Fraunhofer System Research for E-Mobility (FSEM)
Current LCA results and need for further research

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Ganzheitliche Bilanzierung

Fraunhofer System Research for E-Mobility (FSEM)
Current LCA results and need for further research

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Content

The Fraunhofer System Research for Electromobility (FSEM)

Goal of the FSEM is to provide an effective support for realizing a change to an „All-electric Economy“
The FSEM involves than 30 Fraunhofer institutes addressing topics along the whole value chain of E-Mobility, such as:

- Energy generation and Infrastructures
- Interfaces between Power Gird and Electric Vehicles,
- Energy storage
- New vehicle concepts and infrastructures
- Utilization- and metering concepts
- Environmental Assessment

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Goal and Scope

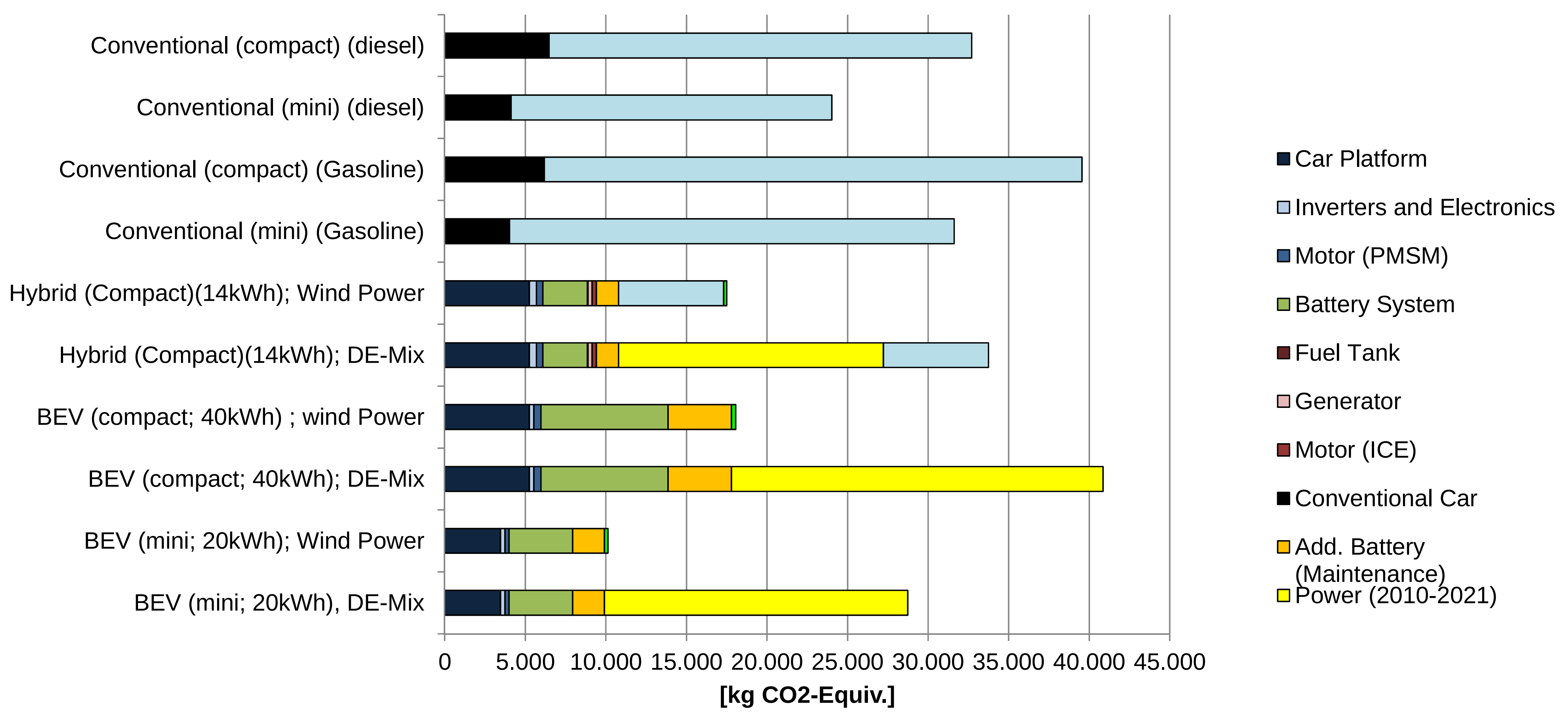
- Main goal of the LCA study is to give a first estimate on the environmental profile of different electric vehicle concepts
- Main focus on the production and use phase of EVs and PHEVs.
- Identification of relevant parameters and indicators
- Scenario screening on the future development of E-Mobility
  (future development of power grid mix and battery system)
- Based on the outcomes the need for further studies is identified
- End of Life / recycling is not considered.
- Effects of E-Mobility to the power grid are not addressed
- The data used for this study is based on FSEM internal information, literature and previous studies
- The modeling carried out with the GaBi4 software and its databases

Main Boundary Conditions

	BEV* (Mini-Class)	BEV* (Compact-Class)	PHEV Hybrid* (Compact-Class)
Battery Technology	Li-Ion (LiNi1/3Co1/3Mn1/3O2)		
Energy Content of Battery [kWh]	20	40	14
E-Motor PMSM [kW]	43	70	68
Power electronics [kg]	34	35	56
Combustion motor [kW]	-	-	41
Generator [kW] ([kg])	-	-	41
Car, Platform and other parts [kg]	736	1115	1115
Total Mass (Car) [kg]	1037	1670	1505
Energy consumption, electrical** [kWh/100 km] (German power mix and wind power)	18,7	22,9	20,4
Fuel consumption [l/ 100 km]***	-	-	6,9
Lifetime Battery (years)	8		
Lifetime other components (years)	12		
Mileage (dayly/annual/lifetime)	39 / 14.300 / 171.600		

**Exemplified car configurations, **Calculated according to ADAC Eco-Test, ***Emission profiles of conventional vehicles based on HBEFA3.1*

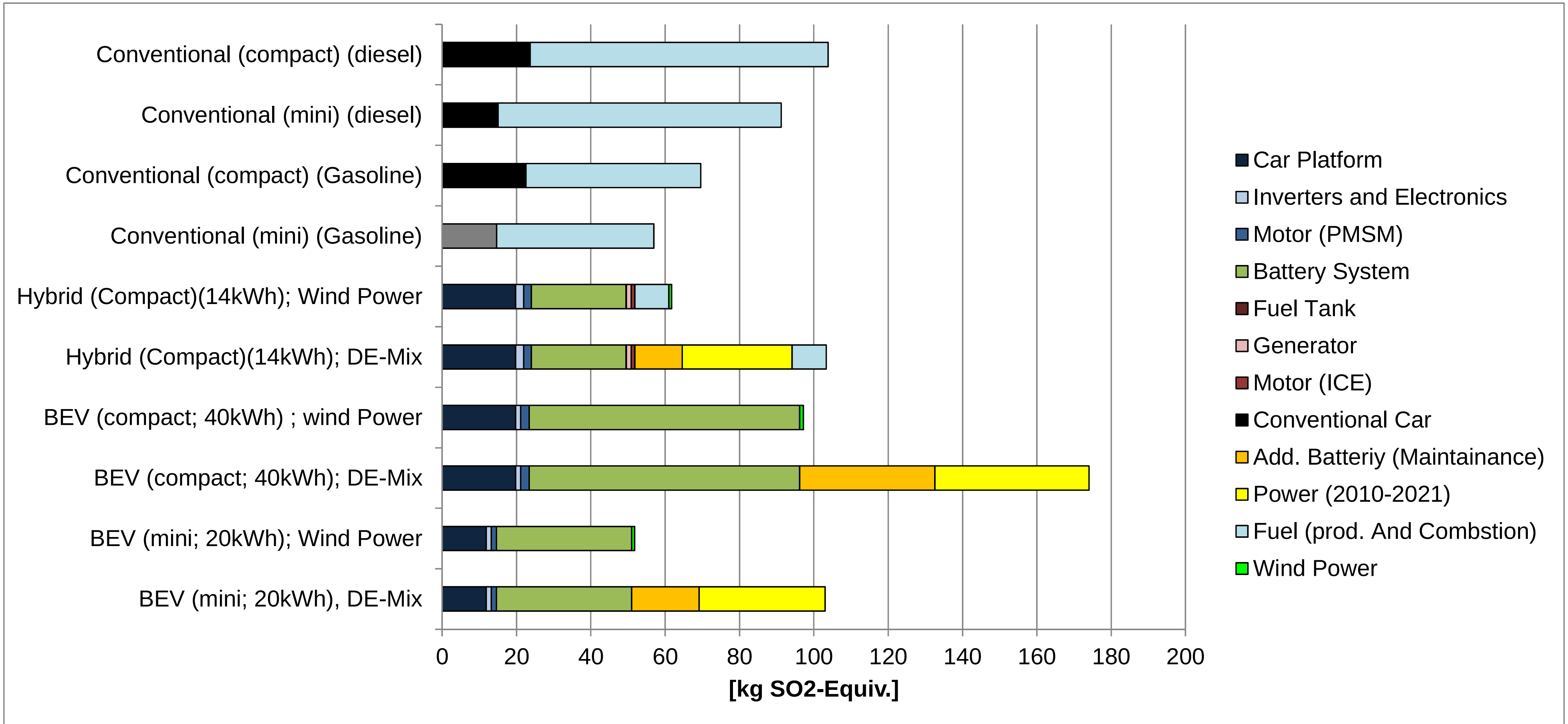
Results of Scenario 2010: Global Warming Potential



The share of the production phase of EVs increases in comparison to the conventional by a around factor 2. The EVs have lower impacts than the conventional vehicles during the use phase . The GWP of electric vehicle concepts results in a range of gasoline vehicles, diesel vehicles are not reached, yet. Significant contributions of the production of the battery system, mainly due to the production of cathode metals.

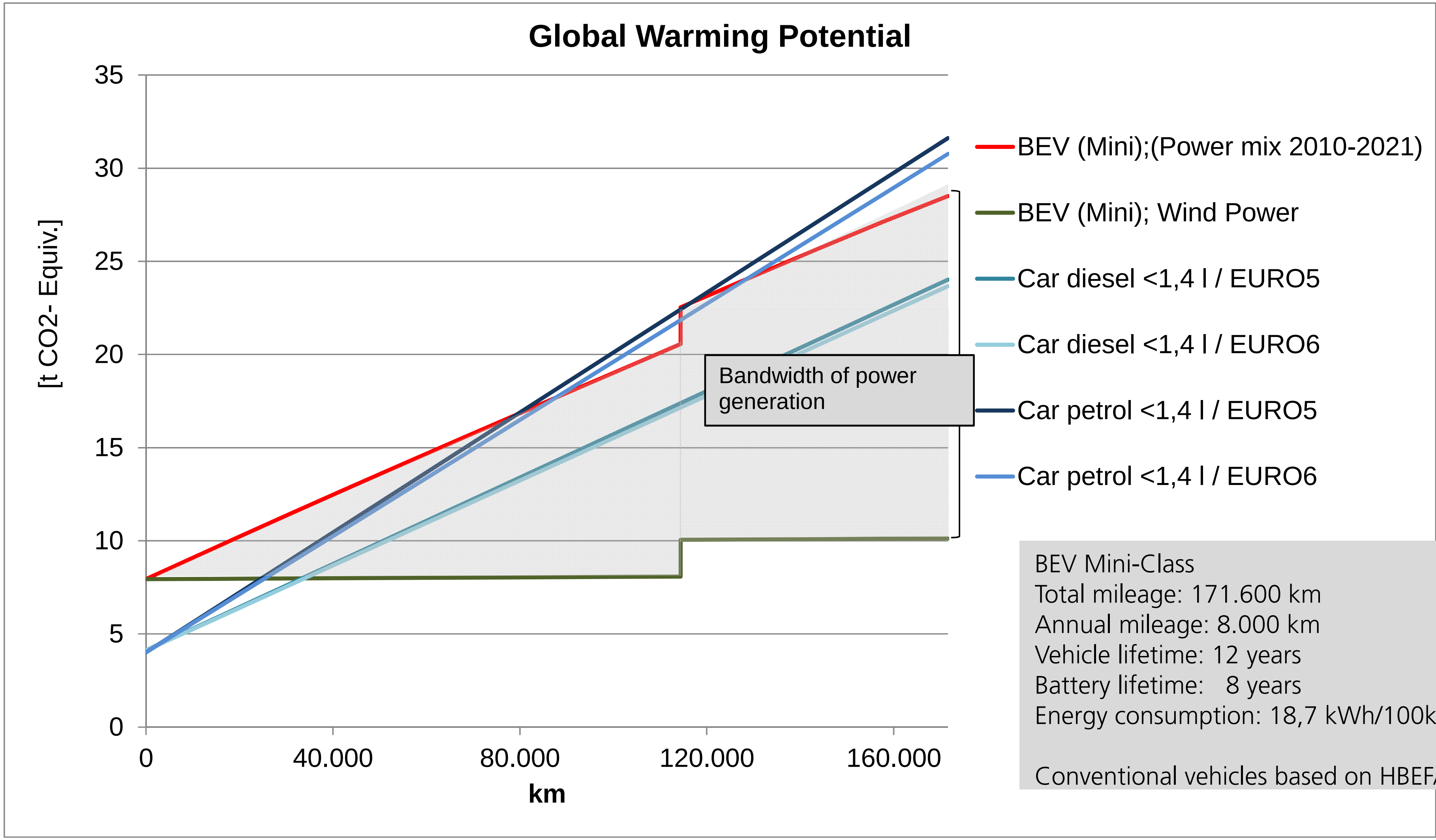
Using Wind power, significant reductions in comparison to conventional vehicles are reached.

Results of Scenario 2010: Acidification Potential



AP of electric vehicle concepts is considerably higher than the conventional car concepts.
Main contribution of the battery system. Depending on the dimensioning of the battery system used in the different EV concepts, the production phase is ~ 2 to 4 times higher than the conventional vehicles. Even though the EVs have lower impacts in the use phase, the impacts of the production phase cannot be compensated.

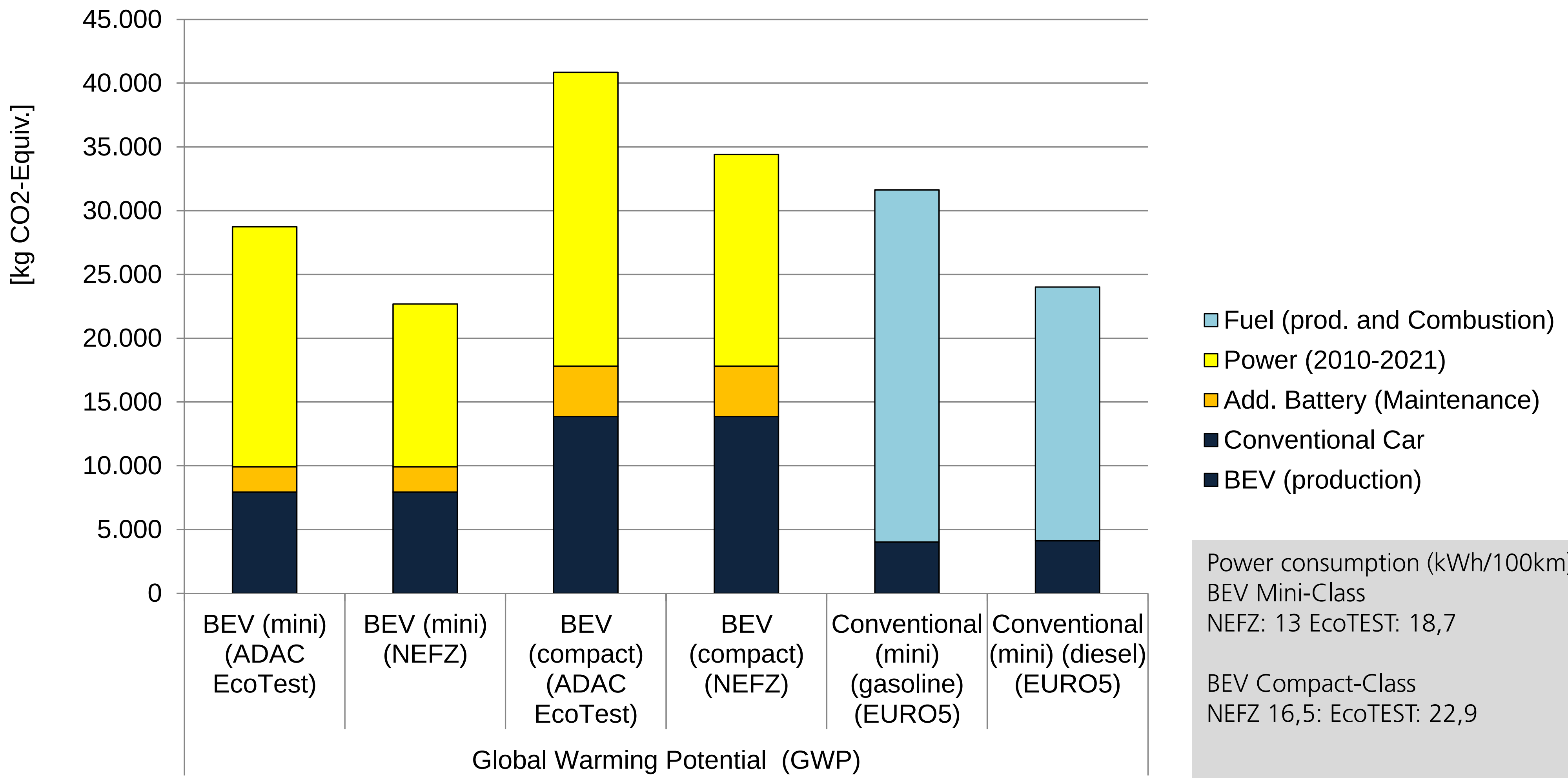
Dependency of Power generation and Battery System (MiniBEV)



BEV Mini-Class
Total mileage: 171.600 km
Annual mileage: 8.000 km
Vehicle lifetime: 12 years
Battery lifetime: 8 years
Energy consumption: 18,7 kWh/100km

Conventional vehicles based on HBEFA3.1

Dependency of selected Driving Cycle (BEVs)

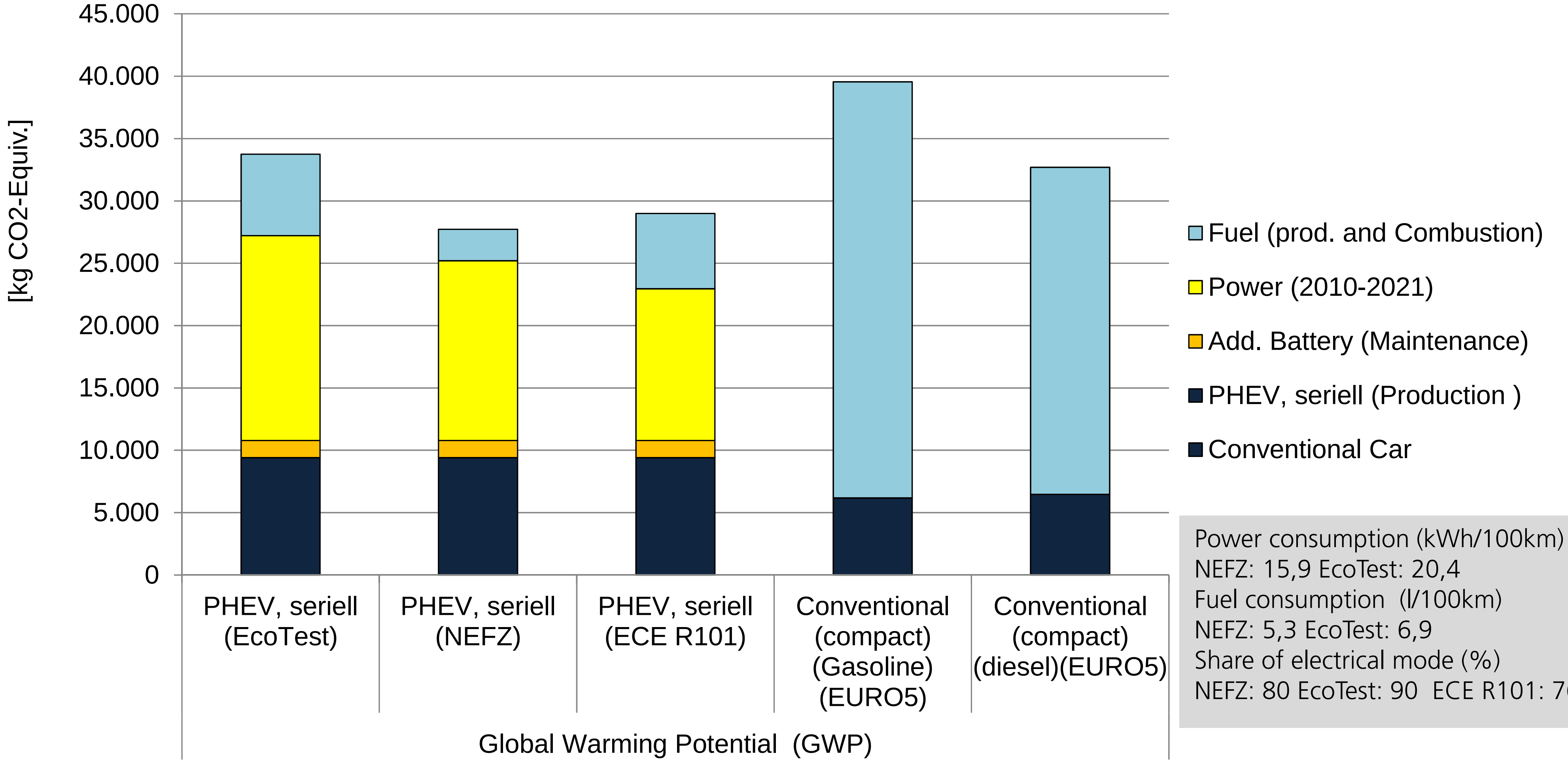


Power consumption (kWh/100km)
BEV Mini-Class
NEFZ: 13 EcoTEST: 18,7

BEV Compact-Class
NEFZ 16,5: EcoTEST: 22,9

Considerable differences in the energy consumption of EVs according to chosen driving cycle, which results a variation from ~ 15 to 20% in the vehicle life cycle. The driving cycles do not necessarily reflect real vehicle specific driving profiles. These aspects have to be evaluated in future studies.

Dependency of selected Driving Cycle (PHEV)



Power consumption (kWh/100km)
NEFZ: 15,9 EcoTest: 20,4
Fuel consumption (l/100km)
NEFZ: 5,3 EcoTest: 6,9
Share of electrical mode (%)
NEFZ: 80 EcoTest: 90 ECE R101: 76

Depending on the chosen driving cycle and method for calculating the share of electrical driving mode, the results vary by ~ 16. Two methods a used: assumption by the electrical range and average driving distances (DAT report) and calculation by ECE R101
Also for the PHEVs vehicle and user specific utilization profiles are required.

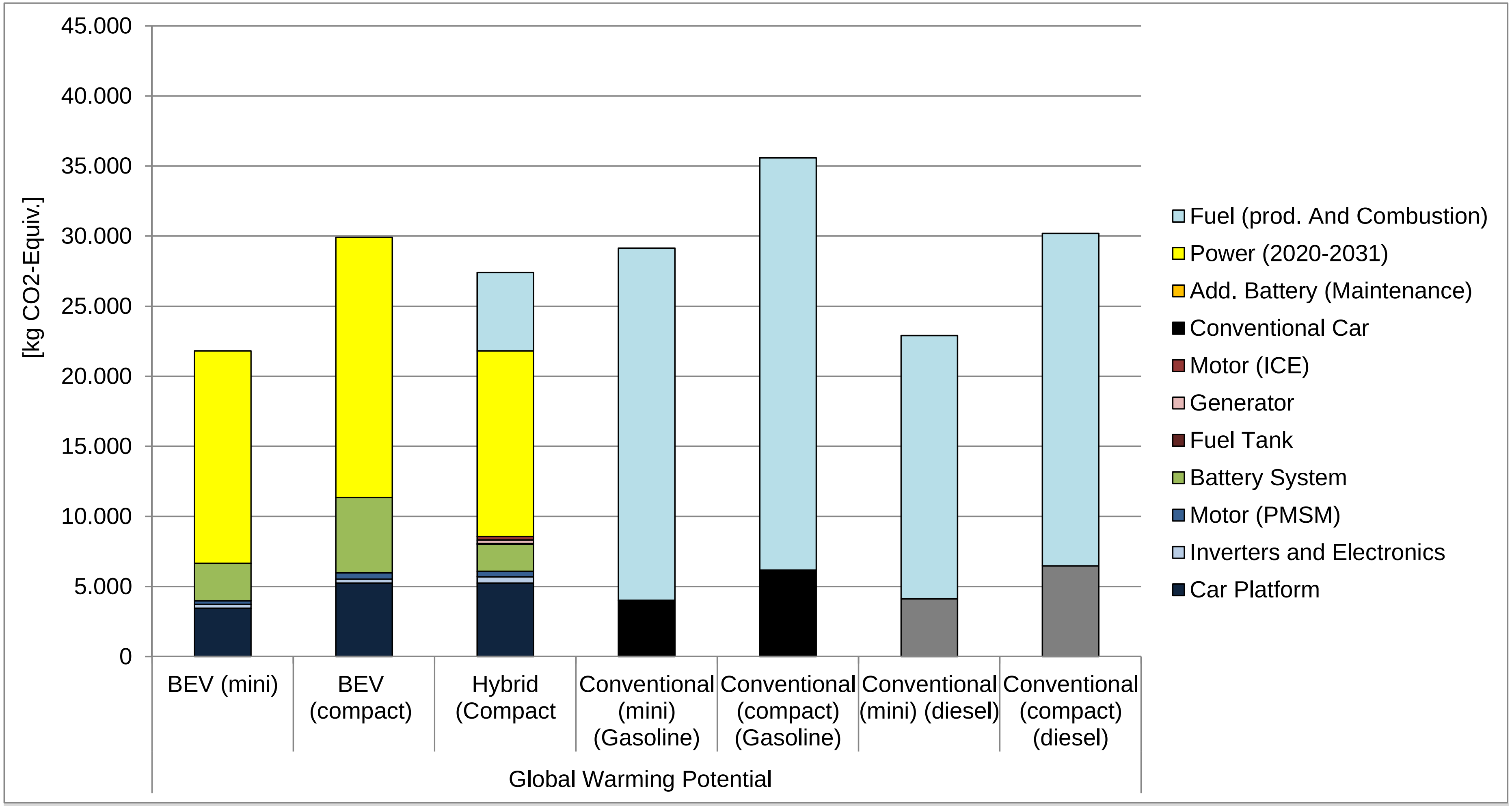
Relevant Parameters

- Power production mix (Power grid mix vs. renew. Energy (wind power))
- Battery system
  - Lifetime and dimensioning, energy density of cells
  - Upstream processes and production of raw materials Production (cathode materials, graphite)
- Energy consumption of vehicles
  - Driving cycle (NEFZ vs. ECO Test)
  - Need for vehicle and user specific utilization profiles to allow a fair comparison to combustion vehicles. *(e.g. Vehicles used as city car, for medium and long distances)*
- Total mileage of vehicles

Scenario 2010-2020: Boundary conditions

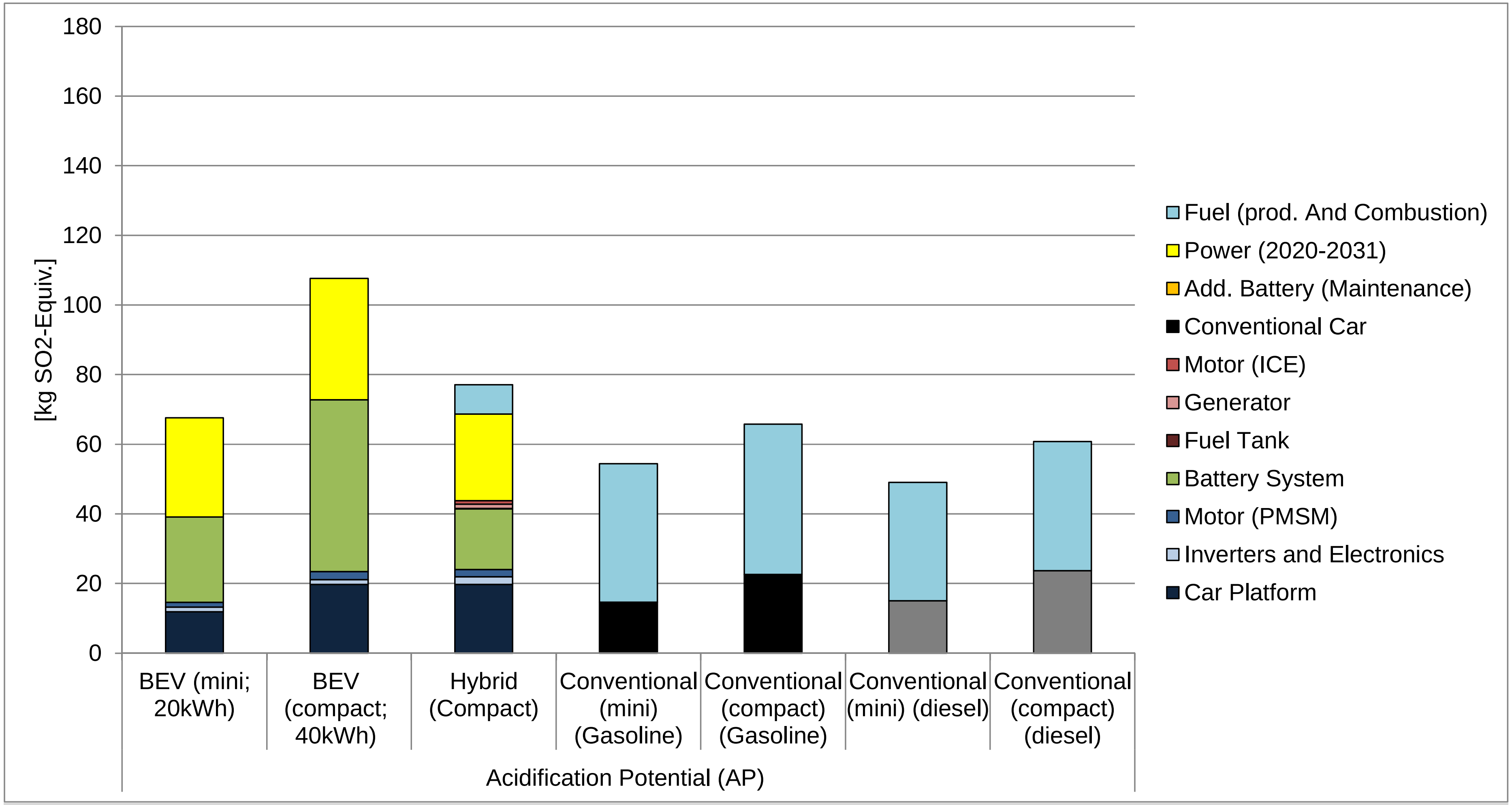
- Future development of the German power grid mix
- Share of renewable energies in power grid mix: ~17% (2010) , ~ 58 (2030)
- Dynamic adjustment of the environm. profile of the power grid mix
- Increased lifetime of battery system from 8 years (2010) to 12 years (2020)
- Increasing energy density of battery cells from 135 Wh/kg (2010) to 200Wh/kg (2020, optimistic)
- Fixed electric driving range to keep the comparability of results. Improvements of batteries result in lower battery weights and hence lower impacts in the production phase
- Combustion vehicles based on the scenarios of HBEFA 3.1

Results of Scenario 2020: Global Warming Potential



Significant reductions due to the higher share of renewable energies in the power grid mix, increased battery lifetime and energy density of the cell. The GWP of the EV concepts reach the dimension of diesel vehicles. Significant reductions are achieved by using renewable power (e.g. wind power) for the battery charging

Results of Scenario 2020: Acidification Potential

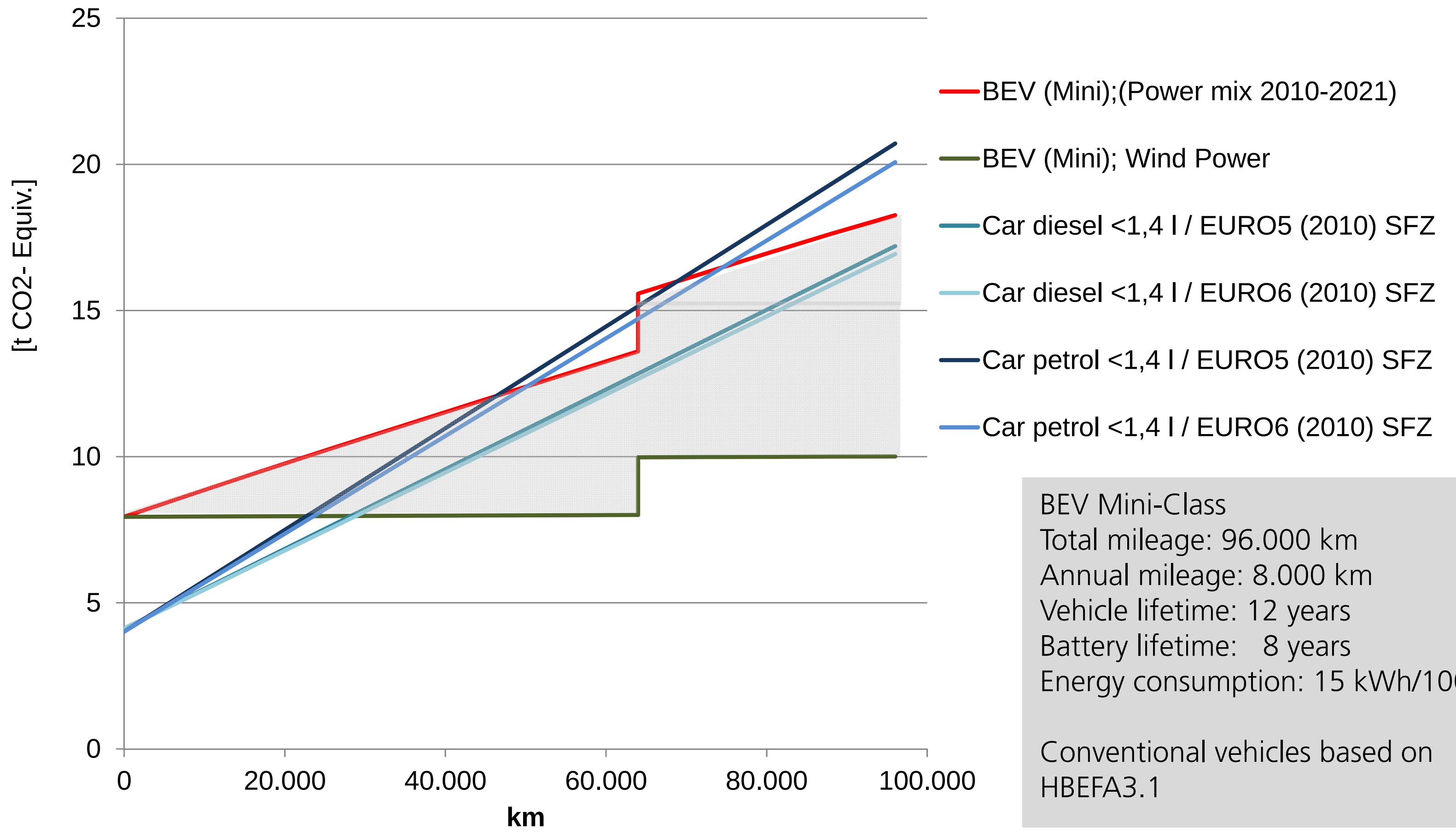


Significant reductions in the AP, mainly due to increases battery lifetime and performance. Due to considerably higher impacts of the production phase of EV-Concepts, conventional vehicle concepts are not reached.

Scenario Analysis: Mini-Class BEV used as City Car

- Investigation of a Mini-Class BEV used as city car
- Two cases:
  - Low driving distance (8000km/a ~22 km/day)
  - High driving distance (14.300km/day; ~39km/day); (e.g. car sharing)

Scenario 2010: Mini-Class BEV used as City Car, low mileage (GWP)

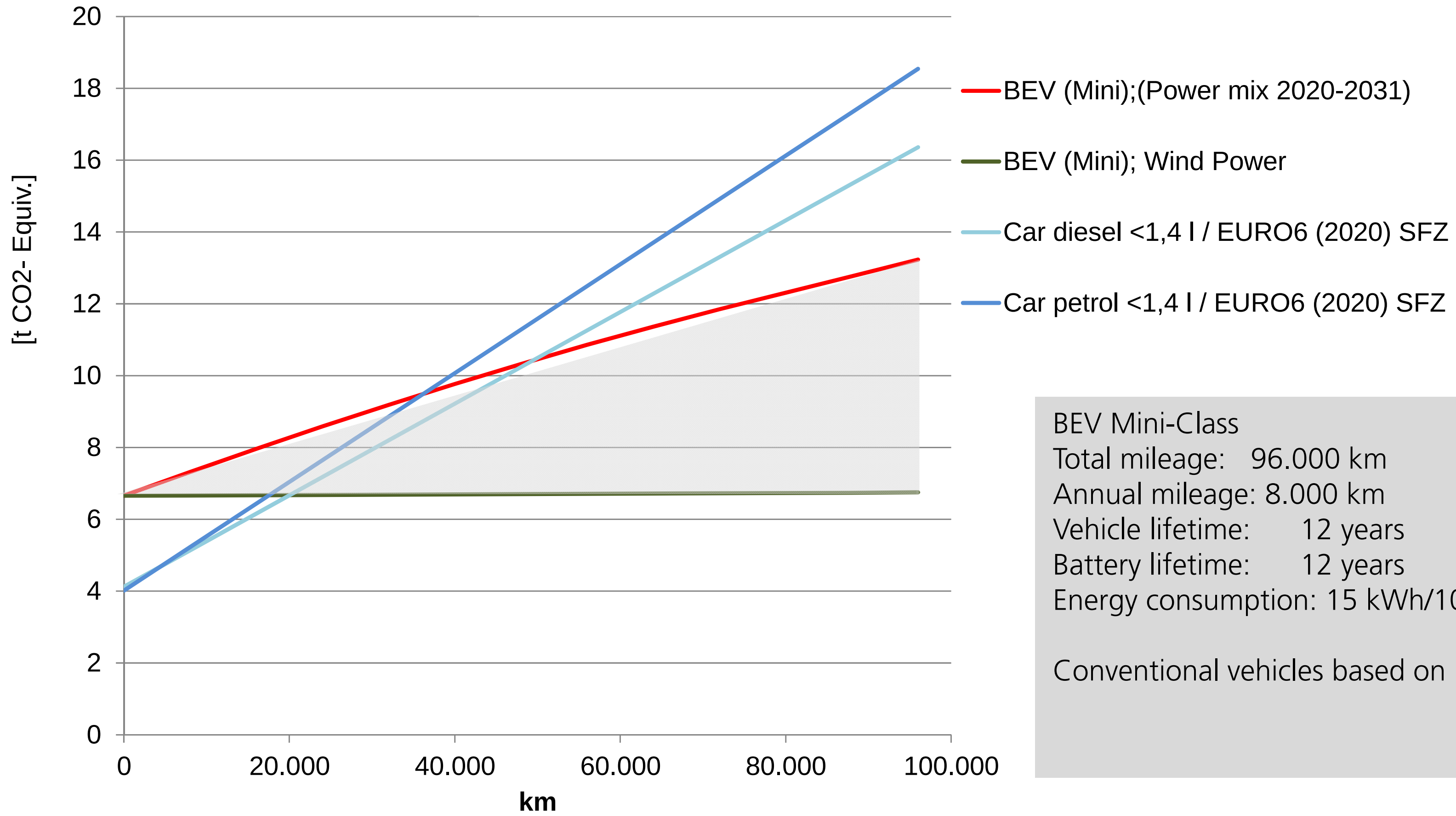


BEV Mini-Class
Total mileage: 96.000 km
Annual mileage: 8.000 km
Vehicle lifetime: 12 years
Battery lifetime: 8 years
Energy consumption: 15 kWh/100km

Conventional vehicles based on HBEFA3.1

Due to the lower mileage, the relevance of the production phase increases. EVs have a lower energy consumption in the city use, whereas the fuel consumption of CVs increases. Therefore, even with a lower mileage the BEV reaches a range between the gasoline and diesel vehicles. The break even to gasoline vehicles is close to the end of the use phase at ~75.000 km.

Scenario 2020: Mini-Class BEV used as City Car, low mileage (GWP)

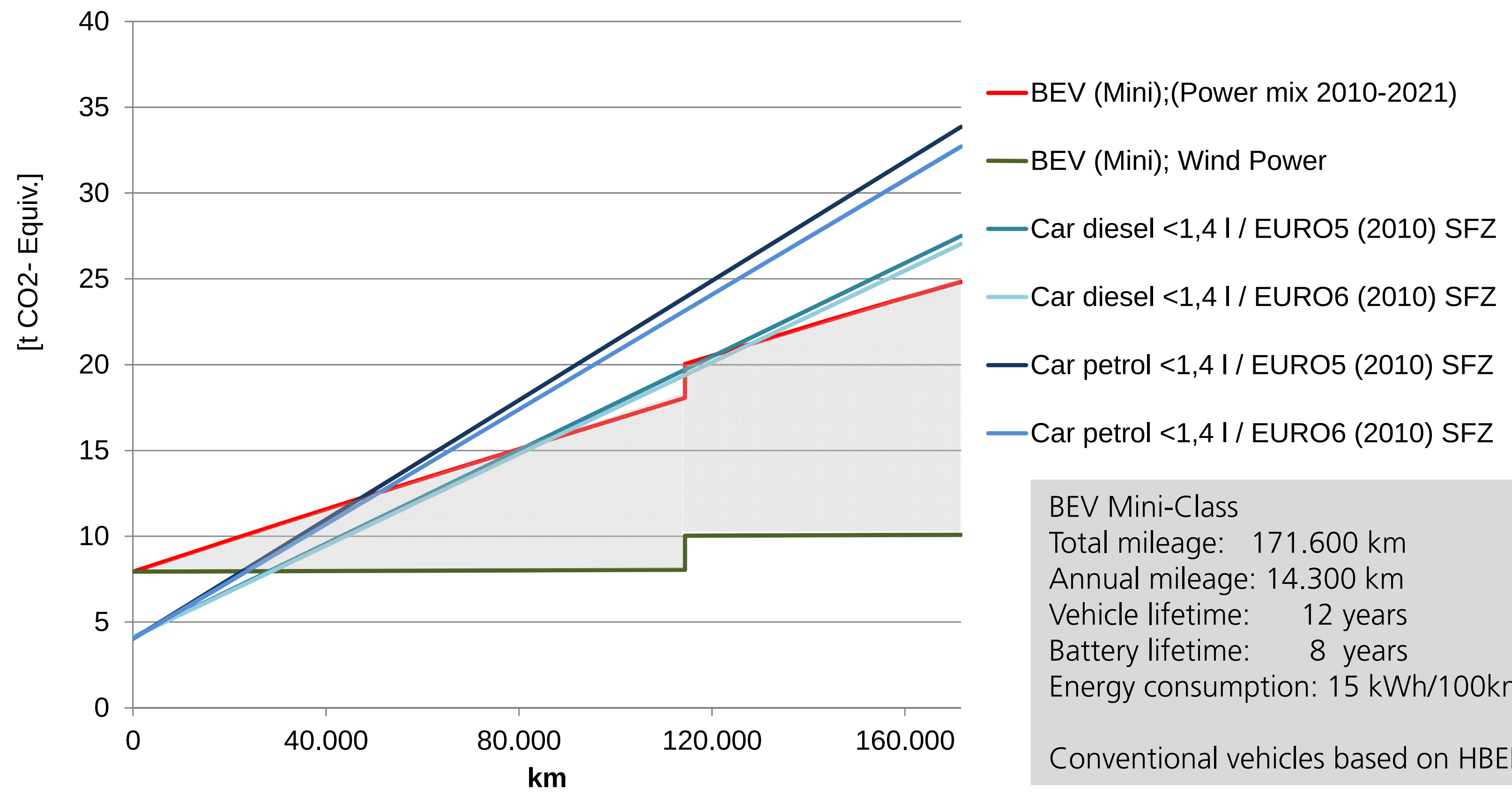


BEV Mini-Class
Total mileage: 96.000 km
Annual mileage: 8.000 km
Vehicle lifetime: 12 years
Battery lifetime: 12 years
Energy consumption: 15 kWh/100km

Conventional vehicles based on HBEFA3.1

Due to future improvements of the battery system and a higher share of renew. Energies in the power grid mix, significant reductions compared to the CVs are reached in scenario 2020. The break even is between 40.000 and 50.000 km.

Scenario 2010: Mini-Class BEV used as City Car, high mileage (GWP)

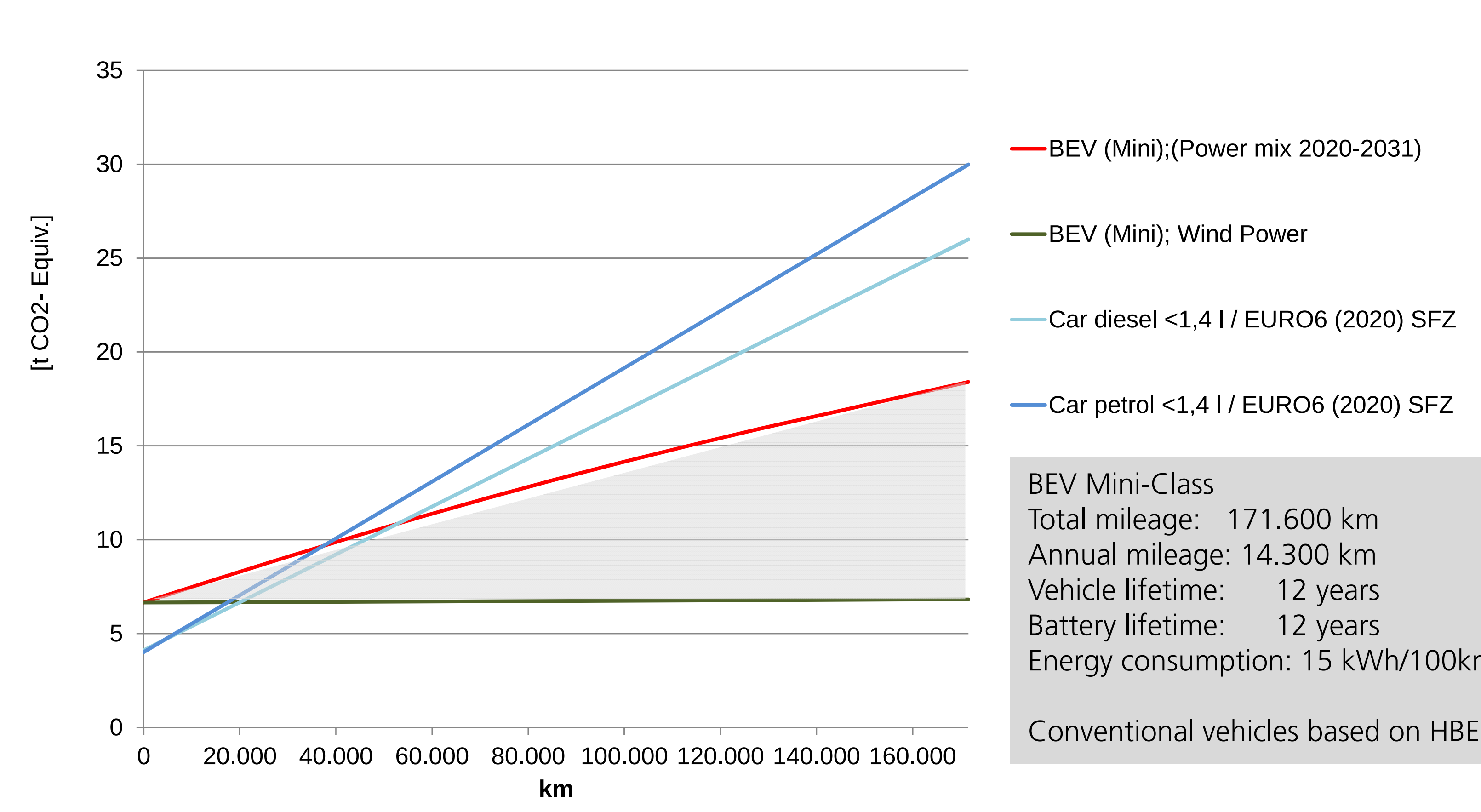


BEV Mini-Class
Total mileage: 171.600 km
Annual mileage: 14.300 km
Vehicle lifetime: 12 years
Battery lifetime: 8 years
Energy consumption: 15 kWh/100km

Conventional vehicles based on HBEFA3.1

Due to the higher mileage, the mini-class BEV in the city use reaches considerable reductions to gasoline vehicles and slight reductions compared to diesel vehicles. The break even to gasoline vehicles is at around 50.000km and to the diesel at around 125.00km

Scenario 2020: Mini-Class BEV used as City Car, high mileage (GWP)



BEV Mini-Class
Total mileage: 171.600 km
Annual mileage: 14.300 km
Vehicle lifetime: 12 years
Battery lifetime: 12 years
Energy consumption: 15 kWh/100km

Conventional vehicles based on HBEFA3.1

Due to future improvements of the battery system and a higher share of renew. Energies in the power grid mix, significant reductions compared to the CVs are reached in scenario 2020. The break even is between 40.000 and 50.000 km.

Need for further research

Production

- LCA datasets: Better knowledge of the raw material production and upstream processes of relevant materials (Li, Co, Ni, Mn, Nd, Dy) and their future development (environmental profile, availability of resources, recycling concepts and processing)
- Future development of components: Materials, technology, alternative concepts (e.g. E-motor: PMSM; ASM, reluctance, battery technologies (e.g. LiFePO4; Li-Ploymer, etc.)
- Detailed LCA study of EV battery systems in cooperation with producers and all relevant players in supply chain and raw material production
- End of Life / Recycling: Technologies and strategies

Utilization

- Scenarios of the developments of Power Mix to increase the shares of renewable energies
- Possible impacts of E-mobility to the power grid
- Investigation of vehicle and user specific utilization profiles to ensure representative LCA results
- Identification of beneficial fields of use (e.g. car sharing) /mobility concepts

Methodology

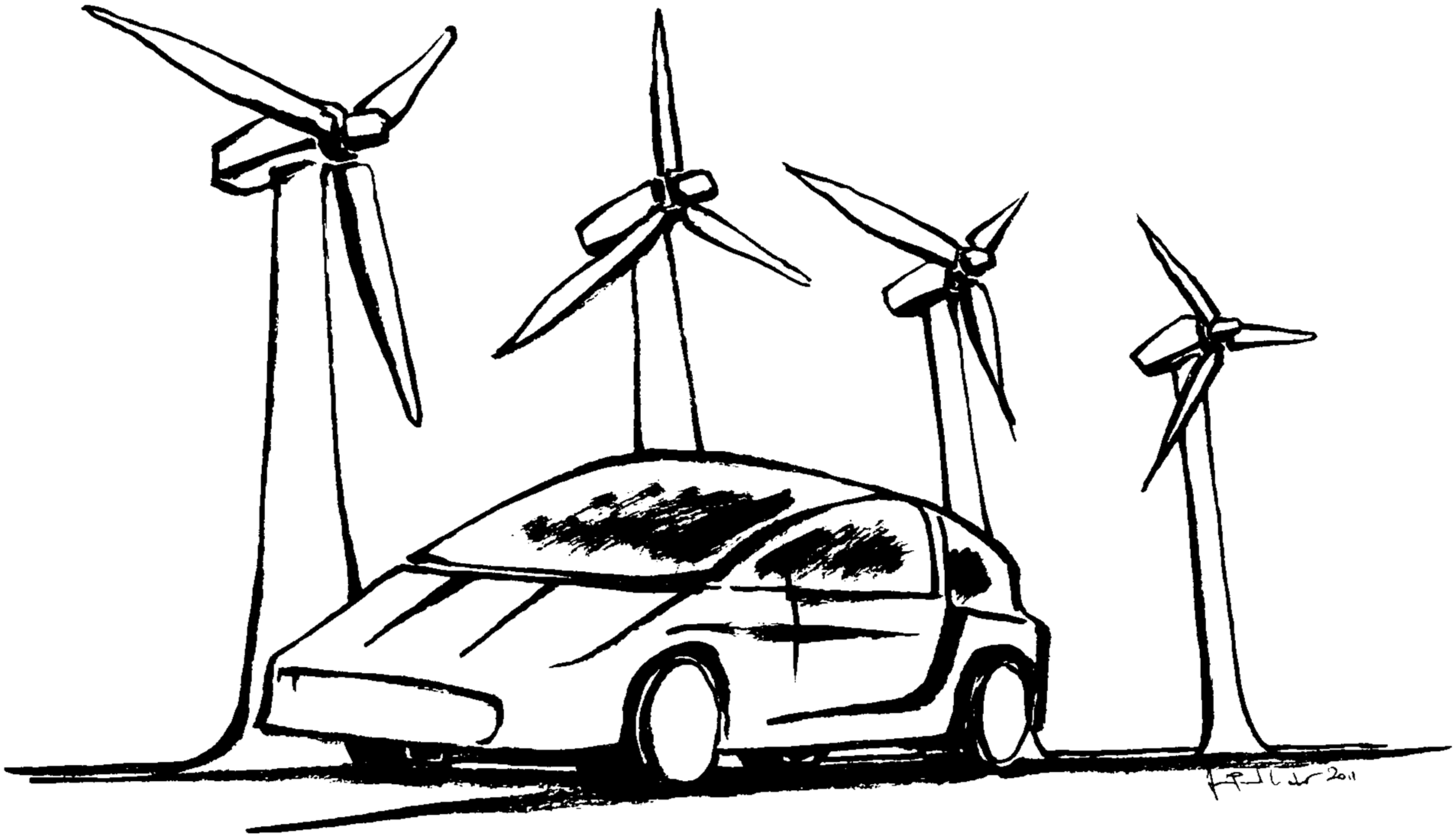
- Methodology for a regional differentiation of caused emissions in LCA (e.g. local emissions like SO_2, NO_x).
- Many variable parameters require a common agreed approach for the LCA of E-mobility to ensure comparability and consistency of future LCA studies.

Summary and Conclusion

First estimate on the environmental profile shows that:

- The relevant parameters of E-Mobility are the power generation mix, battery system, driving profile and mileage
- Add. components lead to an increased relevance of the production phase, especially due to the use of rare materials for batteries
- Lower impacts during the use phase
- Using renewable energies a significant reduction of the GWP is reached
- Using the local power mix, the GWP of current EVs are in a comparable rage with gasoline vehicles.
- The AP of EVs is considerably higher, mainly due to the production of required raw materials for the battery systems
- Scenarios show that In long term view considerable improvements can be reached
- There are still many open questions that have to addressed on future studies

Thank you for your attention!



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