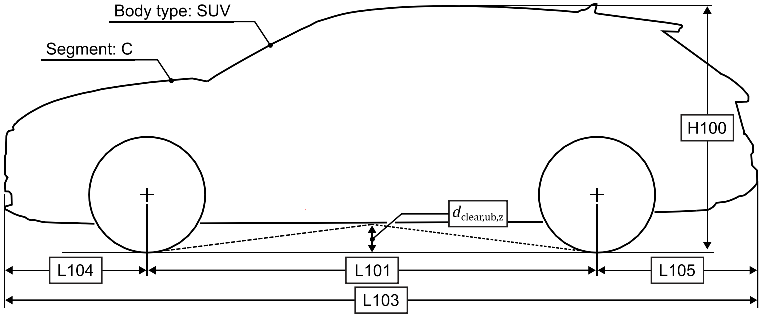


➡ How do we model the components?

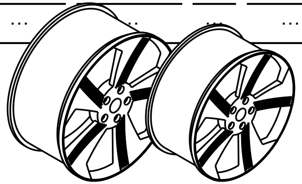
Approach
Component modeling through concept engineering

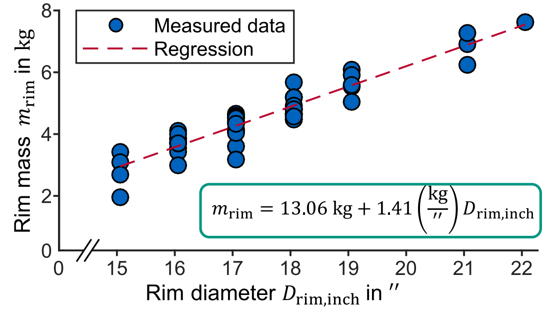
- Concept engineering = component dimensioning with basic design parameters

Vehicle dimensions → Component mass



Part	Diameter	....	Mass
Rim 1	16''	...	9 kg
Rim 2	18''	...	11 kg
...	...	...	...



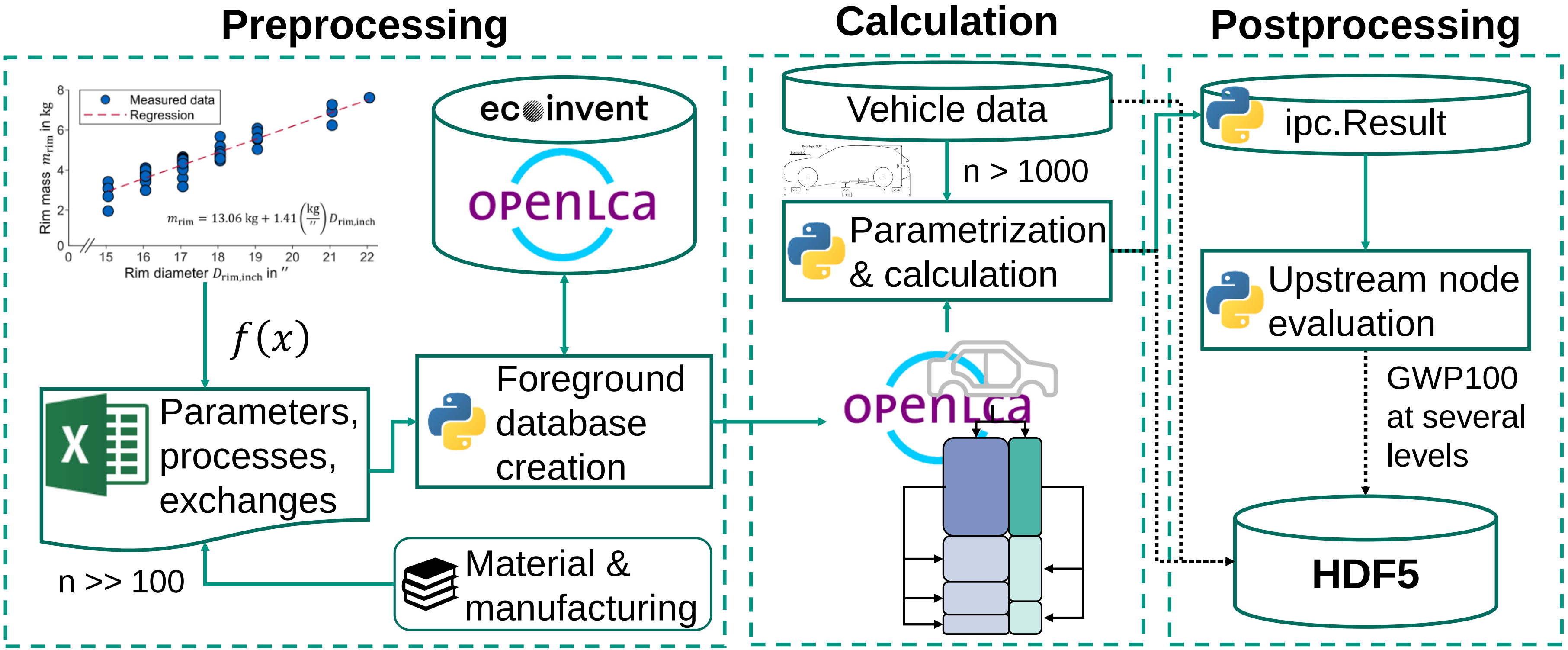


NICOLETTI, L., 2022. Parametric Modeling of Battery Electric Vehicles in the Early Development Phase. Dissertation. München. Available: https://mediatum.ub.tum.de/doc/1647238/1647238.pdf

- Combination of mass with material information from literature

➡ Application of formulas/fixed values for **over 50 components → Automation**

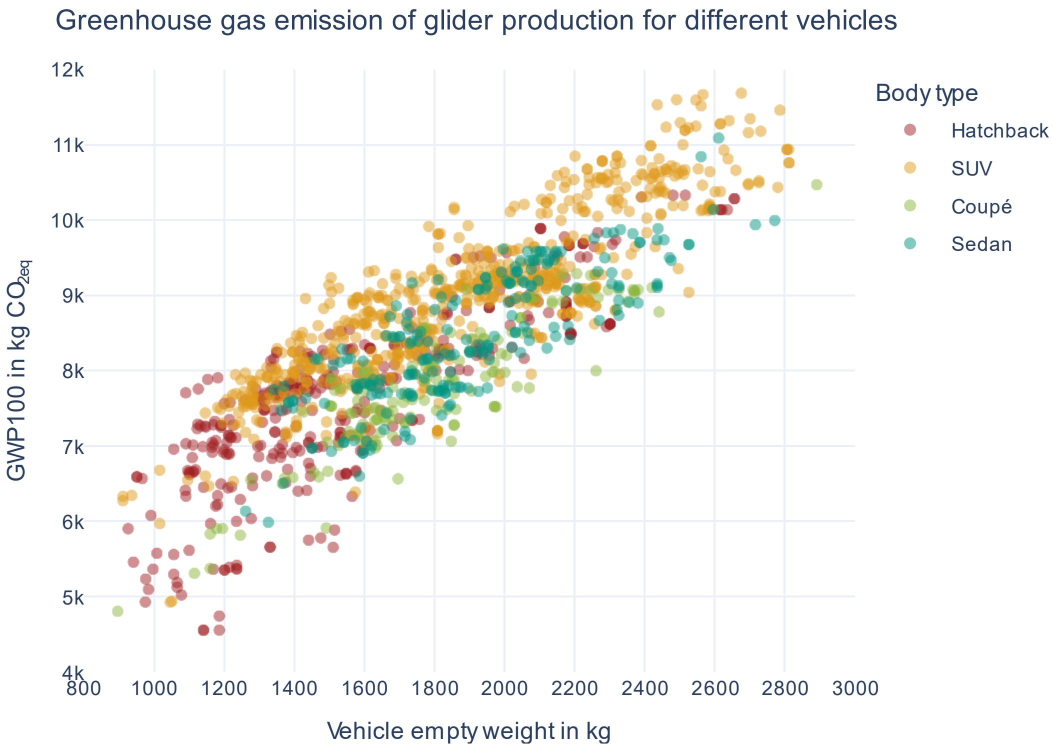
Approach
Automatized implementation in Python and openLCA



Results

Exemplaric GWP100 „result cloud“

- Environmental impacts for large number of vehicles
- Further insight by combining impact results with meta data, such as:
  - Body type
  - Powertrain
  - …



Results

Exemplaric GWP100 „result cloud“ – per FU

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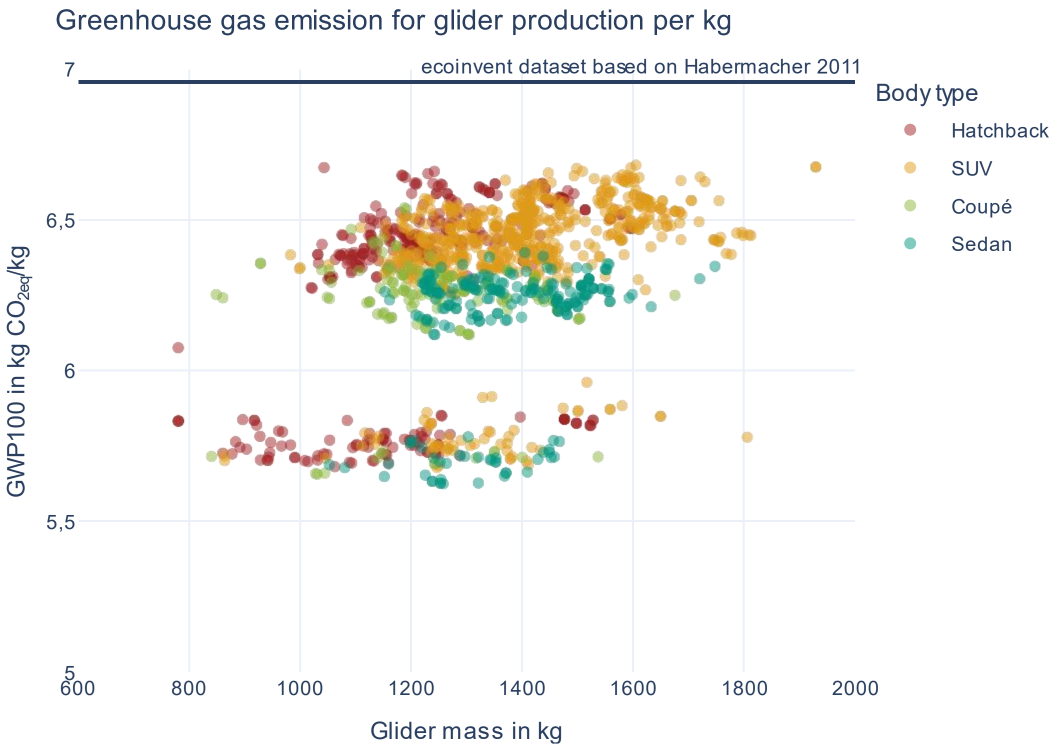
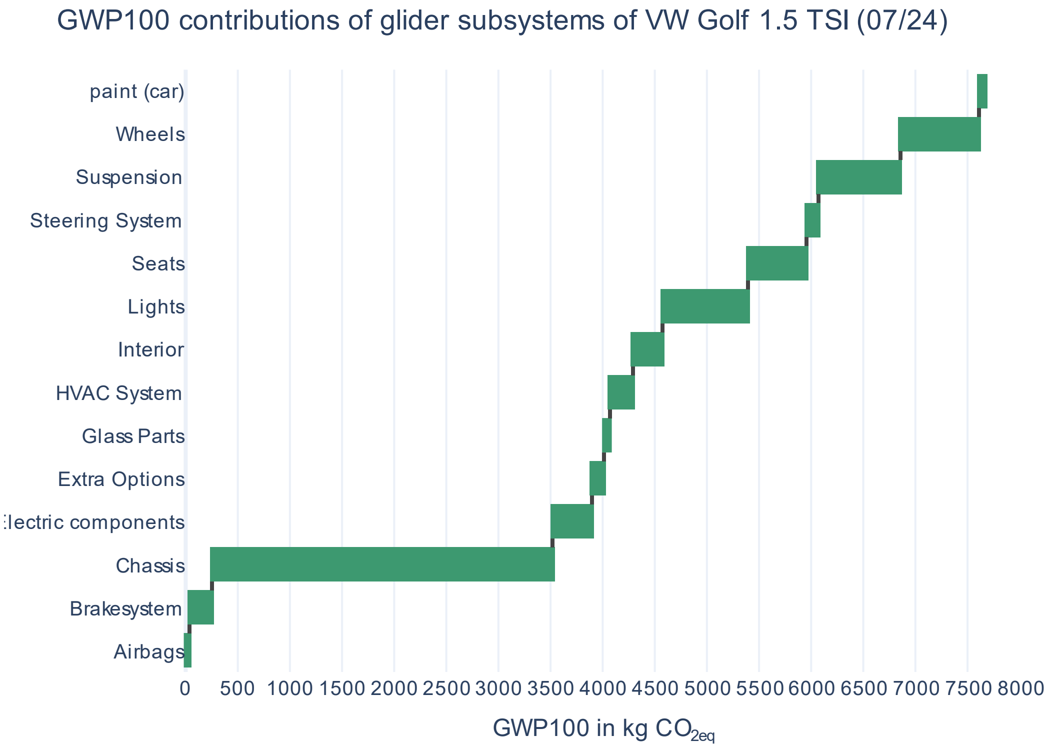


Habermacher, F., 2011. *Modeling Material Inventories and Environmental Impacts of Electric Passenger Cars. Comparison of LCA results between electric and conventional vehicle scenarios* [online]. Masterarbeit. Zürich https://www.empa.ch/documents/56122/458579/MasterThesis_Habermacher.pdf/7d82e2fb-247c-4e6e-a549-32e82bda8a37

Results
Exemplaric GWP100 waterfall diagram

- Subsystem and component contribution analysis thanks to:
  - Model level of detail
  - Upstream tree evaluation
- Challenge: both possibility of and demand for further validation
- Evaluation of ecoinvent process contribution possible



Summary

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01 REQUIREMENTS

- Increased level of detail of passenger car models
- Large variability through parameters
- Connection with large ADAC database

02 CHALLENGES

- Modeling and parametrization effort in openLCA
- Correlation between input data and results
- Analysis at different system levels

03 SOLUTIONS

- Use of Python libraries olca-ipc and olca-schema to automize
  → Model creation
  → Parametrization
  → Calculation
  → Result breakdown and export to HDF5

Outlook

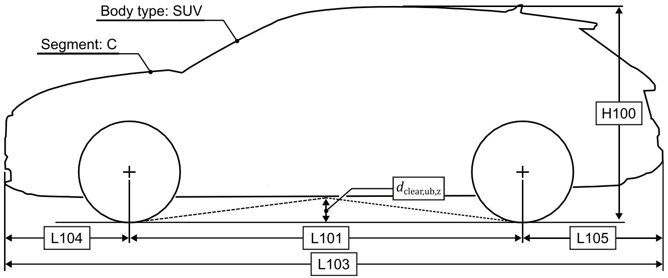
- Further evaluation and analysis:
  - Plausibility checks of intermediate results, such as calculated masses
  - Validation at different system levels
  - Correlations of meta with result data

- Extension of methodology towards powertrains

- Variations regarding materials and production network

Thank you for attention!
Feel free to ask questions ☺

Approach
Component modeling through concept engineering



Vehicle dimensions
Length | Width | Height | Wheelbase | Overhang | Gross vehicle mass
Body type | Drive axle | Door no. | Tire dimensions | Max. axle loads

Material assumptions
Hood | Door | Trunk | Fender | Aluminium percentage in the frame

Vehicle features
Rear axle type | All-wheel steering | Air suspensions | Headlights type
Rear seat type, sliding | Seat no. | Panorama roof | Sliding roof
Subwoofer | Cluster type | Phone connectivity | Tow hitch | Spare tire
HUD | Park assist | LKS | ACC | Types of airbags

Scalable components
Front + rear axle links | Front + rear passive spring damper
Rear axle links multi | Front + rear brakes | LV cables
Center console | Interior trim
Body in white | Hood | Door
Trunk | Doors | HVAC
Steering system | Tires | Rims
Front + rear window glass | Front + rear seats

Optional, fixed-value components
ADAS functionality
Types of airbags
Infotainment equipment

Vehicle image from: NICOLETTI, L., 2022. Parametric Modeling of Battery Electric Vehicles in the Early Development Phase. Dissertation. München. Available: https://mediatum.ub.tum.de/doc/1647238/1647238.pdf

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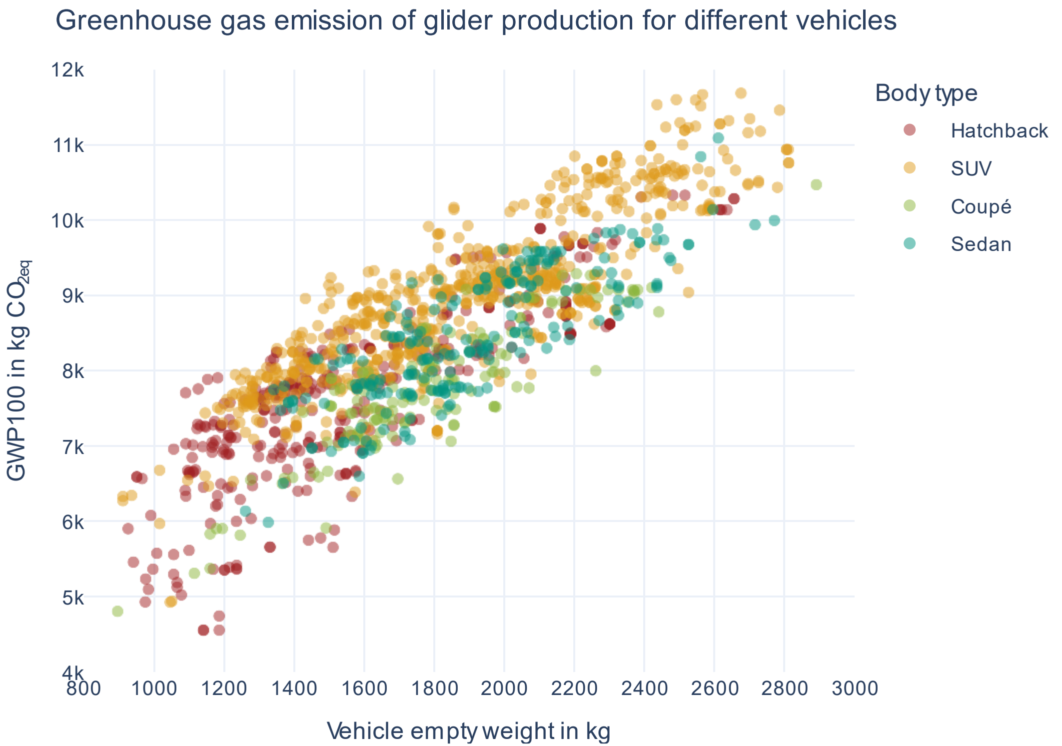
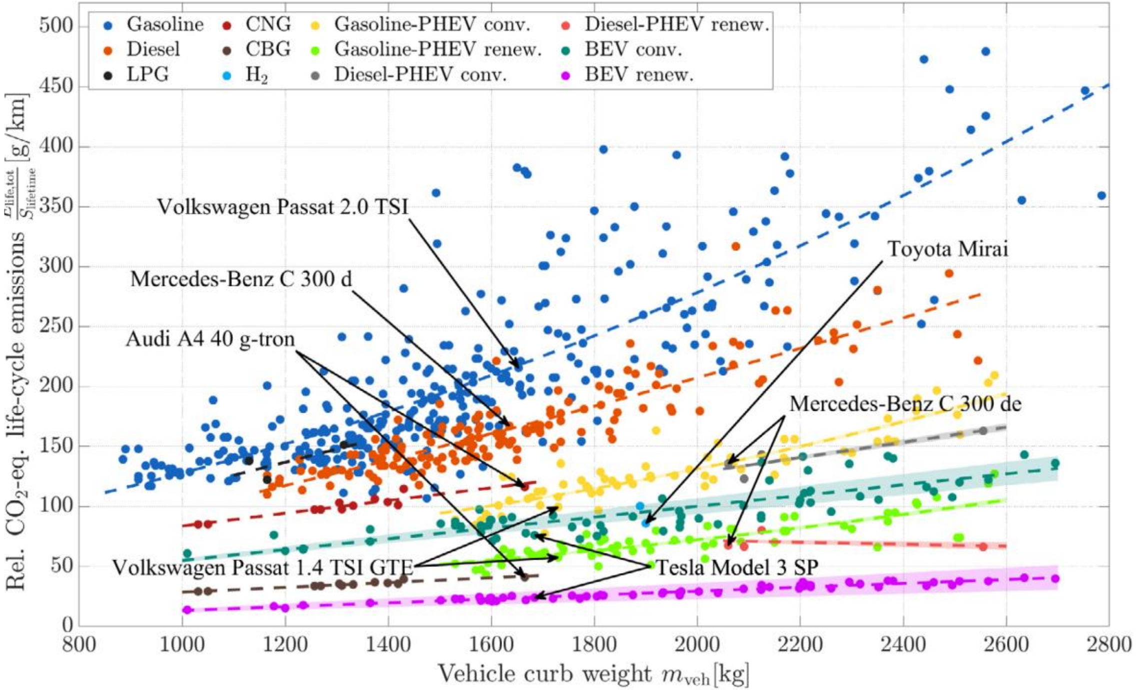


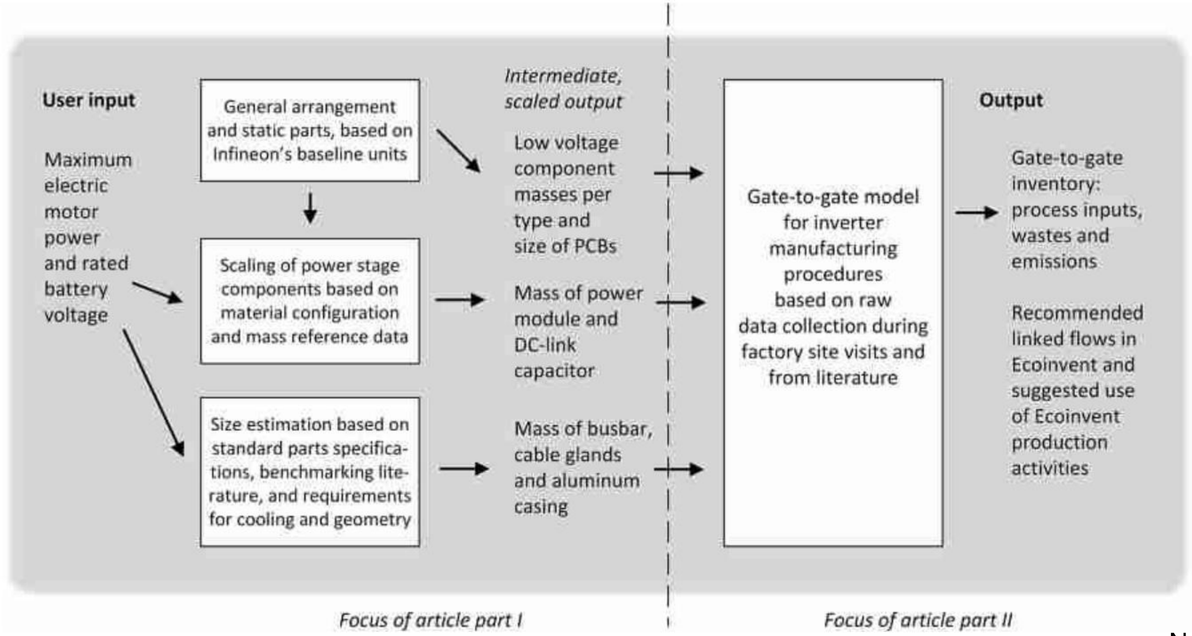
Literature – „Rule of three“ approach

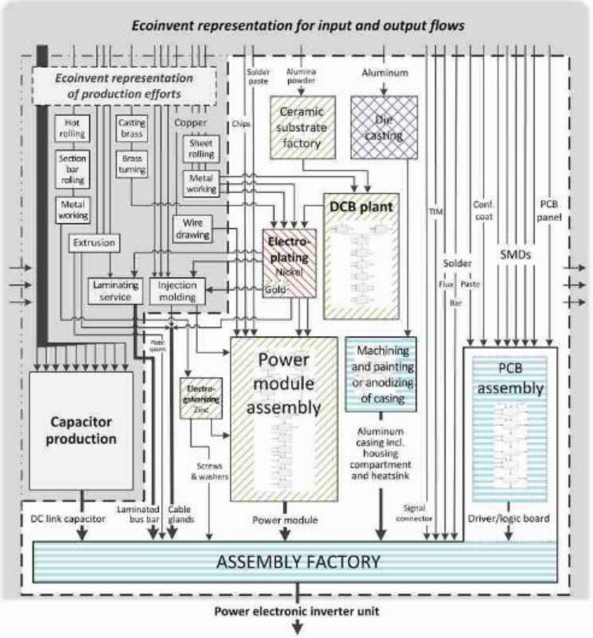
- Mass-dependent GHG formula for main components
  - Battery
  - „Vehicle – Battery“
- GHG formula with fuel consumption
- Large data variety with data from ADAC



Buberger, J., Kersten, A., Kuder, M. et al. (2022) Total CO2-equivalent life-cycle emissions from commercially available passenger cars. Renewable and Sustainable Energy Reviews 159:112158. https://doi.org/10.1016/j.rser.2022.112158.

Literature – Scalable LCI publications by Nordelöf et al.





Nordelöf, A., M. Alatalo und M.L. Söderman, 2019. A scalable life cycle inventory of an automotive power electronic inverter unit—part I: design and composition [online]. *The International Journal of Life Cycle Assessment*, **24**(1), 78-92. ISSN 0948-3349. https://doi.org/10.1007/s11367-018-1503-3

Nordelöf, A., 2019. A scalable life cycle inventory of an automotive power electronic inverter unit—part II: manufacturing processes [online]. *The International Journal of Life Cycle Assessment*, **24**(4), 694-711. ISSN 0948-3349. https://doi.org/10.1007/s11367-018-1491-3