The environmental performance of current & future passenger vehicles

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ETH Zurich, June 19th – 22nd 2017
LCA is a technique to assess environmental impacts associated with all the stages of a product's life cycle from-cradle-to-grave, i.e., from raw material extraction through materials processing, manufacturing, distribution, use, repair and maintenance, and disposal or recycling.
Life Cycle Assessment - LCA

Environmental impacts?

Materials, fuels, energy supply, transport, infrastructure, disposal,…

«Background»
LCA data
LCA of passenger vehicles: system boundaries

Bauer et al. 2015
Procedure for consistent vehicle assessment

- Powertrain: ICEV, HEV, PHEV, BEV, FCV, FCHEV
- Fuel type: Gasoline, Diesel, CNG, Hydrogen
- Operating condition: Driving region (Average, City, Rural), Climate
- Vehicle characteristics: Size class (Mini, Small, Midsize, Van), Performance (Low, Avg, High Range)
- Future assessment: Analysis year (2012 - 2050), Scenario definition (Electricity mix, oil price, etc.)

Exogenous options: Input data, Simulation, Endogenous indicators

Vehicle simulation

Specific energy and power density of components

LCA inventory

Specific LCA result by component and energy carrier

LCA indicators

Specific cost of components, energy prices

Manufacturing cost, Total cost

Hofer 2014
LCA of passenger vehicles: key parameters

- Vehicle class & mass
- Lifetime (vehicle & components)
- Fuel demand (test vs. real)
- Reference year
- Background LCI data

ICEV:
- Pollutant emissions, EURO-Standard (test vs. real)

BEV:
- battery – type & manufacturing chain
- range (battery capacity)
- electricity for charging

FCV:
- fuel cell – manufacturing chain
- H₂ supply
LCA of passenger vehicles: acronyms

- ICEV: Internal combustion engine vehicle
- HEV: Hybrid electric vehicle
- BEV: Battery electric vehicle
- FCV: Fuel cell vehicle
- -g: gasoline as fuel
- -d: diesel as fuel
- -c: compressed natural gas (CNG) as fuel
- H2-SMR: Hydrogen from steam methane reforming
- EU mix: average electricity supply in the EU
- PV: electricity from photovoltaics
- NG: electricity from a natural gas power plant
Vehicle mass
Energy consumption for vehicle operation

Bauer et al. 2015

<table>
<thead>
<tr>
<th>Type</th>
<th>2030</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCV</td>
<td>21 kWh/100 km</td>
<td>25 kWh/100 km</td>
</tr>
<tr>
<td>BEV</td>
<td>25 kWh/100 km</td>
<td>21 kWh/100 km</td>
</tr>
<tr>
<td>HEV-c</td>
<td>8.1 l/100 km</td>
<td>6.3 l/100 km</td>
</tr>
<tr>
<td>HEV-d</td>
<td>4.9 l/100 km</td>
<td>6.2 l/100 km</td>
</tr>
<tr>
<td>ICEV-c</td>
<td>6.3 l/100 km</td>
<td>8.1 l/100 km</td>
</tr>
</tbody>
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LCA results: GHG emissions

Bauer et al. 2015
LCA results: GHG emissions

Bauer et al. 2015
LCA results: particulate matter formation

Bauer et al. 2015

Particulate matter formation (PMF)
LCA results: particulate matter formation

Takes into account primary and secondary particles due to:

- $\text{PM}_{10}$
- $\text{NO}_x$
- $\text{SO}_x$
- Ammonia

Bauer et al. 2015
LCA results: trop. ozone formation

Bauer et al. 2015

+ 64% POF
LCA results: trop. ozone formation

Contributions from:
- NMVOC
- NO\textsubscript{x}
- SO\textsubscript{x}
- CO
- CH\textsubscript{4}
Main uncertainties & limitations in LCA

- Emissions of pollutants from ICEV ($\text{NO}_x$, PM, etc.)
- Location-specific assessment of health impacts
- Energy consumption of vehicles (test vs. real)
- Batteries & fuel cells:
  - lifetime, manufacturing chain, future technology development
- Effects of large scale implementation of BEV & FCV
Take home messages

- **BEV & FCV only provide environmental benefits with electricity and H2 from renewable sources**
- **GHG emissions** of BEV & FCV can be reduced by up to 80% compared to ICEV (using hydro or wind power)
- **Other health impacts**: ambiguous LCA results, also with «clean» electricity and H2
  - BEV tend to be «more environmentally friendly» than ICEV
  - FCV tend to be «less environmentally friendly» than ICEV
- **Short-term**: **Natural gas hybrids** show largest potential for reduction of impacts
- **Long-term**: **electric vehicles need**:
  - Enough clean electricity
  - Recycling strategies for batteries and fuel cells
  - Measures against «burden shifting»
Wir schaffen Wissen – heute für morgen

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