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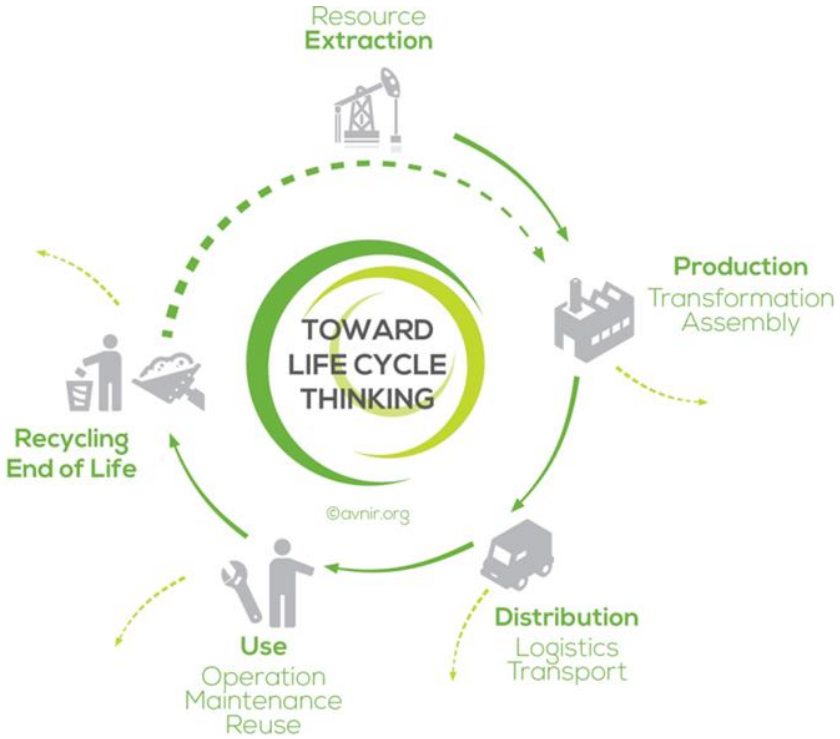
Christian Bauer :: Technology Assessment group :: Paul Scherrer Institut

The environmental performance of current & future passenger vehicles

21. ETH Conference on Combustion Generated Nanoparticles
ETH Zurich, June 19th – 22nd 2017

Life Cycle Assessment - LCA

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.




zero Emission

Life Cycle Assessment - LCA



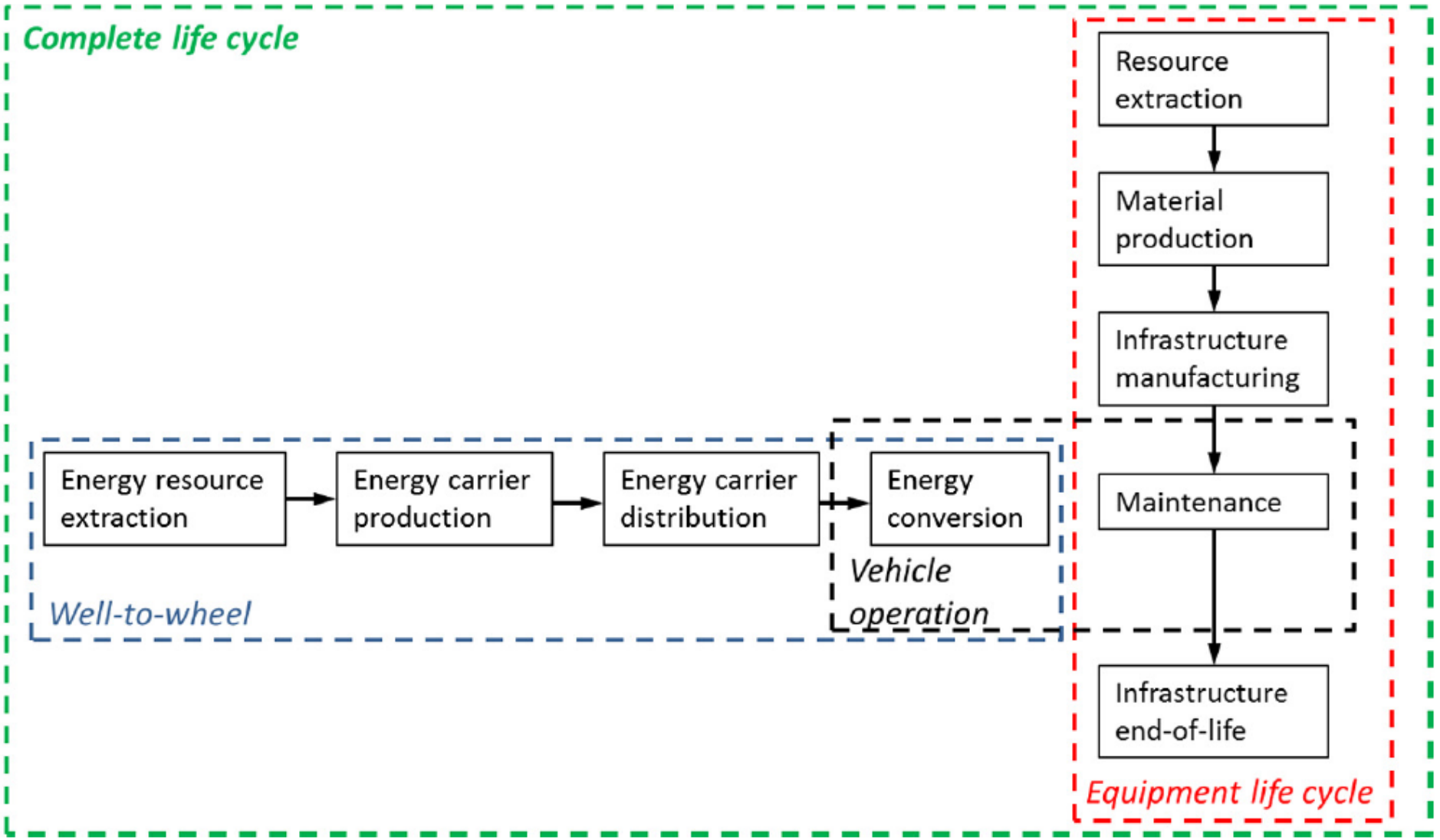


Environmental impacts?

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

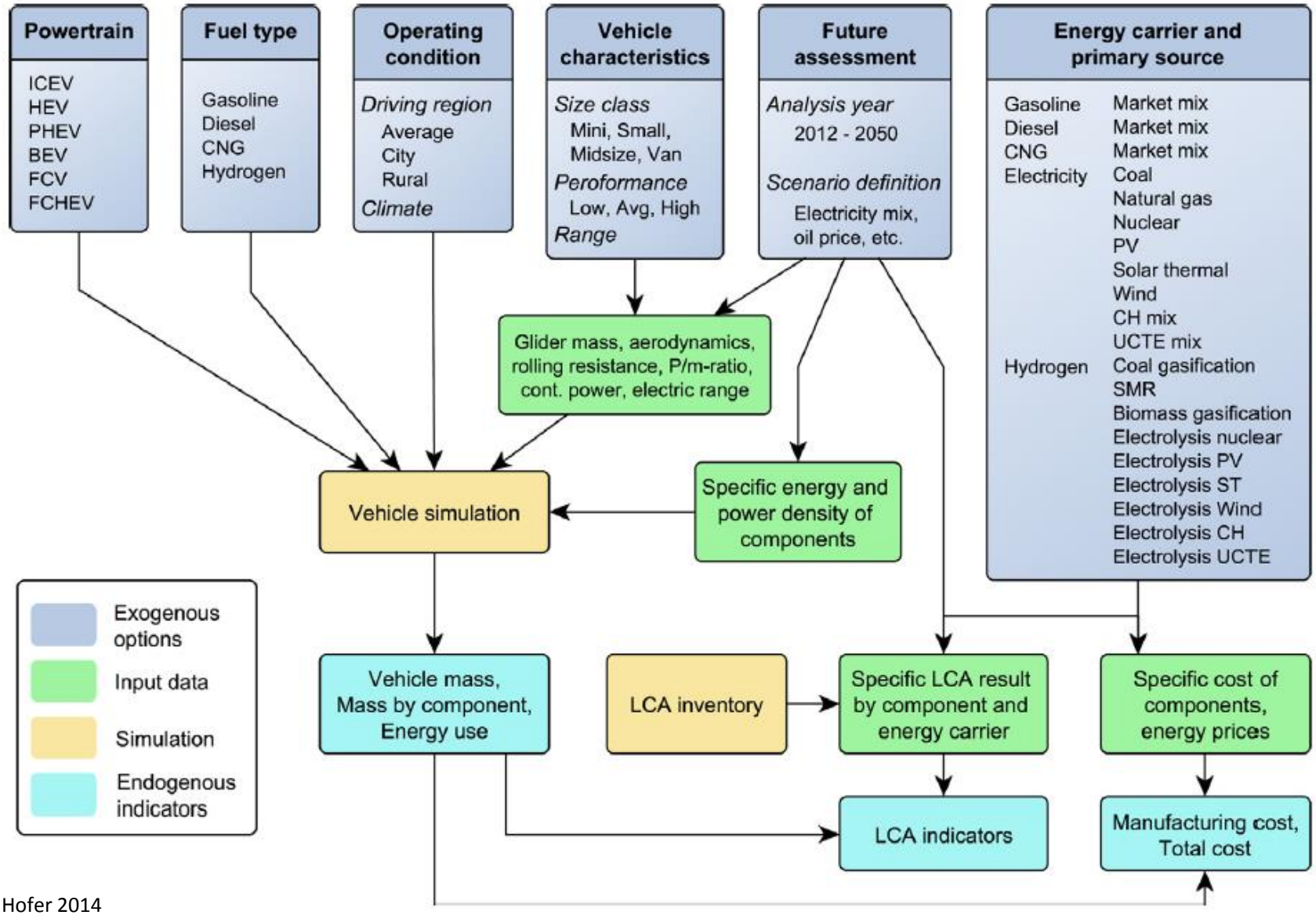
«Background»
LCA data

LCA of passenger vehicles: system boundaries



Bauer et al. 2015

Procedure for consistent vehicle assessment



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
  - H_2 supply

LCA of passenger vehicles: acronyms

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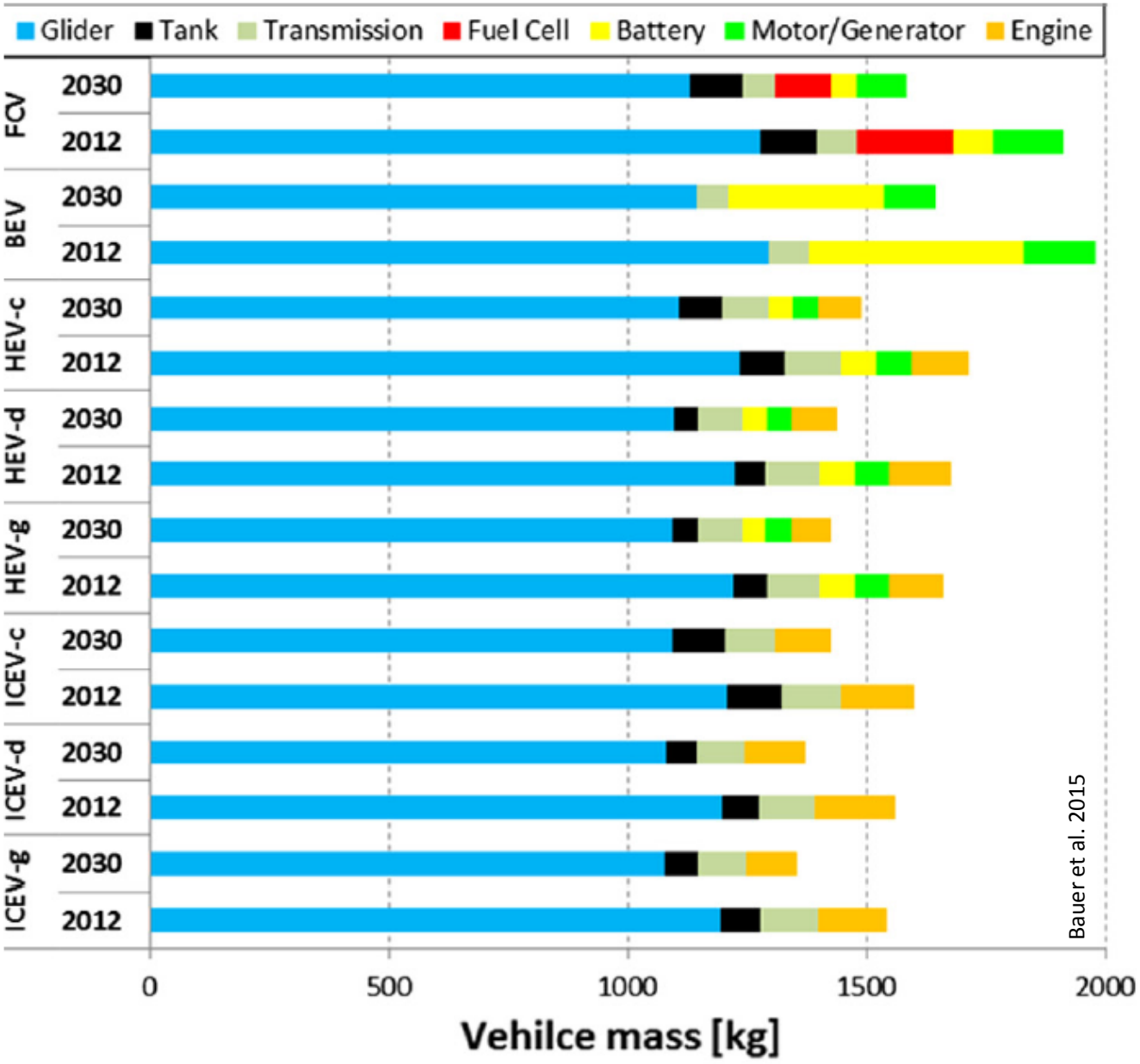
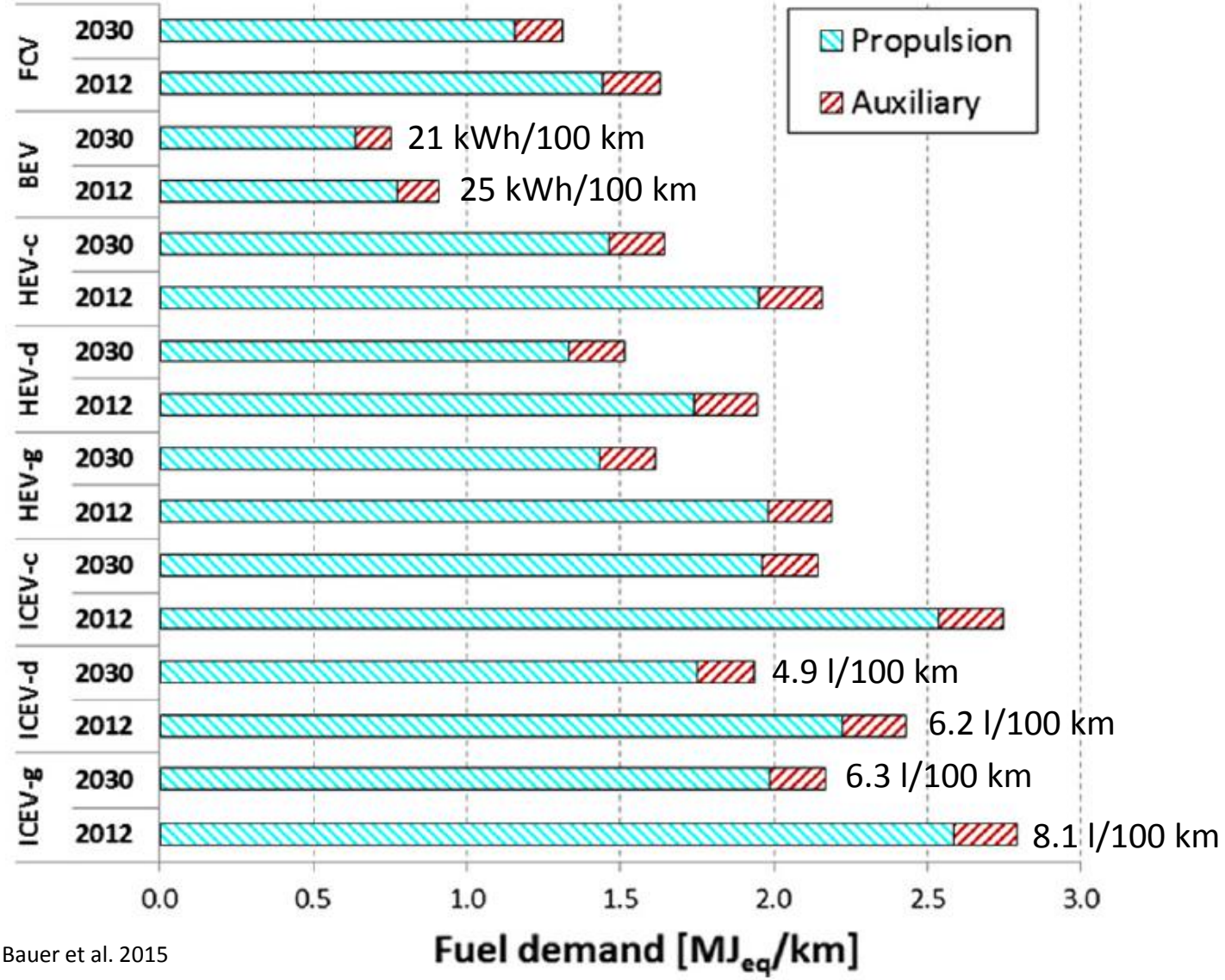
- ICEV: Internal combustion engine vehicle
- HEV: Hybrid electric vehicle
- BEV: Battery electric vehicle
- FCV: Fuel cell vehicle
- -g: gasoline as fuel
- -d: diesel as fuel
- -c: compressed natural gas (CNG) as fuel
- H2-SMR: Hydrogen from steam methane reforming
- EU mix: average electricity supply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

Vehicle mass

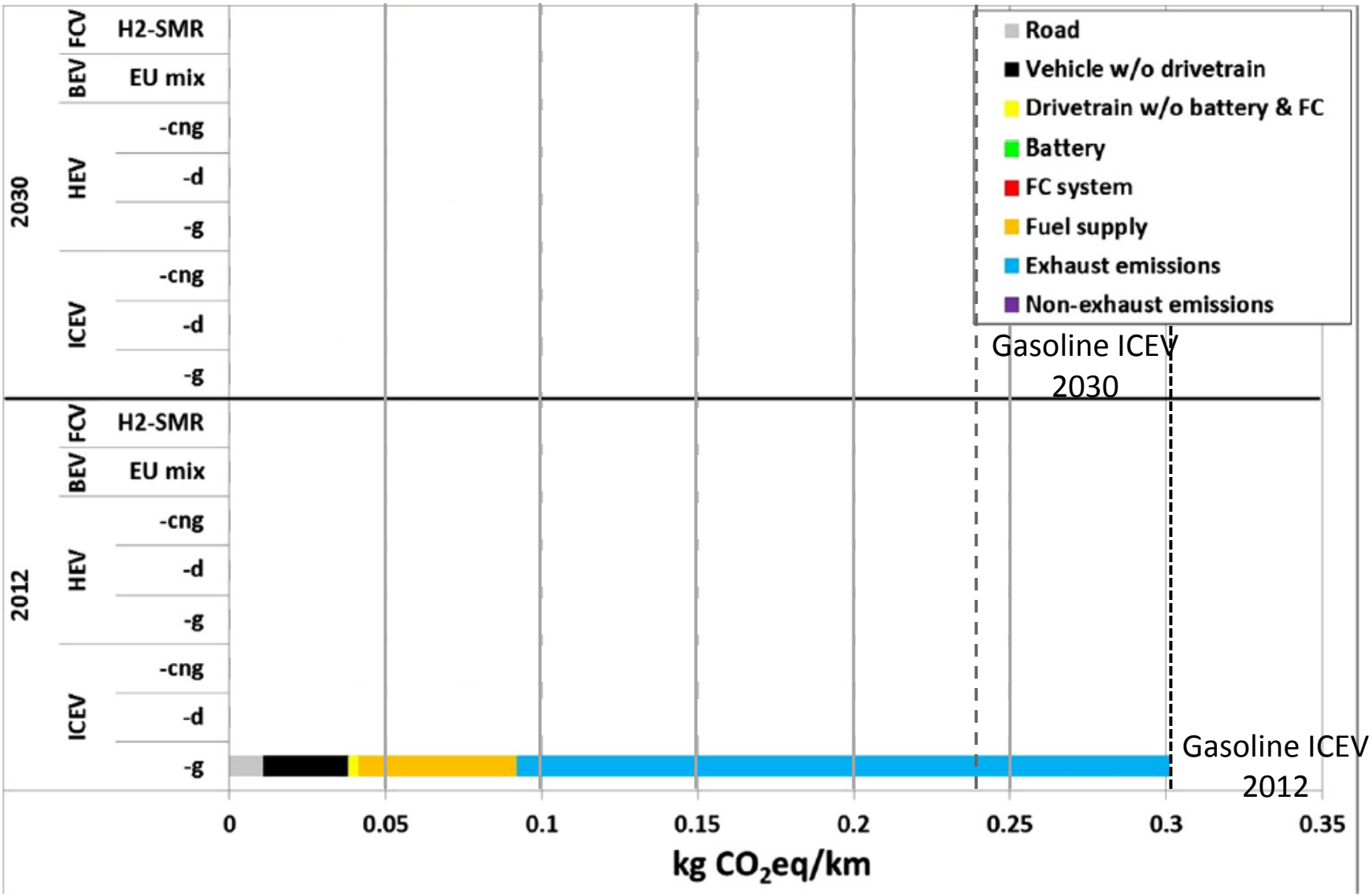


Energy consumption for vehicle operation



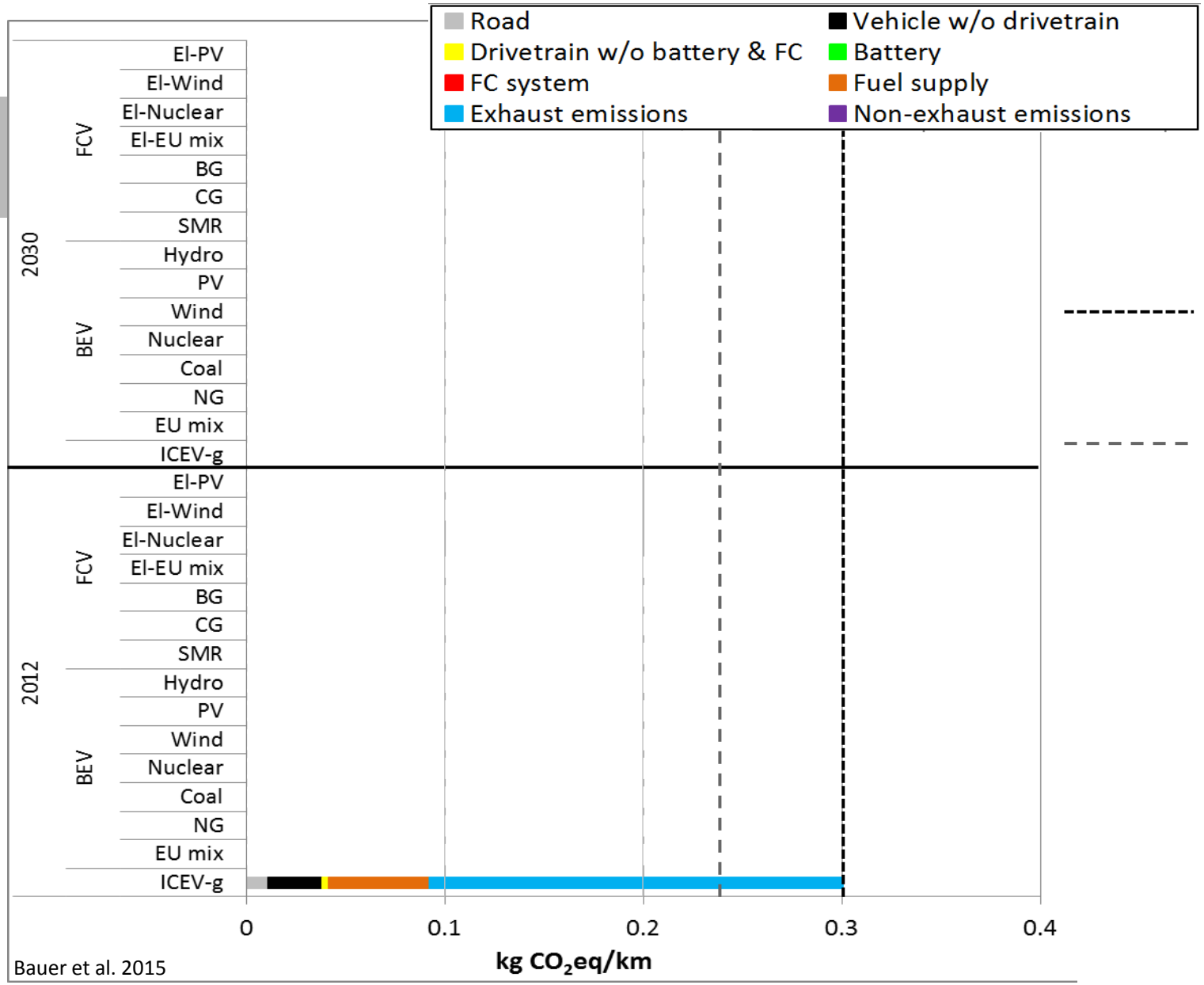
Bauer et al. 2015

LCA results: GHG emissions



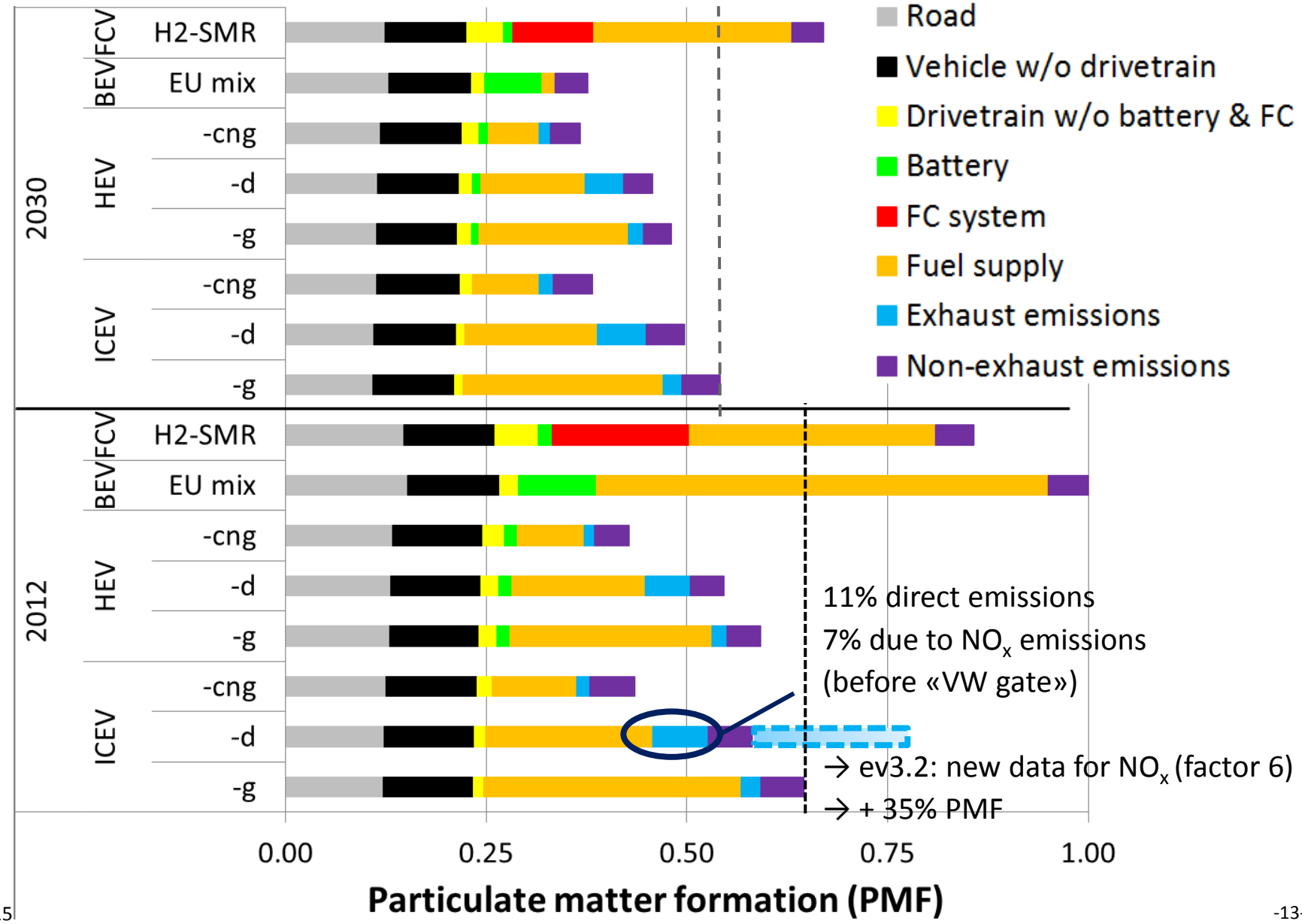
Bauer et al. 2015

LCA results: GHG emissions



Bauer et al. 2015

LCA results: particulate matter formation



Bauer et al. 2015

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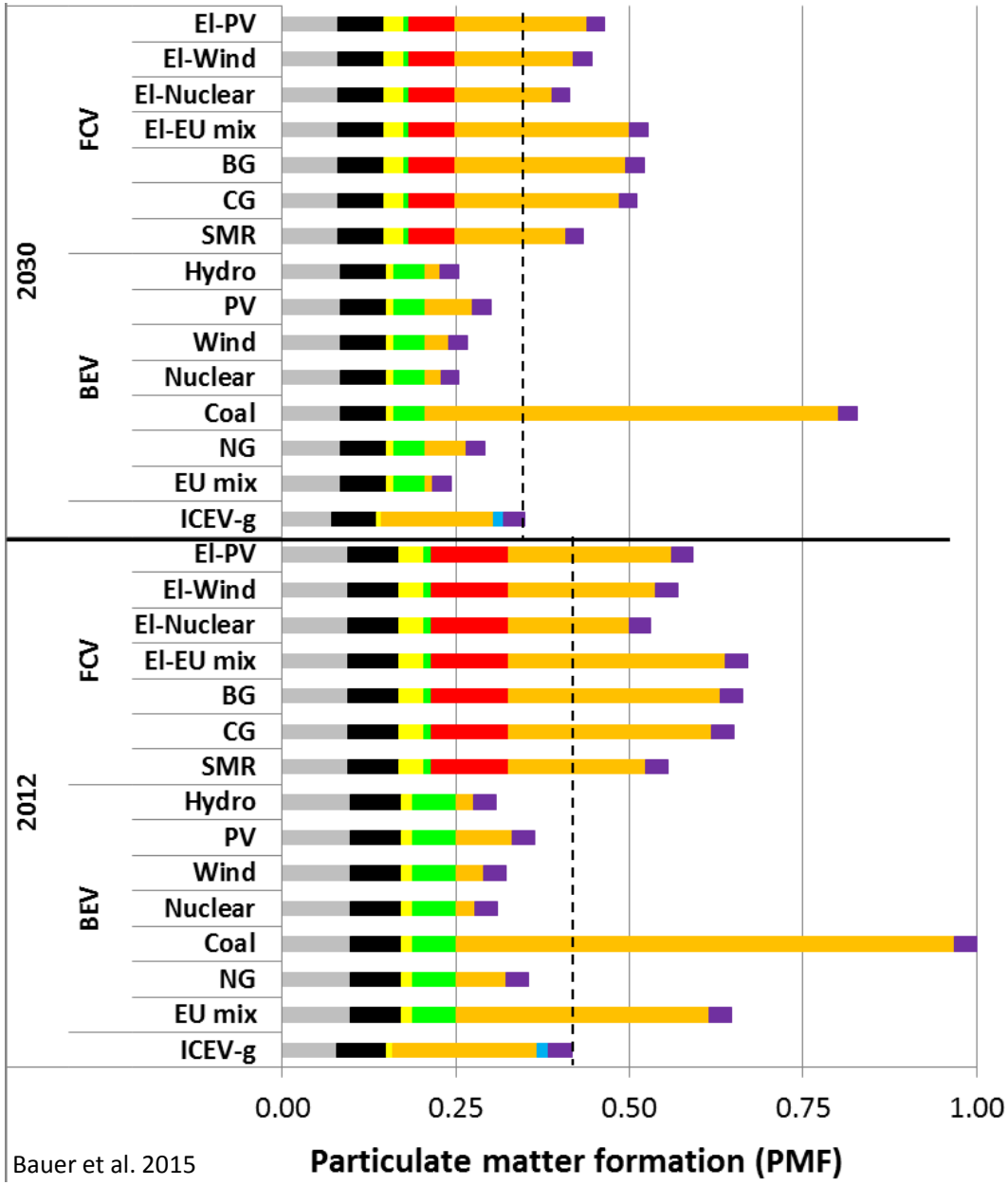


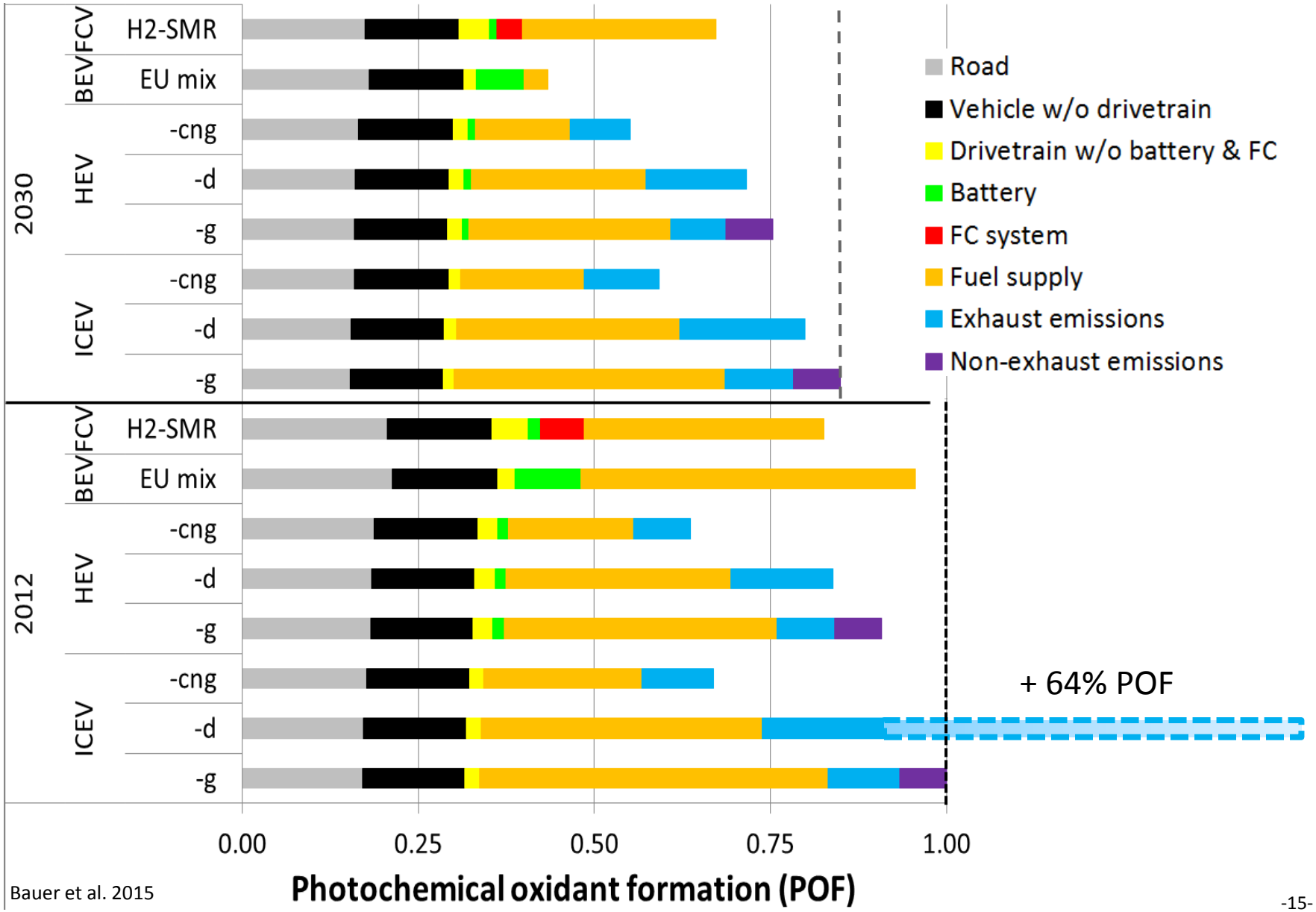
Bauer et al. 2015

- Road
- Vehicle w/o drivetrain
- Drivetrain w/o battery & FC
- Battery
- FC system
- Fuel supply
- Exhaust emissions
- Non-exhaust emissions

Takes into account **primary** and **secondary particles** due to:

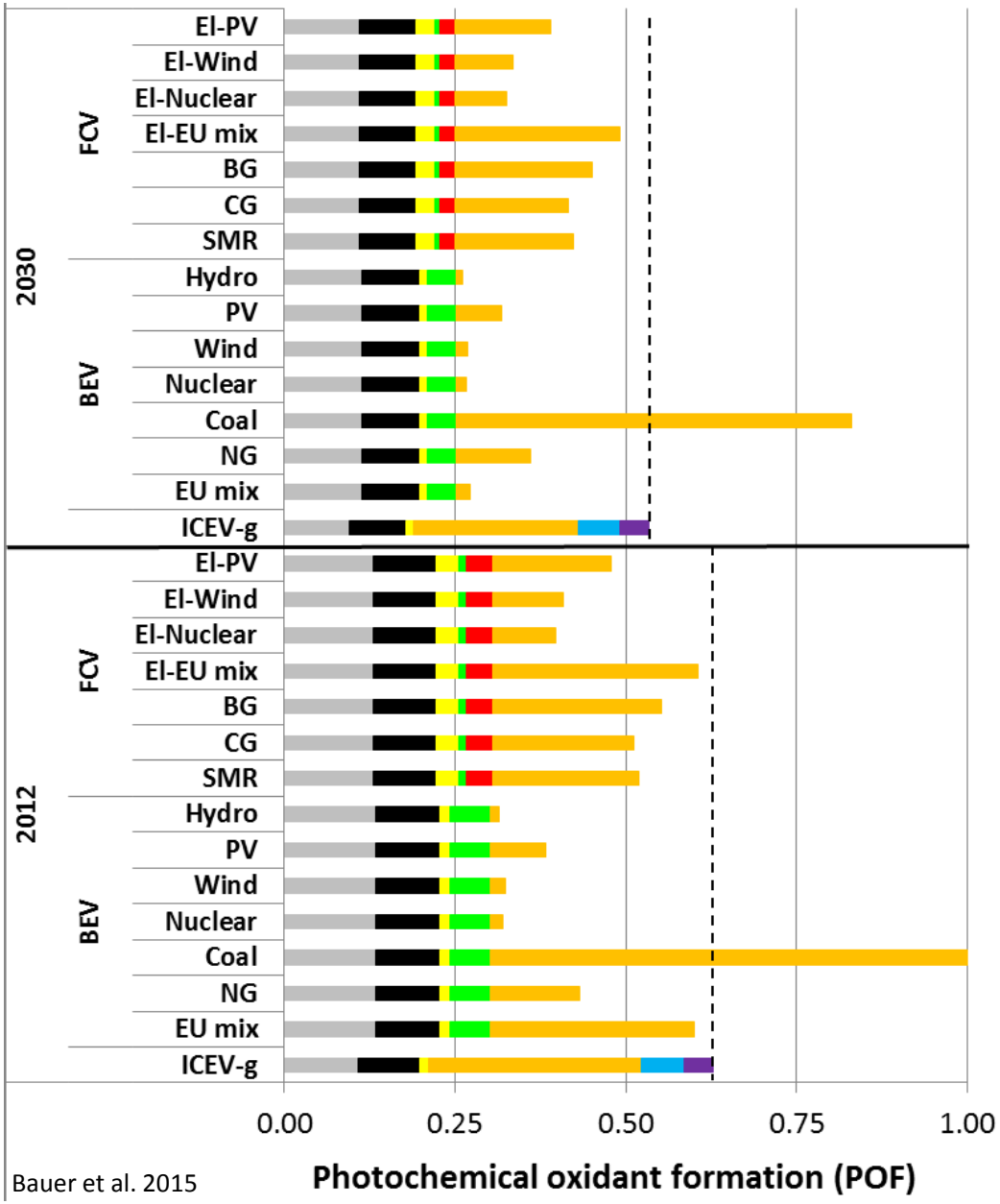
- PM_{10}
- NO_x
- SO_x
- Ammonia

LCA results: trop. ozone formation



Bauer et al. 2015

LCA results: trop. ozone formation



Bauer et al. 2015

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Contributions from:

- NMVOC
- NO_x
- SO_x
- CO
- CH_4

Main uncertainties & limitations in LCA

- Emissions of pollutants from ICEV (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 (unsing hydro or wind power)
- **Other health impacts**: ambiguous LCA results, also with «clean» electricity and H_2
  - 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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Contact:
christian.bauer@psi.ch
https://www.psi.ch/ta/