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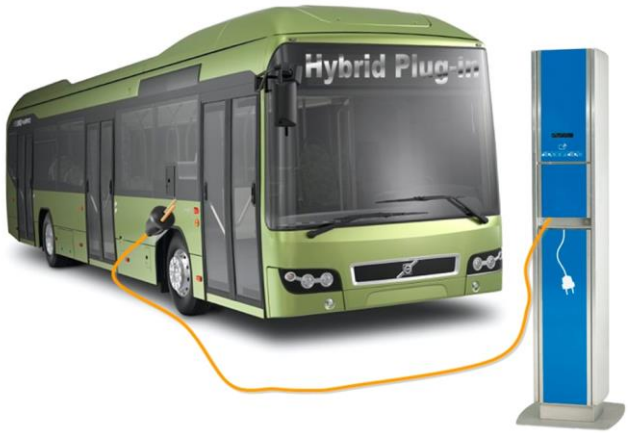
Environmental assessment of current and future urban buses with different energy sources

EVS30 10. October 2017

Introduction

Transport authorities want zero emission buses!

- Starting in next 15 years
- But which to choose?



LCA of Urban Buses

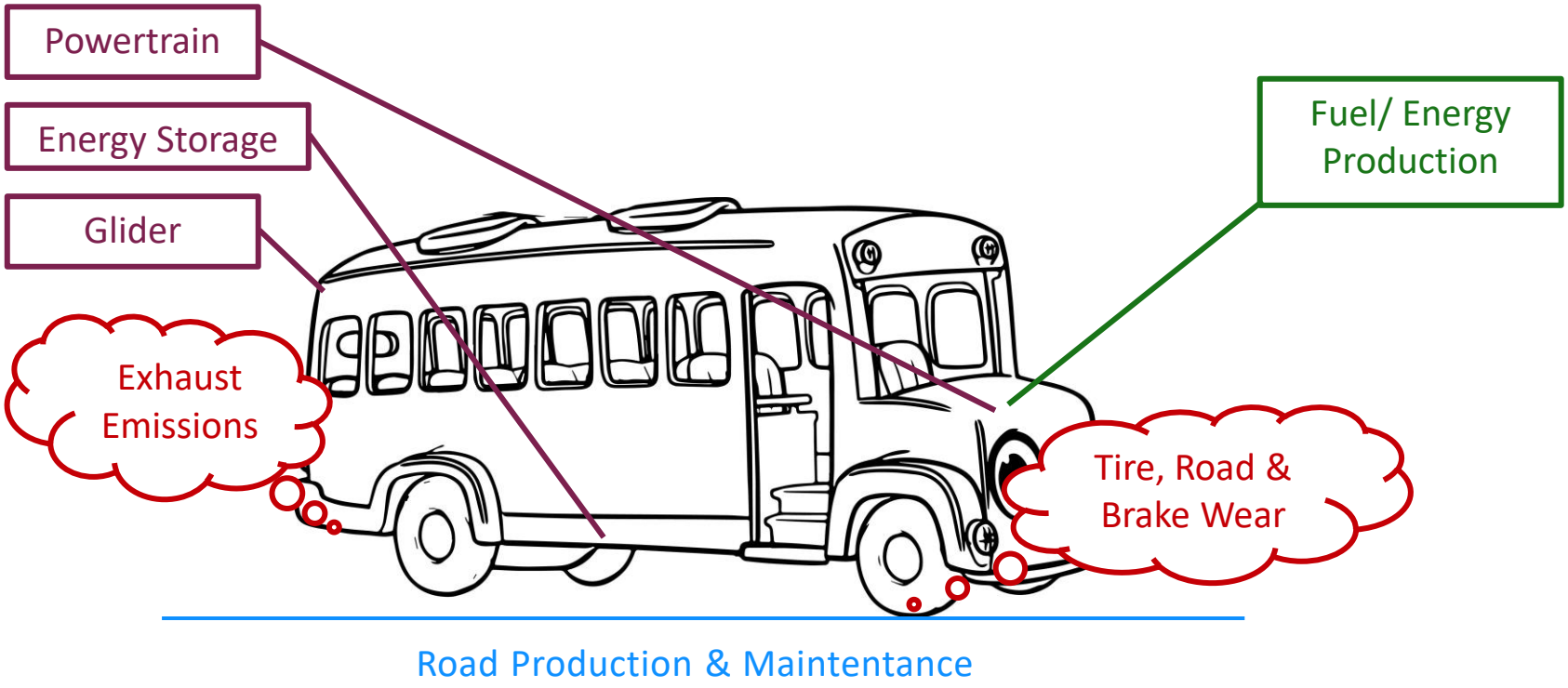
Six powertrain variants

- Diesel
- Diesel hybrid
- Compressed Natural Gas (CNG)
- Fuel cell electric
- Battery electric - on route charging (Battery- SR)
- Battery electric – overnight charging (Battery- LR)

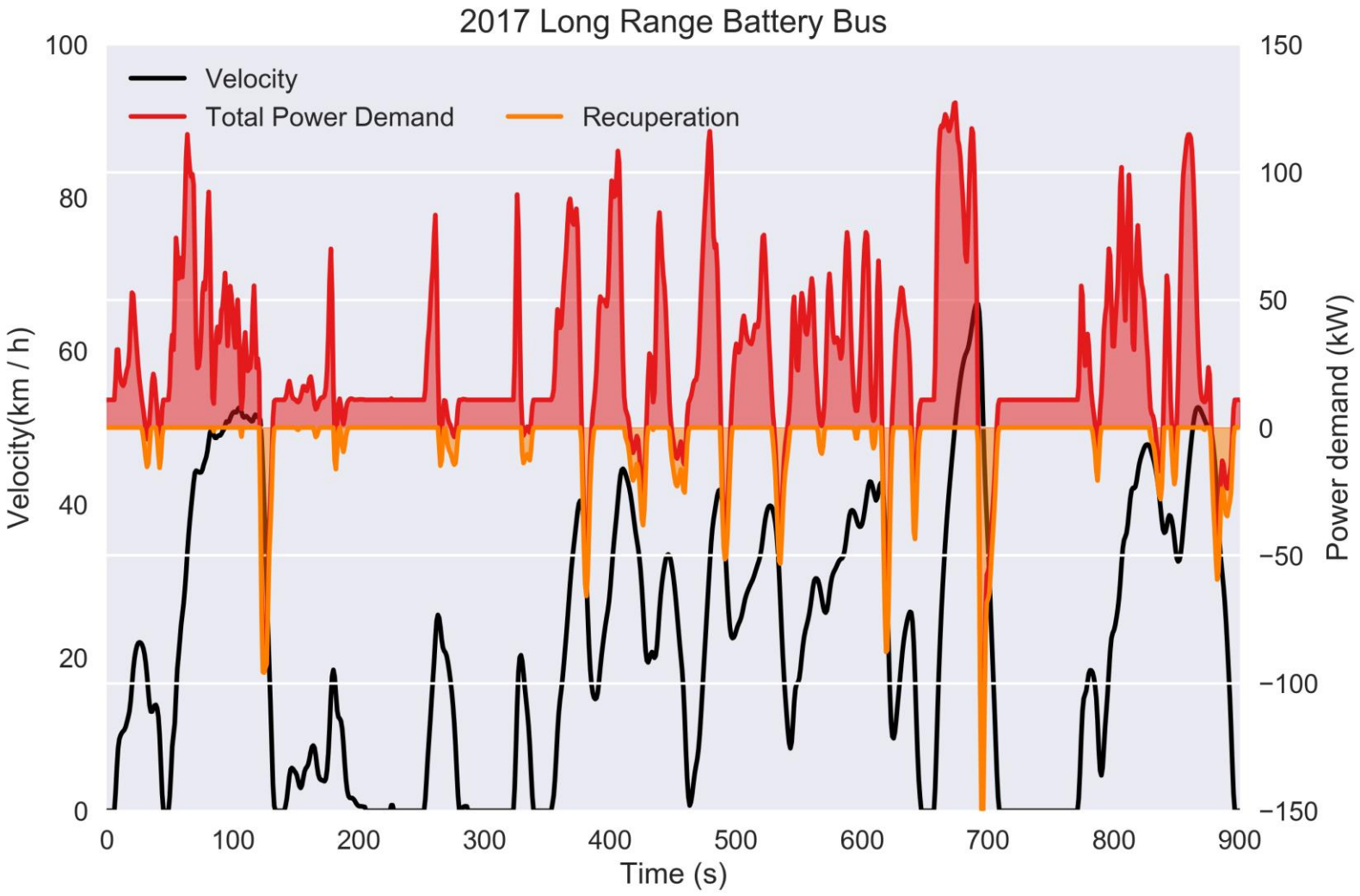
Three major uncertainties:

1. Energy system used to charge/ refill bus
2. Future performance of different technologies
3. Future electricity system used to build bus

Life Cycle Inventory of a Bus

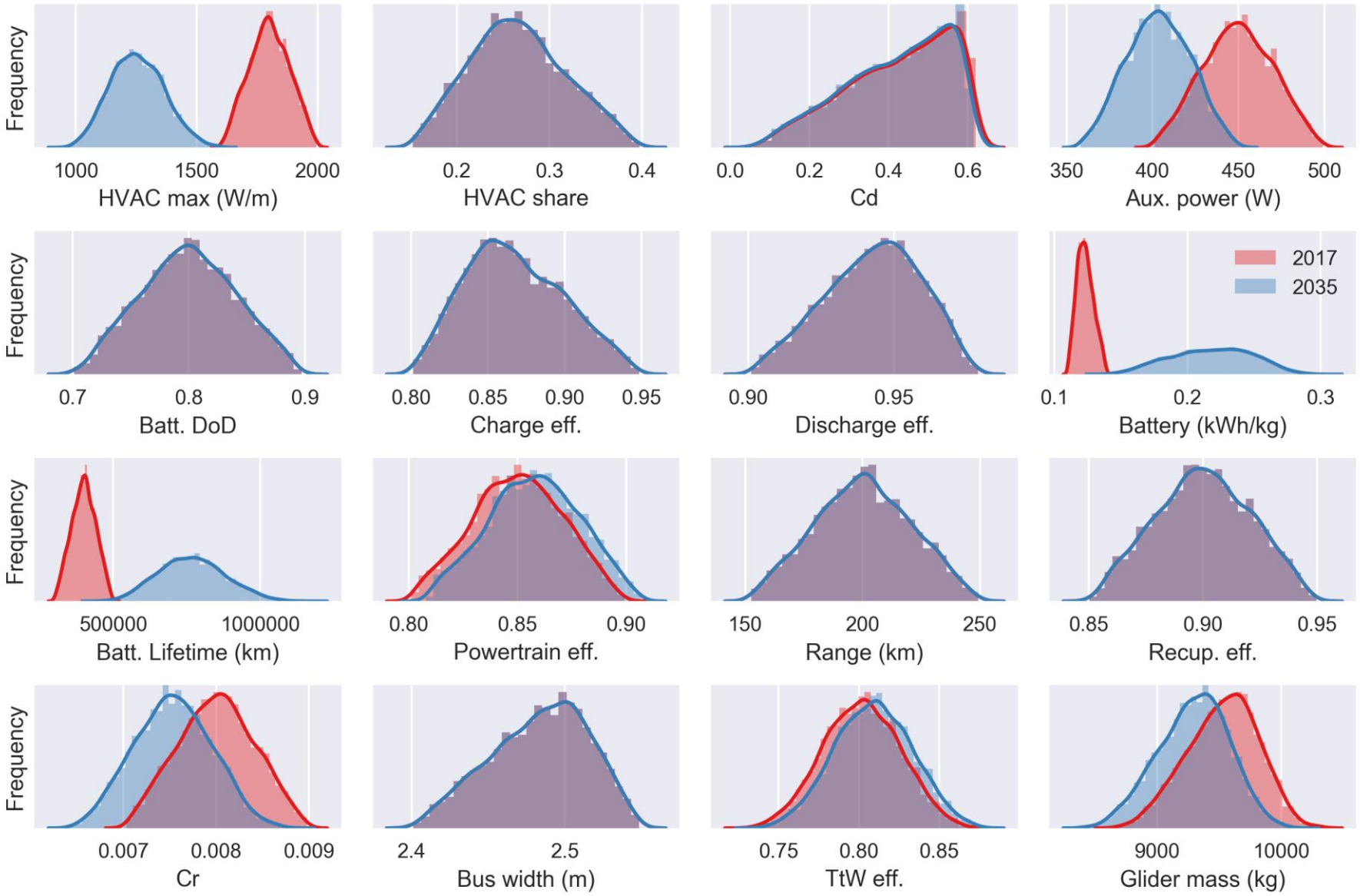


Bus Operation and Energy Demand

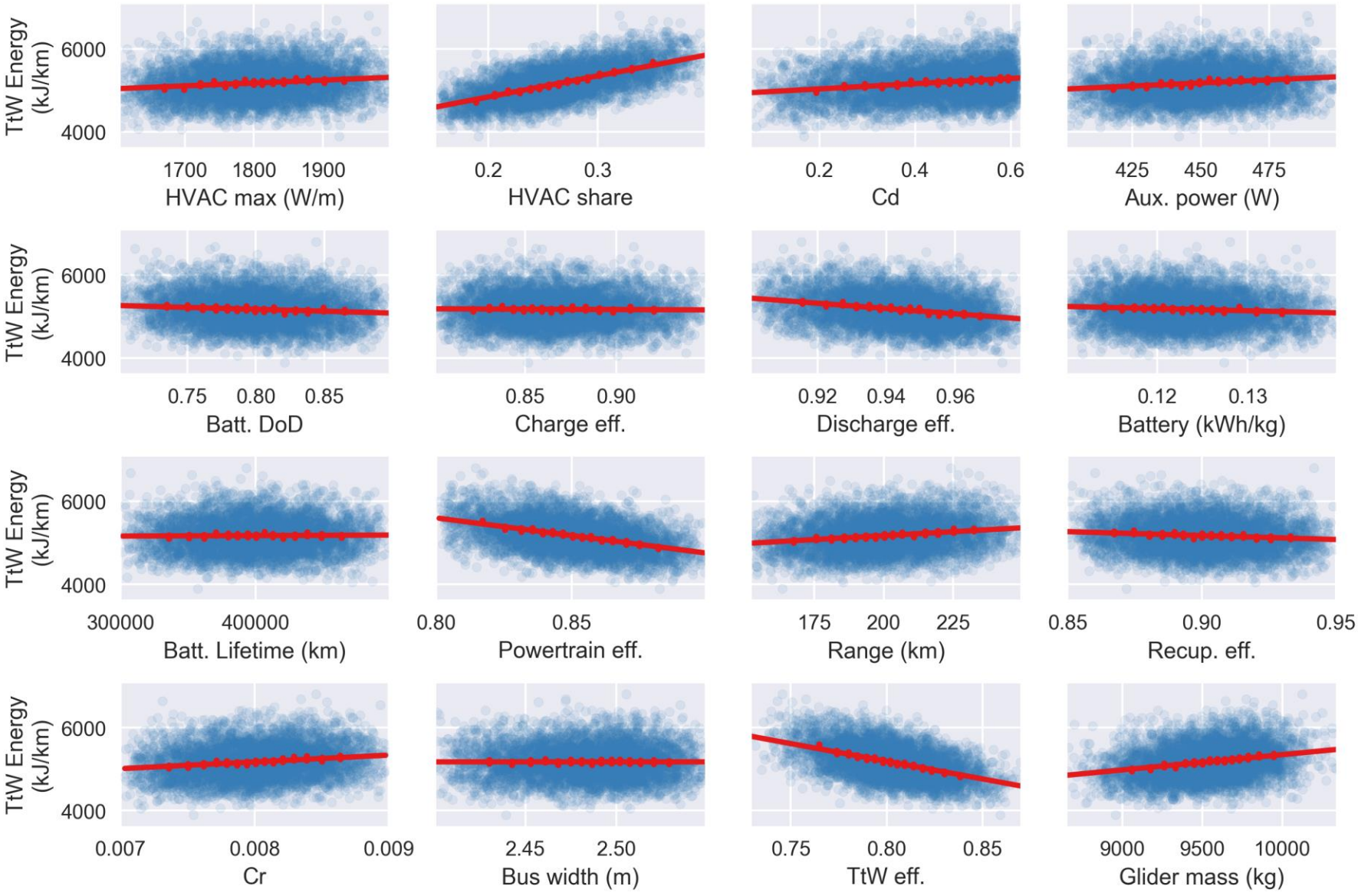


World Harmonized Vehicle Cycle (WHVC) for heavy duty vehicles

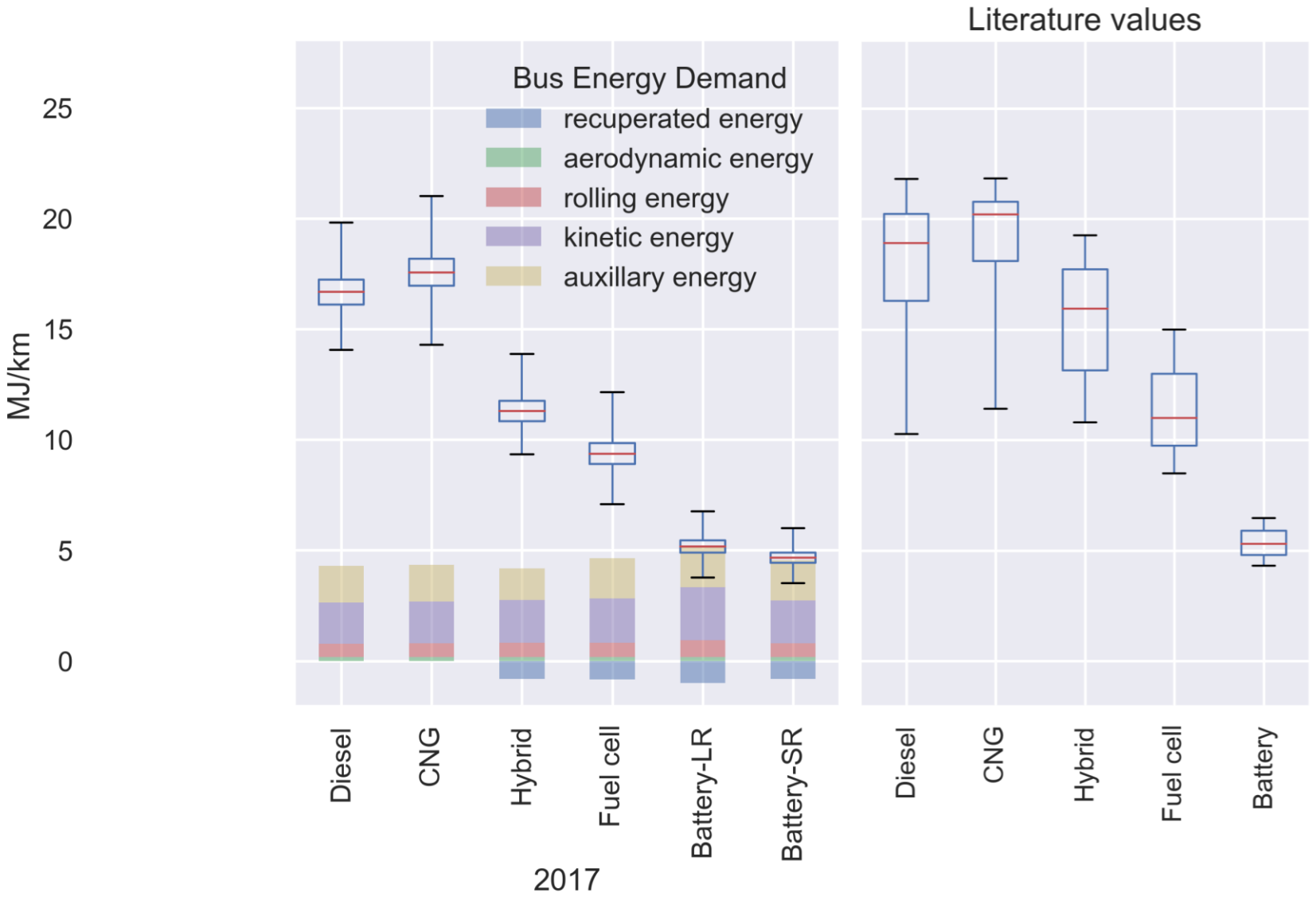
Monte Carlo Input



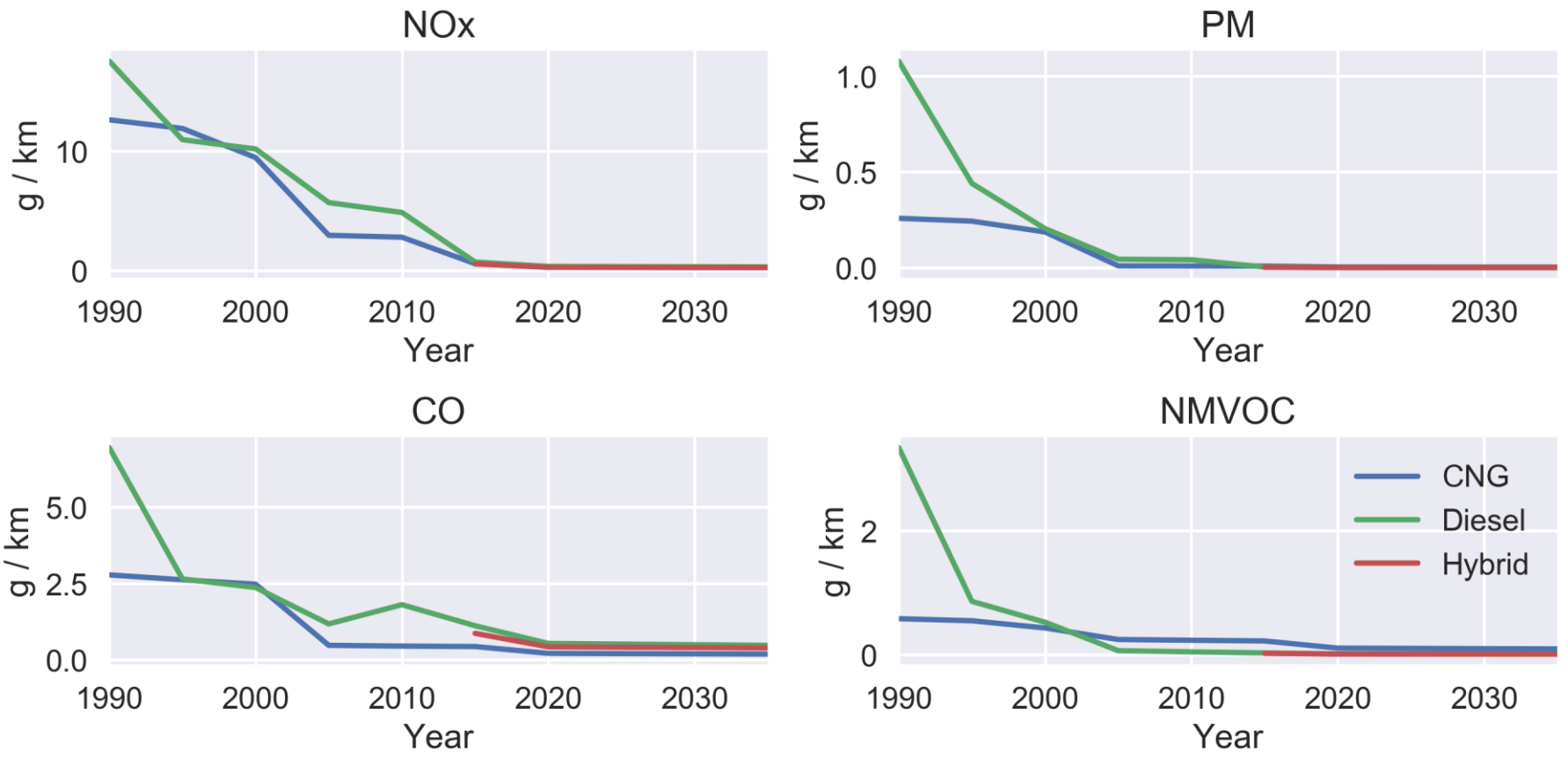
Monte Carlo Result - Energy Consumption



Energy Consumption



Bus operating emissions

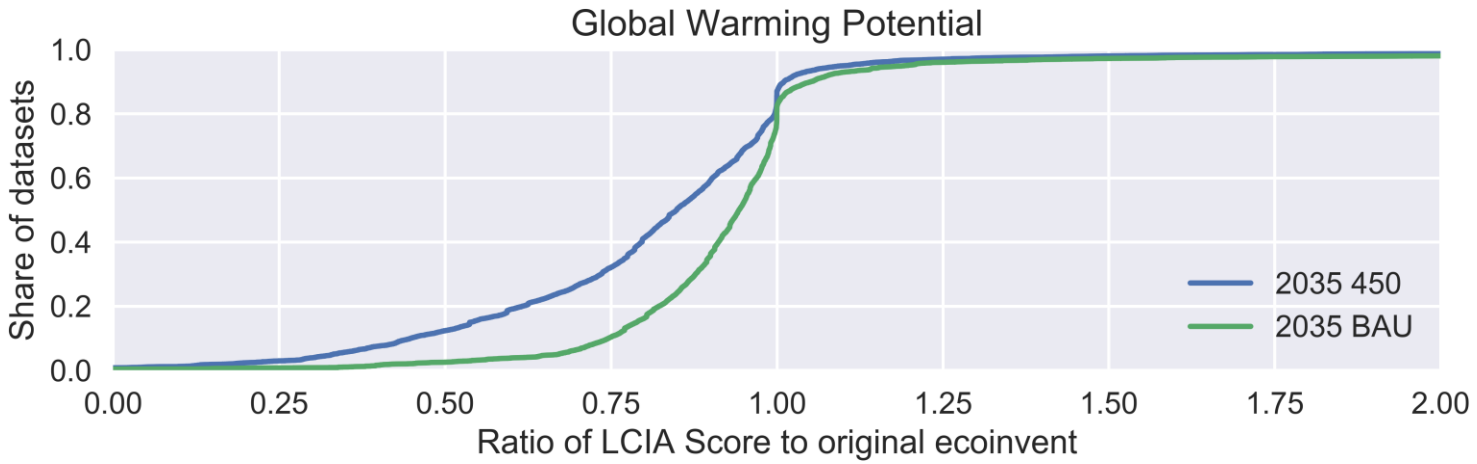


EEA/ EMEP 2013 Air pollutant emission inventory guidebook,

Handbook for Emission Factors (HBEFA 3.2)

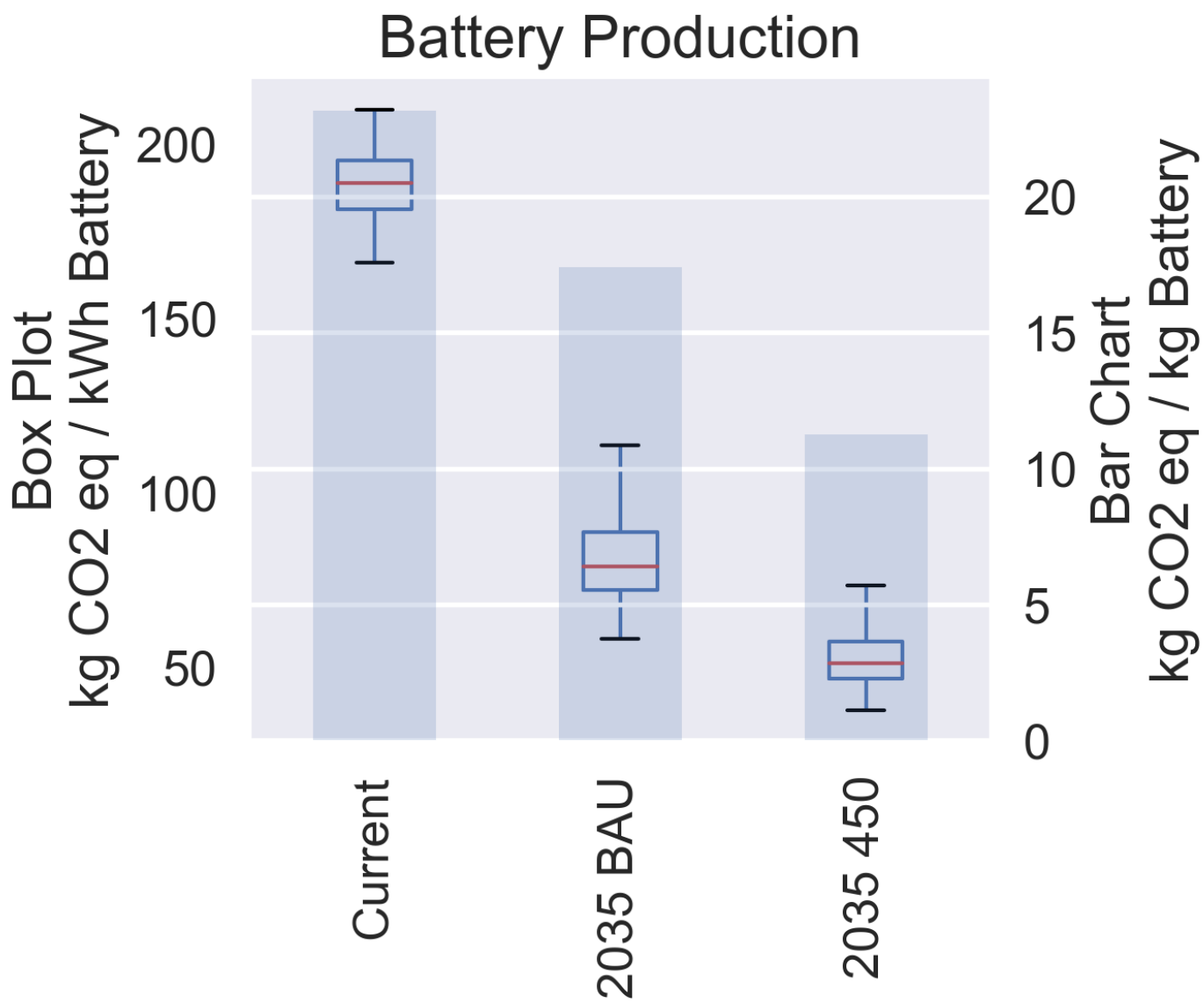
Future Background Databases

- Ecoinvent 3.3 as basis
- Scenario results from IMAGE model
  - 2035 Business as Usual & 450 ppm
  - 26 Global Regions
- Coal, Gas, Nuclear & Biomass electricity technologies
  - Efficiency and selected direct emissions
- Electricity market mixes changed

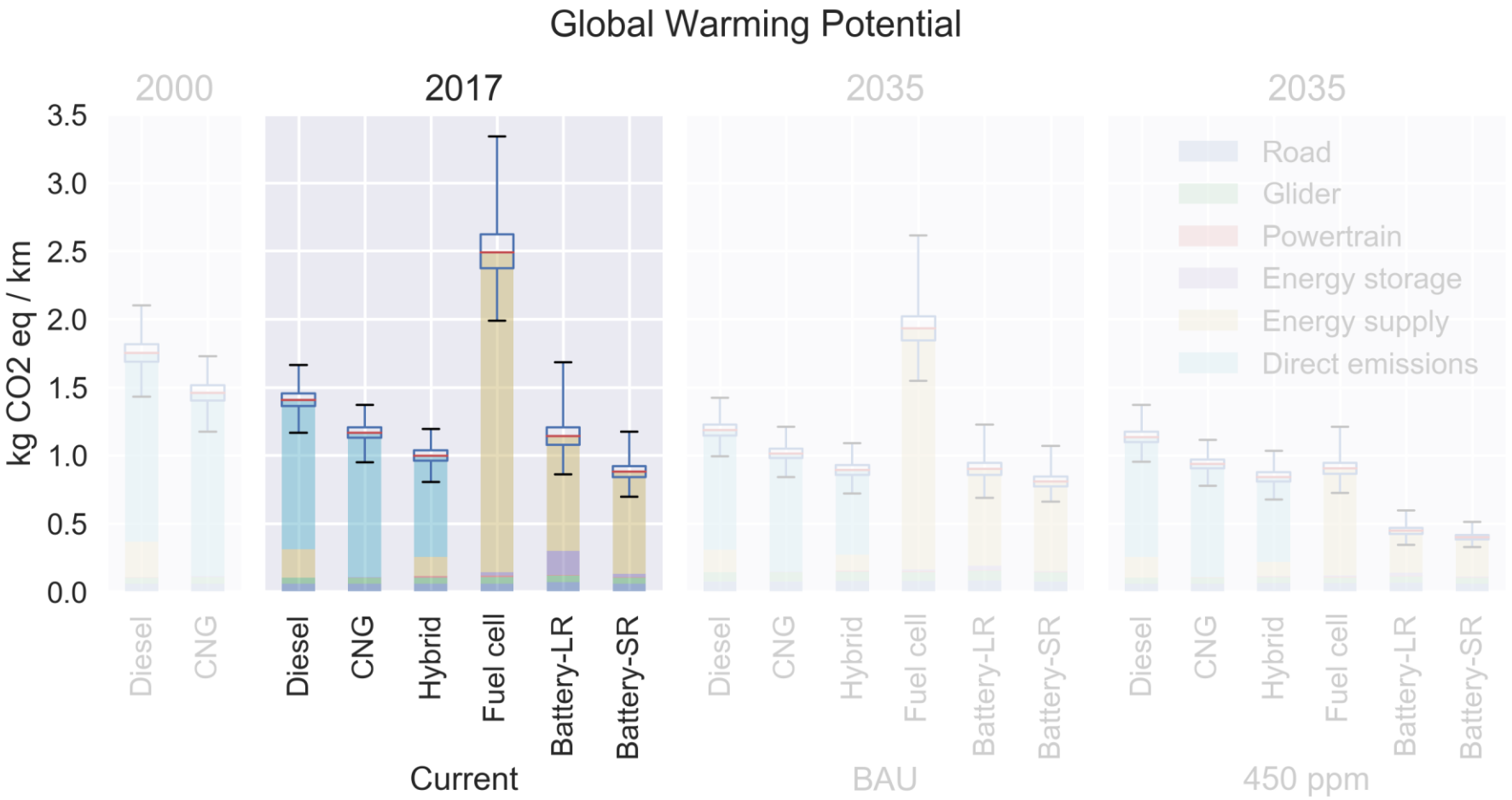


More informaton: github.com/IndEcol/wurst

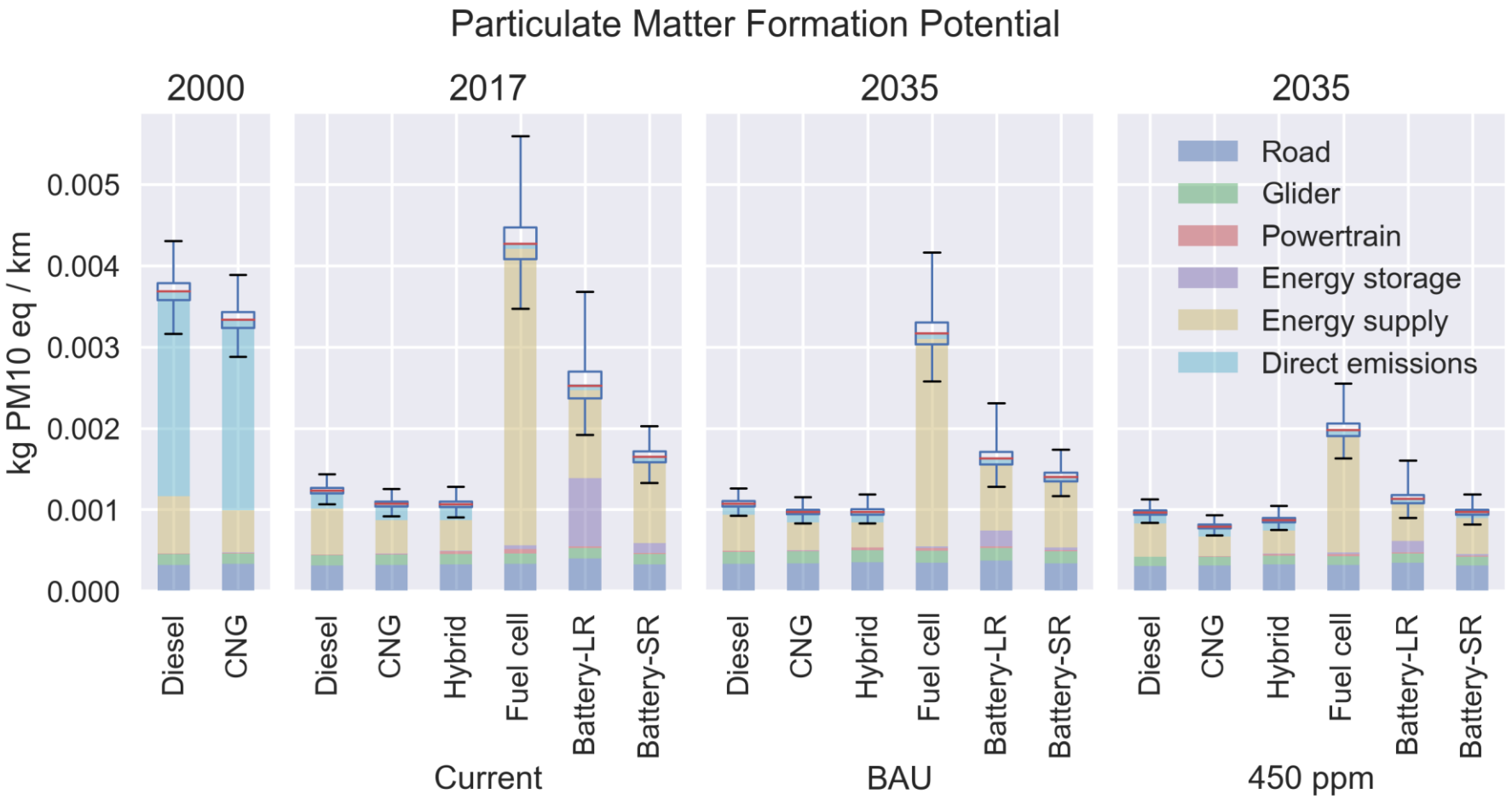
Production of Battery



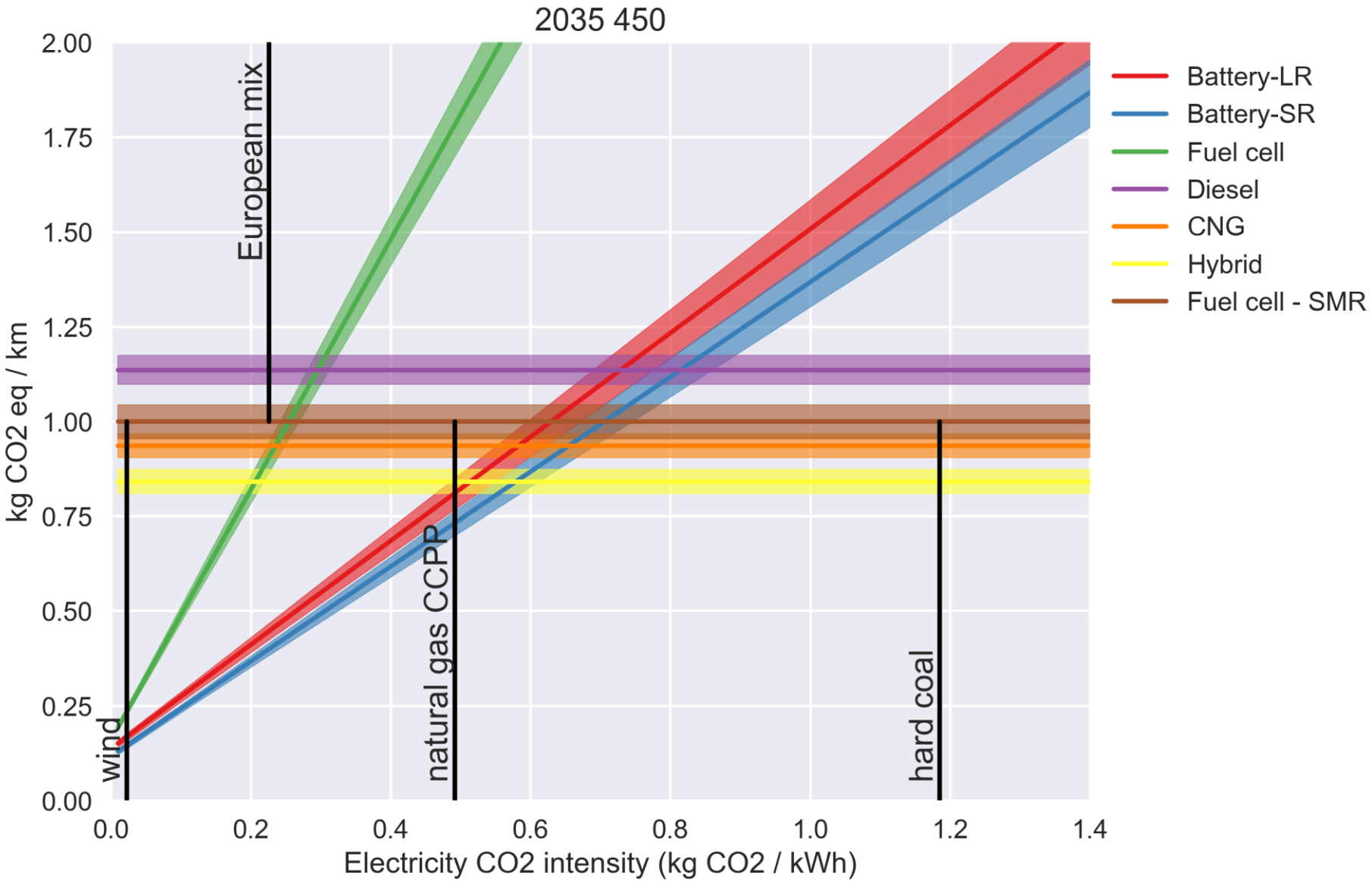
Bus LCA Results



Bus LCA Results



Electricity CO2 intensity – 50% CI



Discussion and conclusions

- The energy system used to build the bus has significant impact on the results
- Results are dominated by energy production / consumption.
  - Most efficient technologies perform best
- Today and in 2035 (BAU) hybrid and battery buses have similar performance with European average, in 2035 (450) battery buses have obvious benefits
- Fuel cell buses require < 150 g CO2 eq/ kWh to be competitive with hybrids, and never outperform battery buses (in terms of climate change)
- Non-CO2 emissions from **modern** combustion buses no longer contribute significantly to LCA results in any category.
  - But LCA isn't the best tool to measure this!

Thank you for listening!

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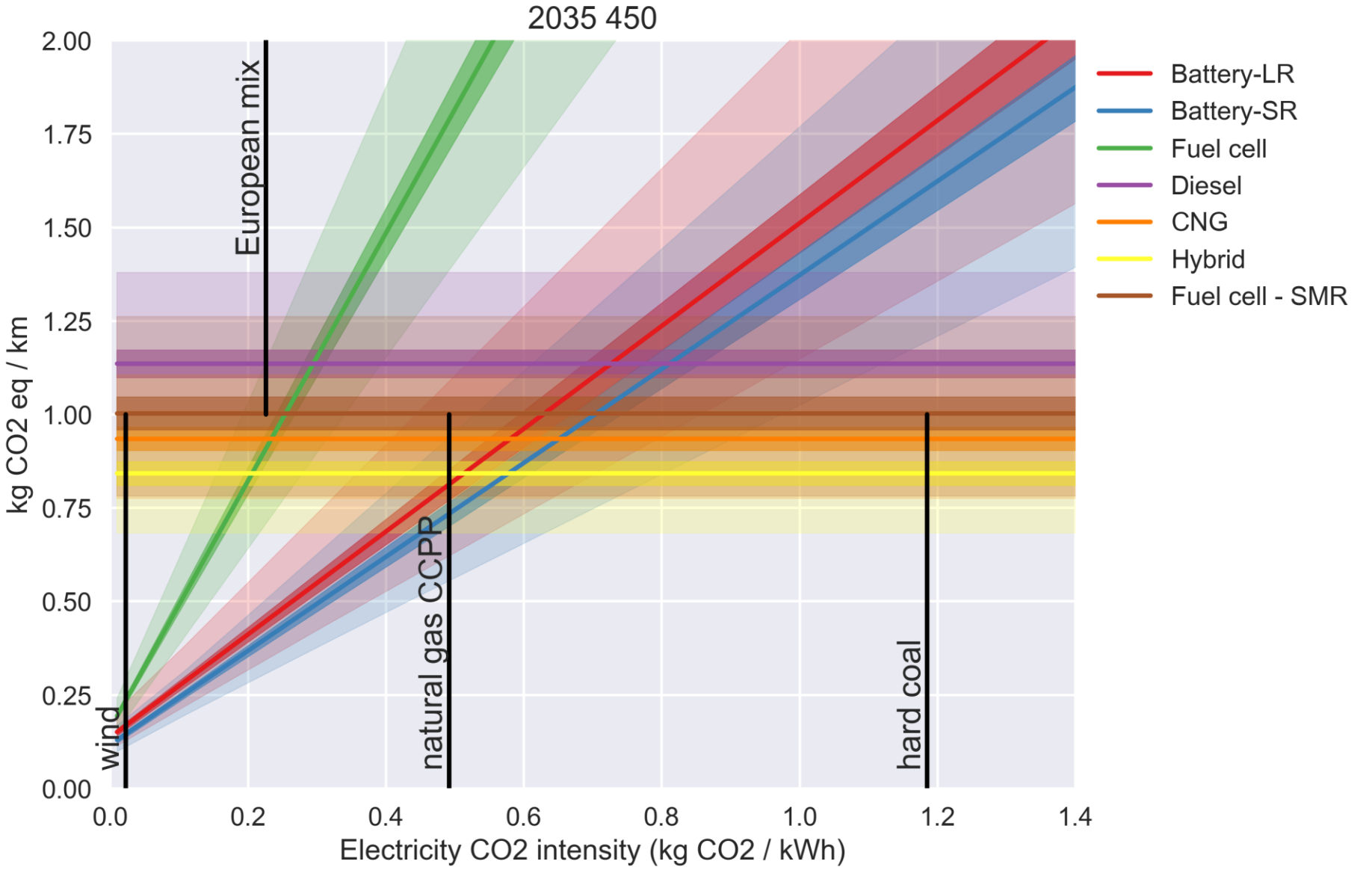
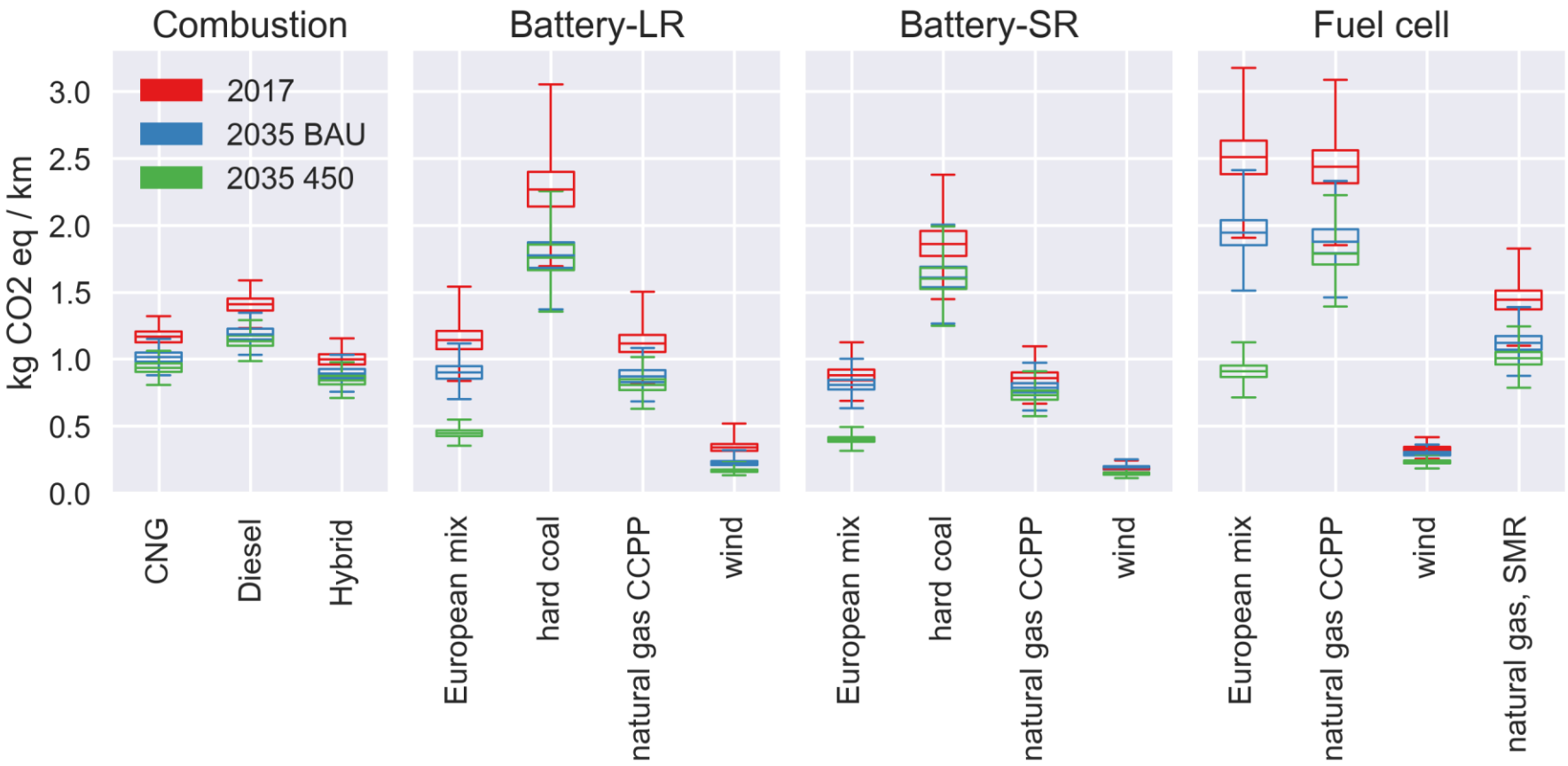
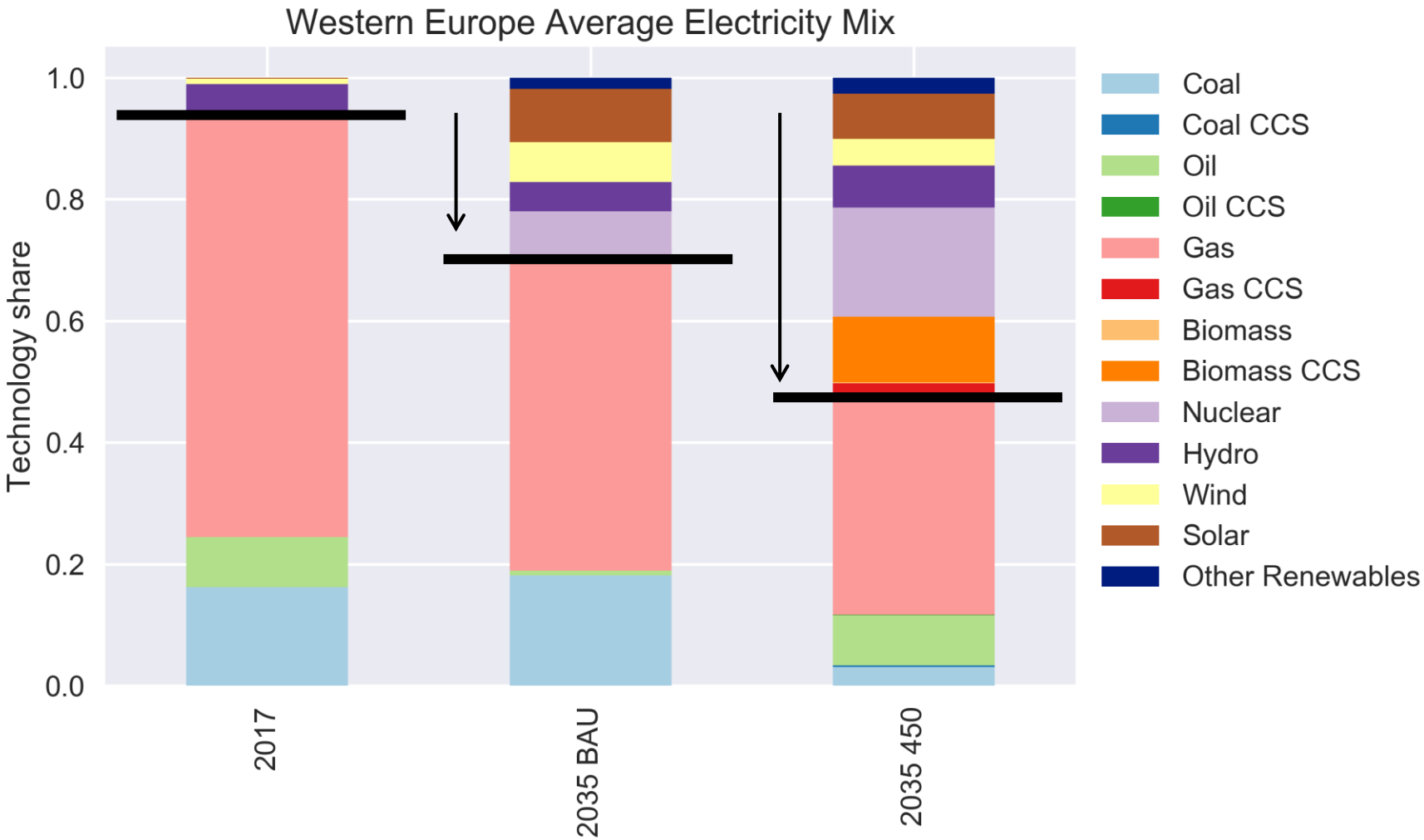
Electricity CO2 intensity – Min/Max



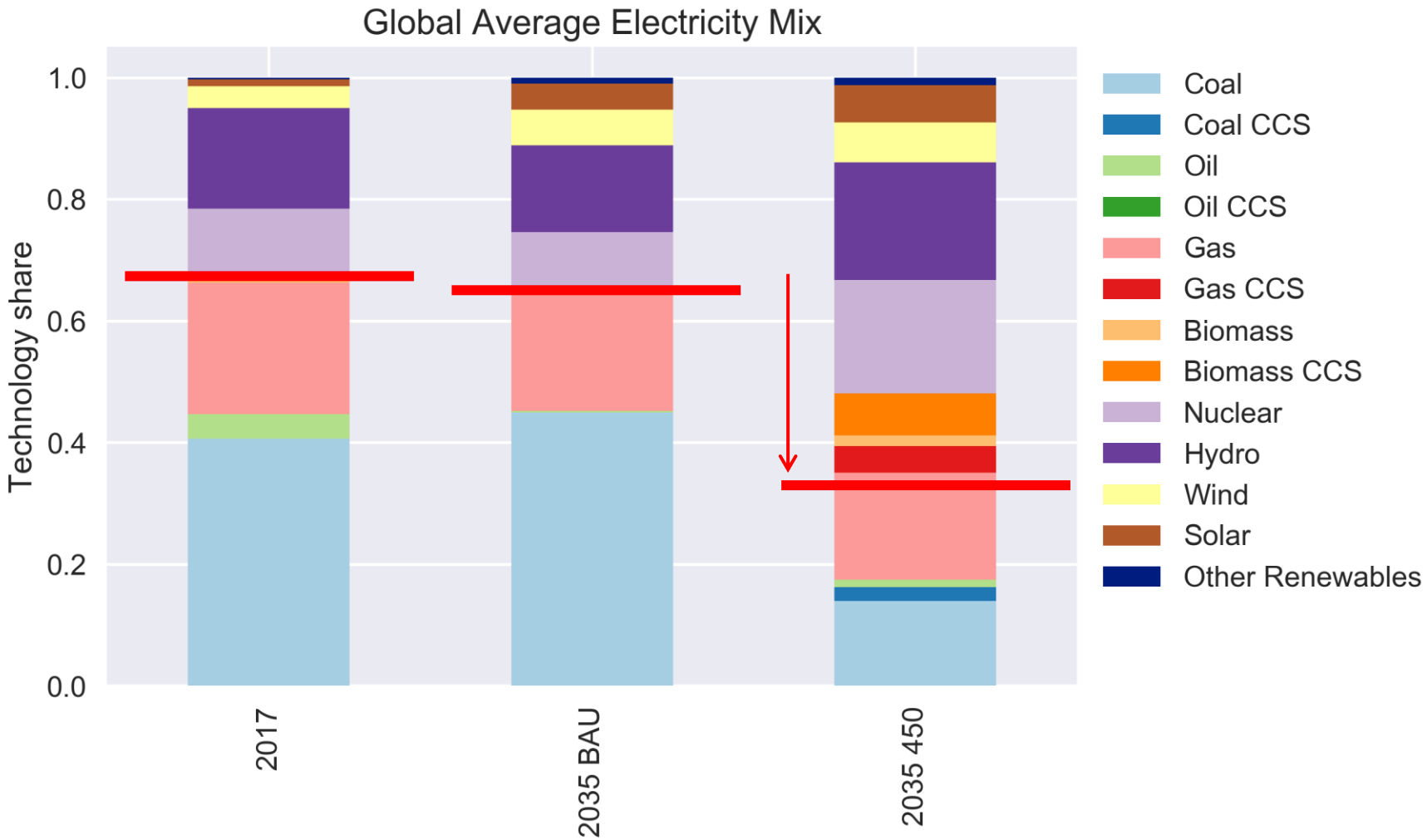
Different Electricity/ Hydrogen sources



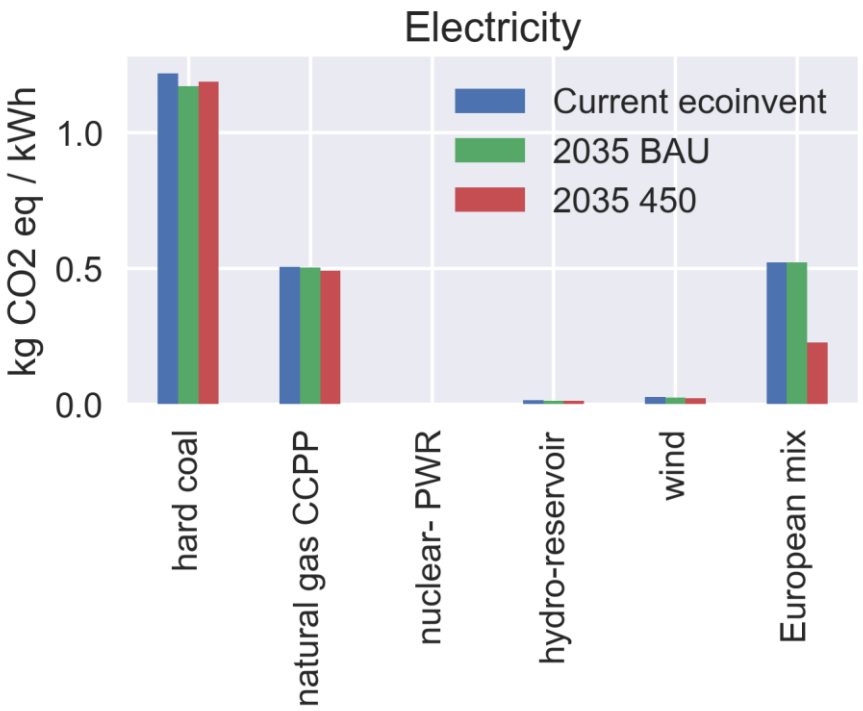
Western Europe Electricity Mix

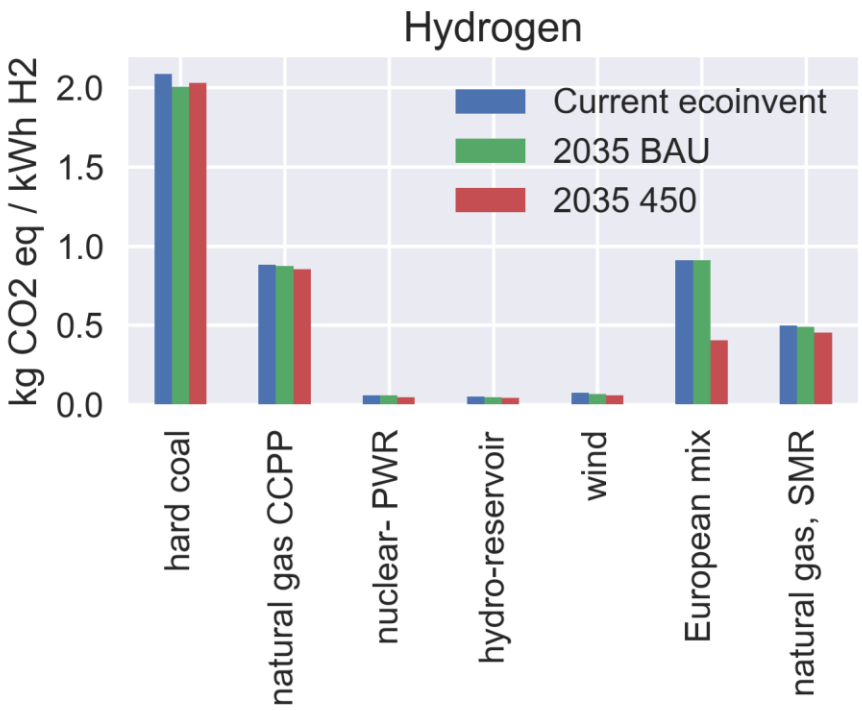


Global Electricity Mix



Energy Production





Production of battery and fuel cell and required replacements