PELMOB

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Environmental Science and Technology
Life Cycle Assessment
Practical Case

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International Management and Leadership

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LCA Methodologies
Part 2: Key considerations for hybrid and electric vehicles

- Currently, there are no automotive targets specifically aimed at reducing CO_2 from production of the whole vehicle
- WTT emissions are also not factored into vehicle CO_2 regulations

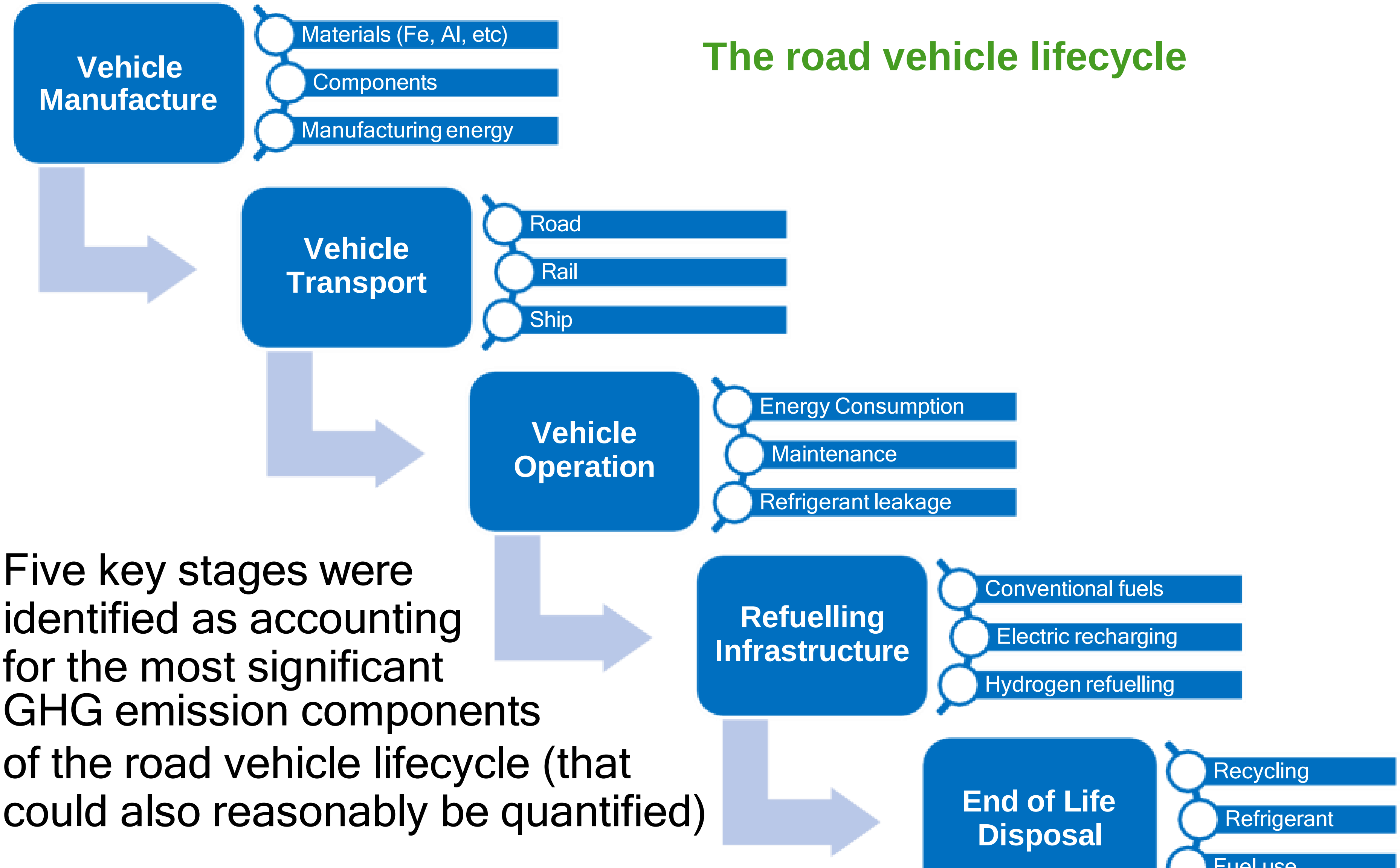
Issues for both hybrid and electric vehicles:

- Availability of reliable **real-world** performance data (i.e. MJ/km)
- Wide range of literature reported values for battery GHG intensity
- Uncertainty on battery lifetime performance/potential replacement

Issues for plug-in EVs only (PHEVs, REEVs and BEVs):

- Very large variation in regional electricity GHG intensity and in estimates for future decarbonisation ⇒ affects all lifecycle stages
- Average or marginal electricity? Recharge at night or in daytime?
- Most studies also DON'T typically account for:
  a) Upstream emissions of fuels used in electricity generation (+16% for UK)
  b) Projected changes in electricity GHG intensity over the vehicle lifetime
- Accounting for recharging losses (often excluded)

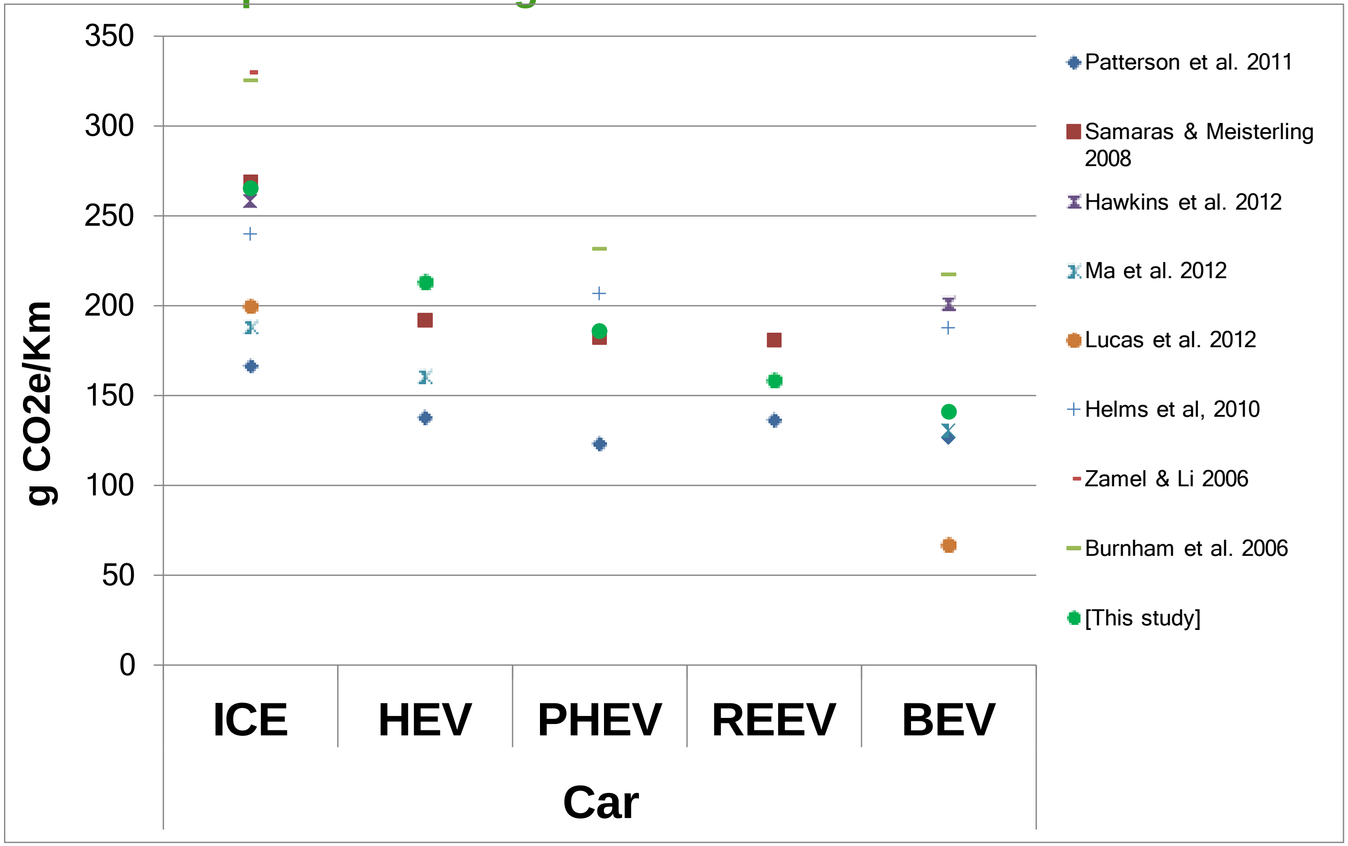
The road vehicle lifecycle



- Five key stages were identified as accounting for the most significant GHG emission components of the road vehicle lifecycle (that could also reasonably be quantified)

Range of overall LCEs in the literature

Road transport technologies



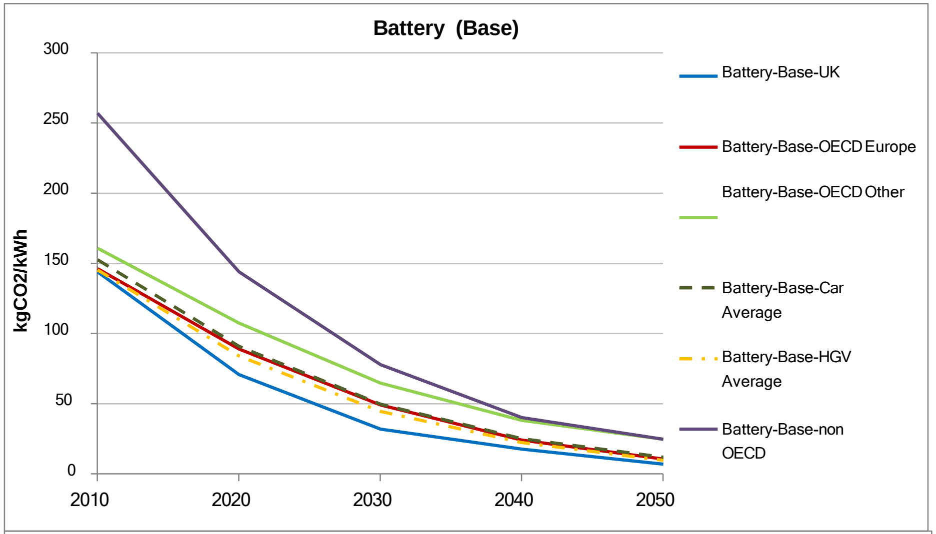
- ❑ Wide range of studies identified and preliminarily screened for suitability
- ❑ Studies selected to be taken forward for further analysis included some or all of the following elements:
  - ✓ Compared as many technologies as possible
  - ✓ Provided sufficient detail/ breakdown for the analysis
  - ✓ Provided additional information/detail on certain aspects (e.g. battery tech, refuelling infrastructure, etc)
- ❑ Other studies also used to provide/supplement key data

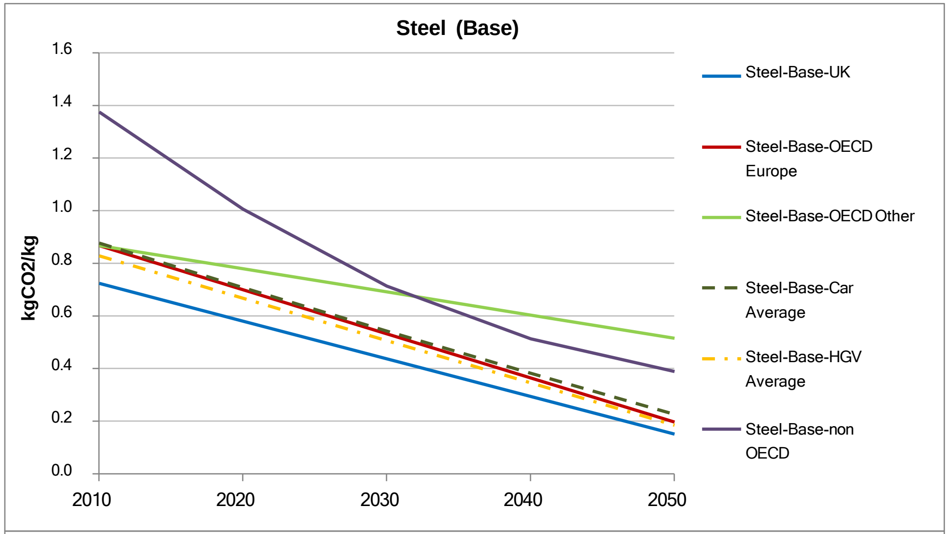
- ❑ Principal differences between values in the studies were largely due to a combination of the following factors / assumptions for the analysis:
  (i) lifetime km (= vehicle lifetime x annual km), ***(ii)*** vehicle size/specification,
  (iii) lifecycle stages covered, ***(iv)*** grid electricity GHG intensity,
  (v) batteries used (size in kg or kWh, assumptions on GHG intensity of manufacture)

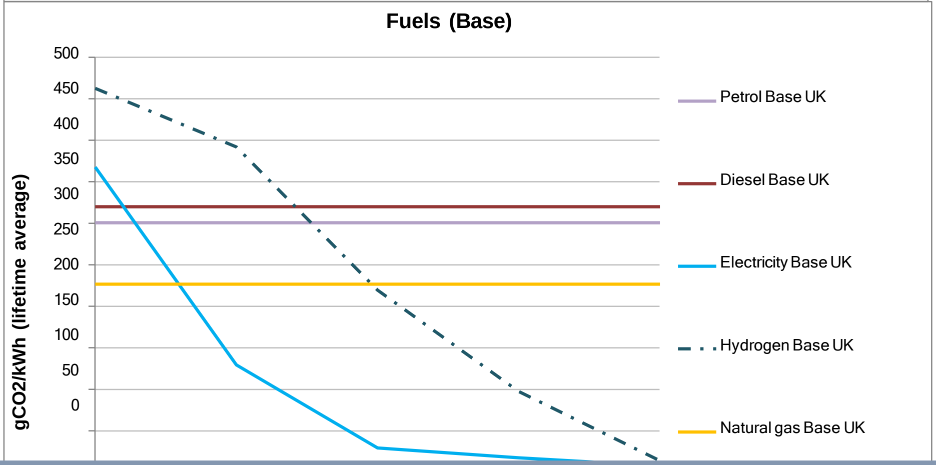
Energy and materials intensity trajectories, vehicle characteristics

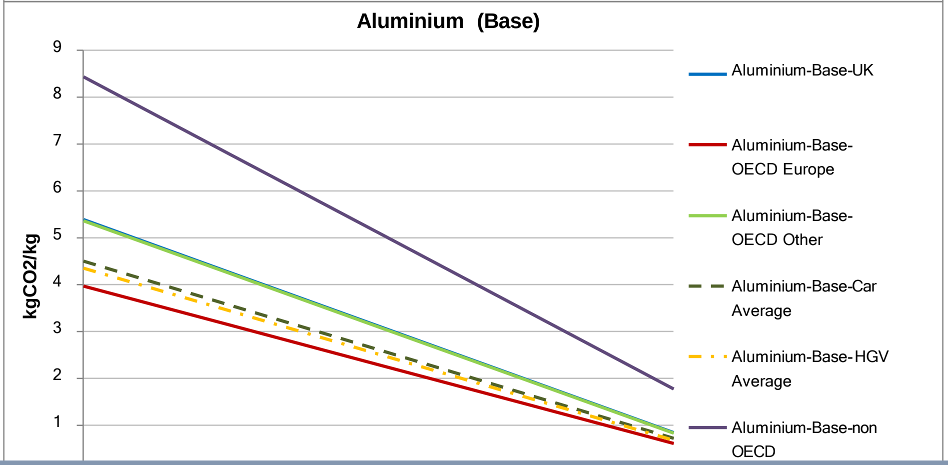
Base case scenario assumptions:

- Fuel factors are average over the operational lifetime for a vehicle in a given year
- Future vehicle performance/characteristics from CCC modelling and recent publications





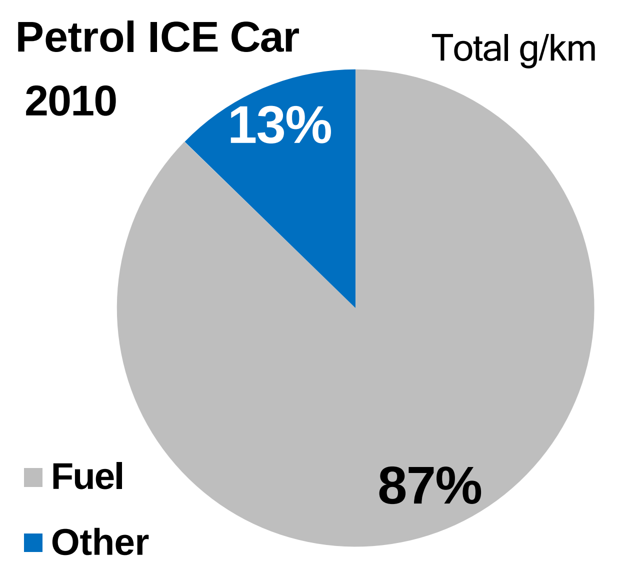


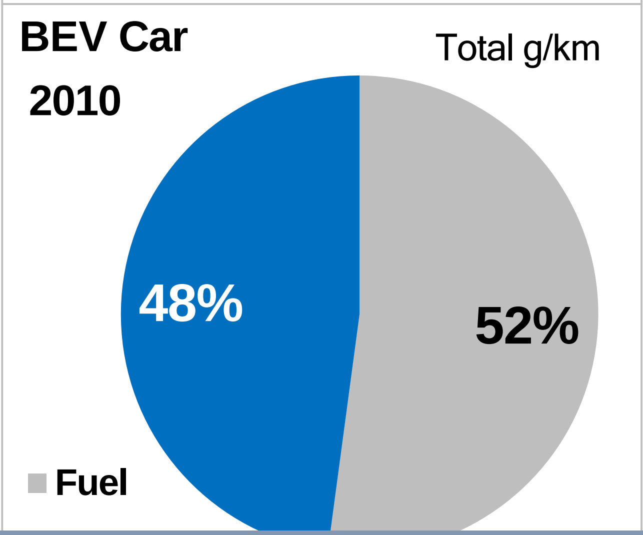


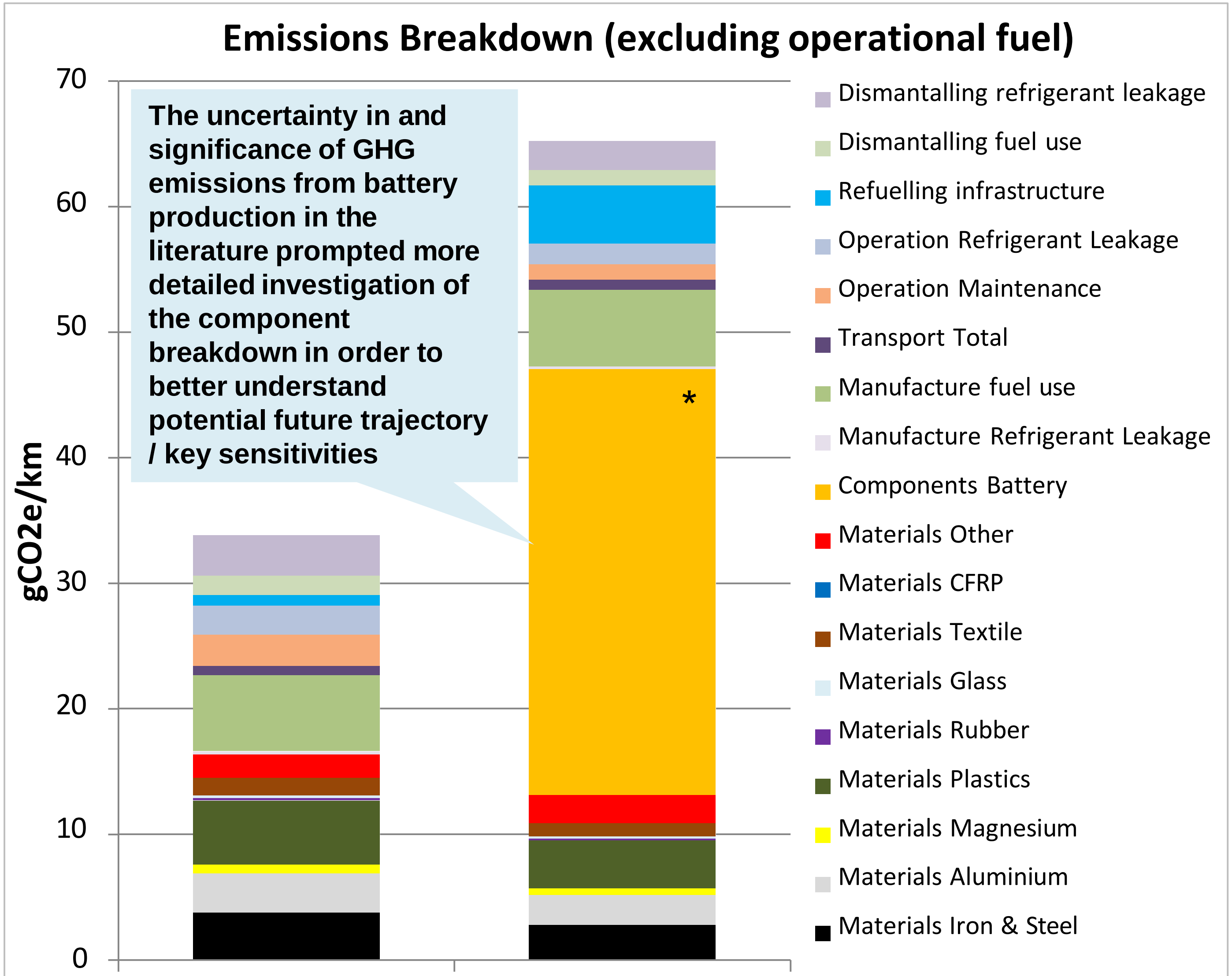
Breakdown of LCEs from the developed model:

Detailed split for 2010 Petrol ICE and BEV cars

* Battery production GHG intensity based on intermediate value in literature from Ricardo (2012)



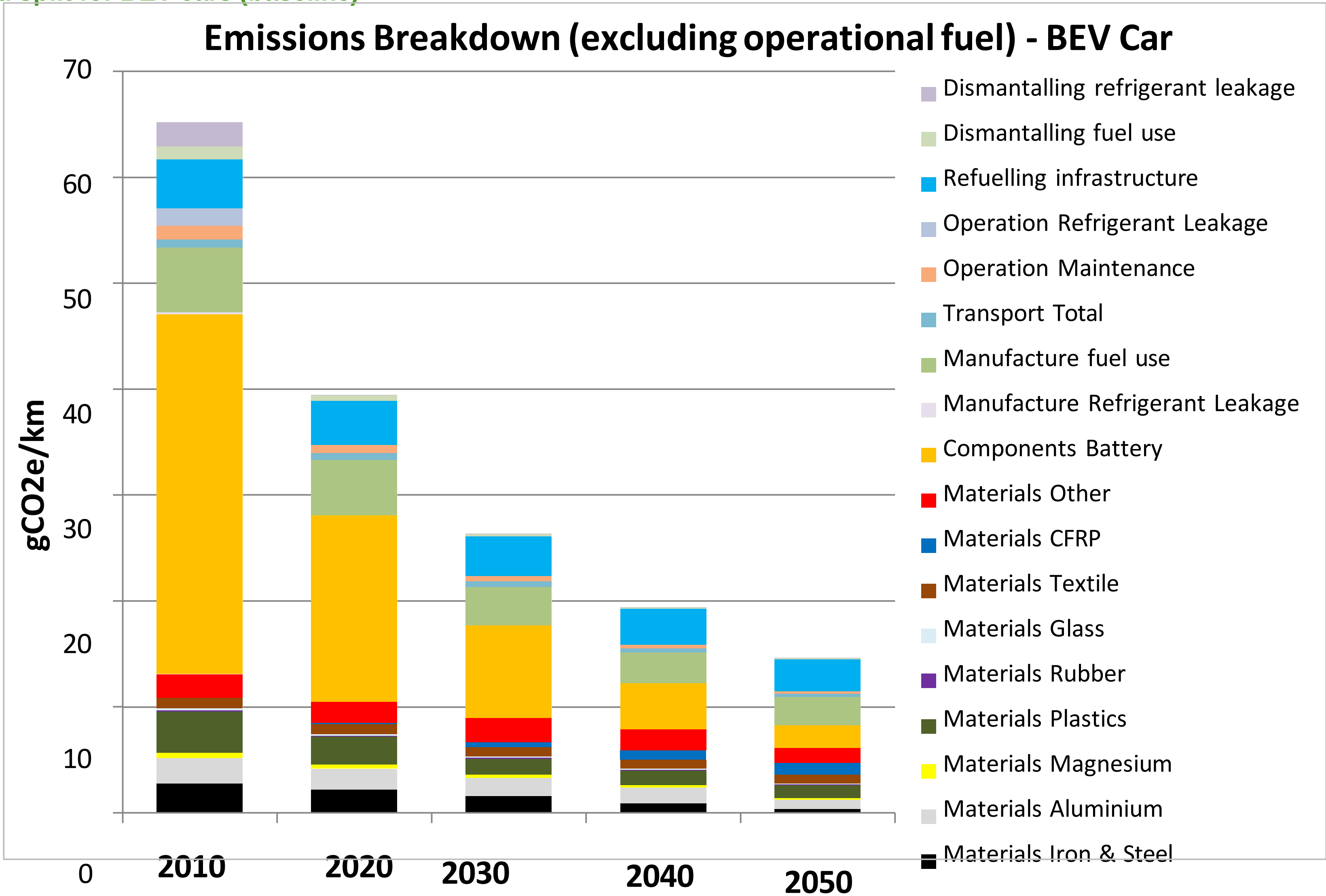




Breakdown of LCEs from the developed model:

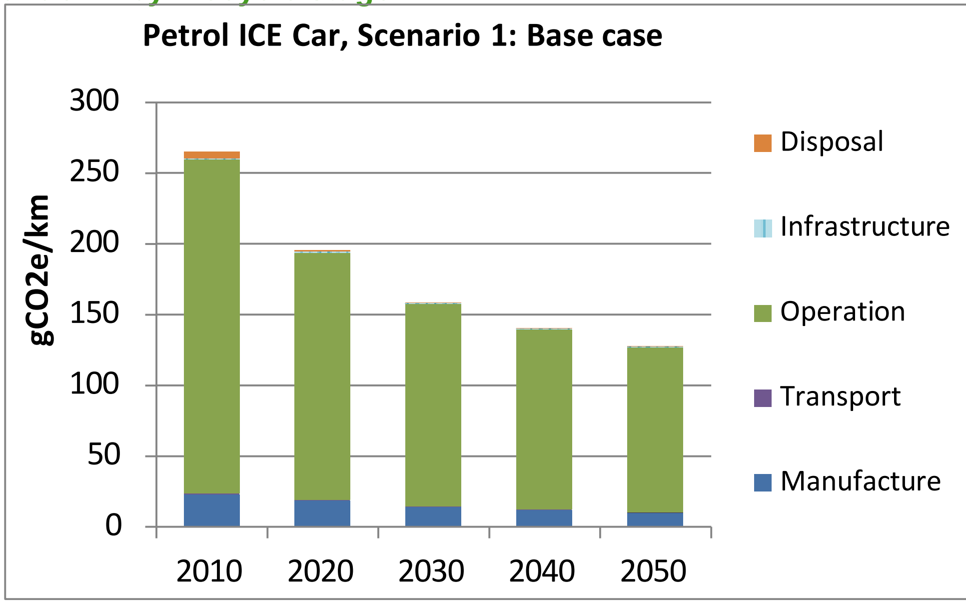
Future trajectory of detailed split for BEV cars (baseline)

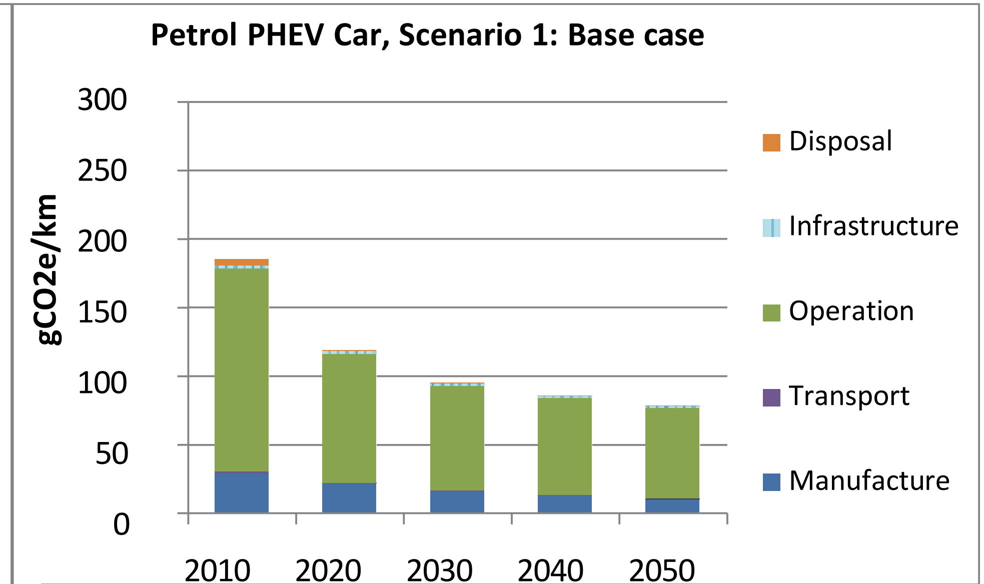
- Significance of batteries in overall LCE footprint of BEVs is anticipated to decrease significantly in the long term under the base case:
- Battery GHG reduction due to:
  - i. Reduced battery weight (/materials);
  - ii. Decarbonised manufacturing energy
  - iii. Improved recycling
  - iv. Reduced GHG intensity of materials used



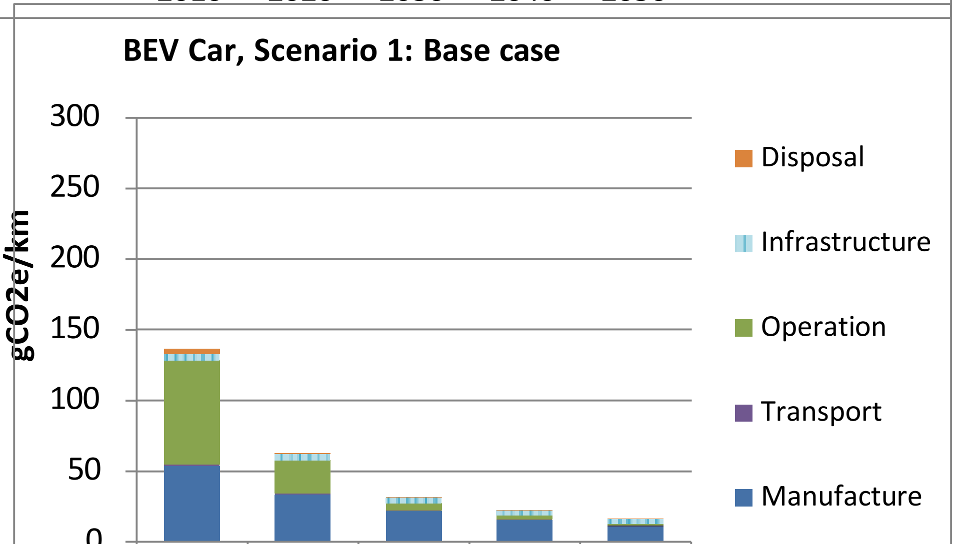
Base case scenario for cars:

Breakdown by lifecycle stage



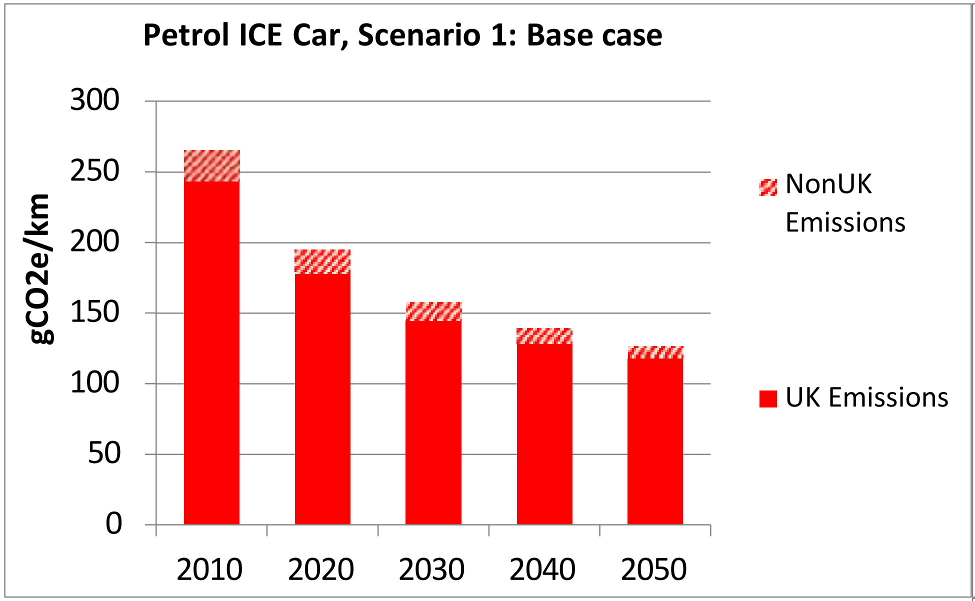


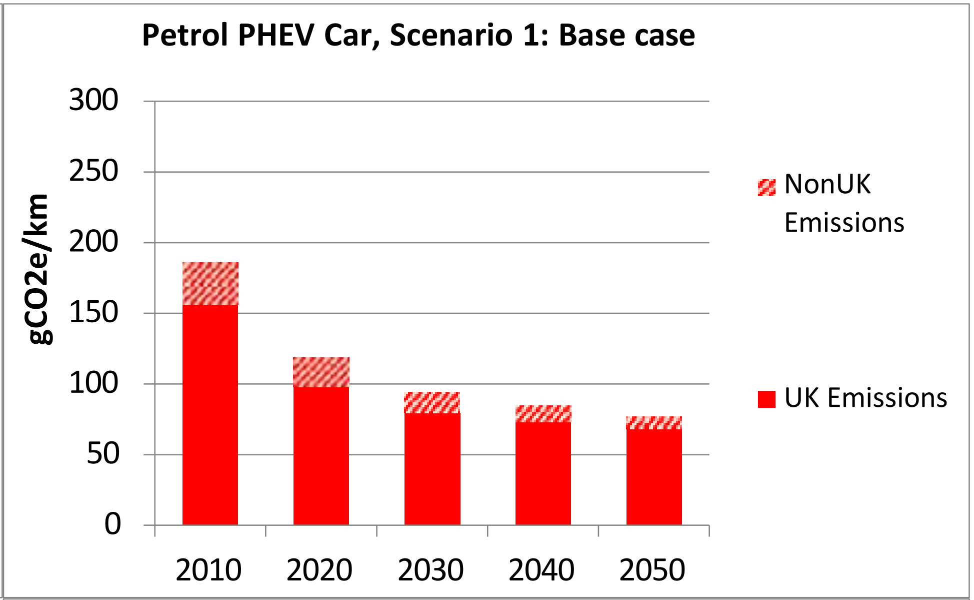
- 2010 petrol car = 159.5 gCO_2/km (test cycle)
- ICE > HEV > PHEV > REEV > BEV
- Manufacturing emissions share increases in future, particularly for BEVs
- Reduced savings from EVs (relative to ICE) - but total LCEs still much lower than for ICE
- Recharging infrastructure a small but still significant component (but more uncertainty)
- 5 gCO_2e/km due to refrigerants in 2010



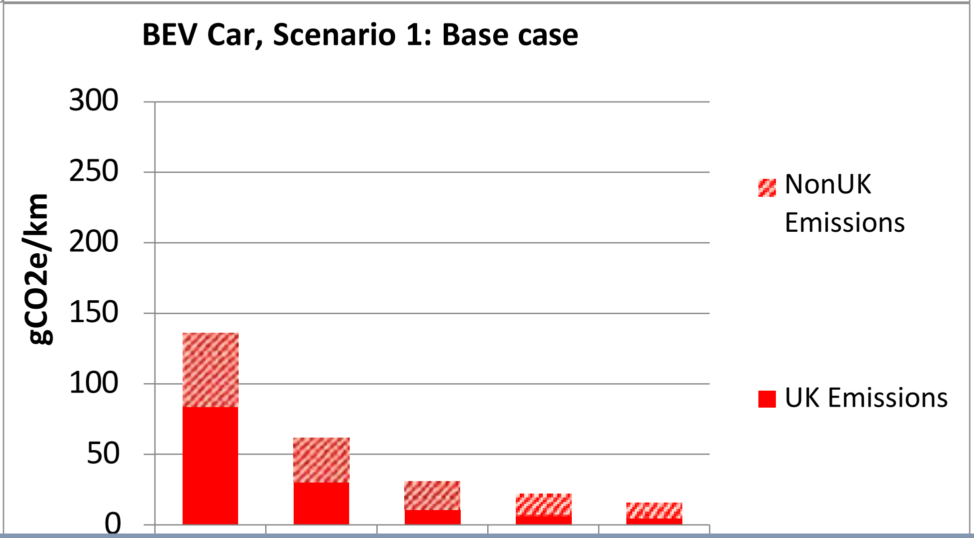
Base case scenario for cars:

Emissions in the UK vs overseas



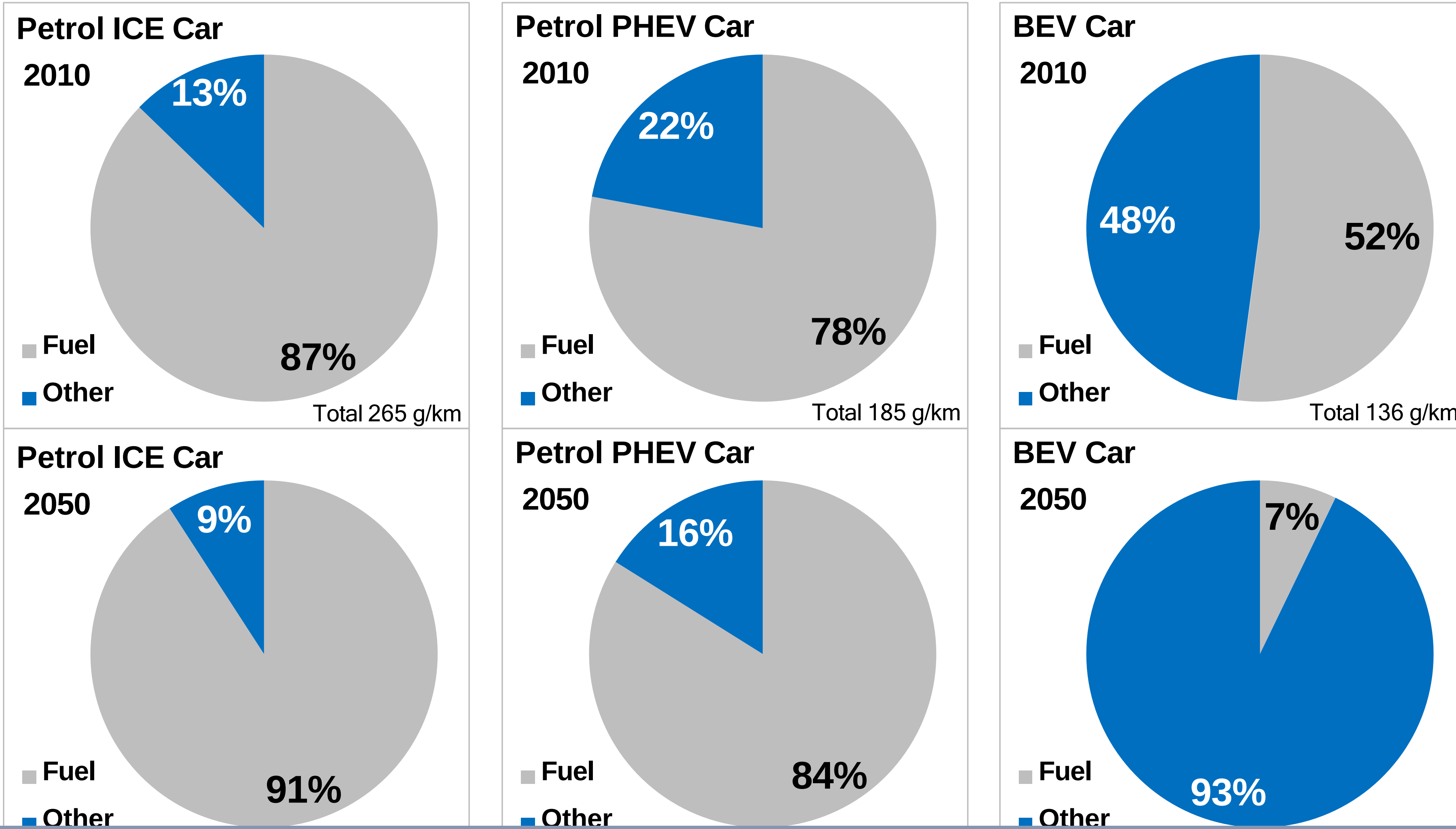


- Proportion of emissions outside UK doesn't change much over time for ICE (2010: ~8%) and PHEV (2010: ~16%) technologies
- >40% of BEV emissions are outside of the UK in 2010, potentially rising to 66% by 2050 (due to vehicle and battery production)
- In the Worst Case scenario (with very high emissions due mainly to the batteries) over 86% of BEV LCE could occur outside of the UK by 2050 (also due to reduction in



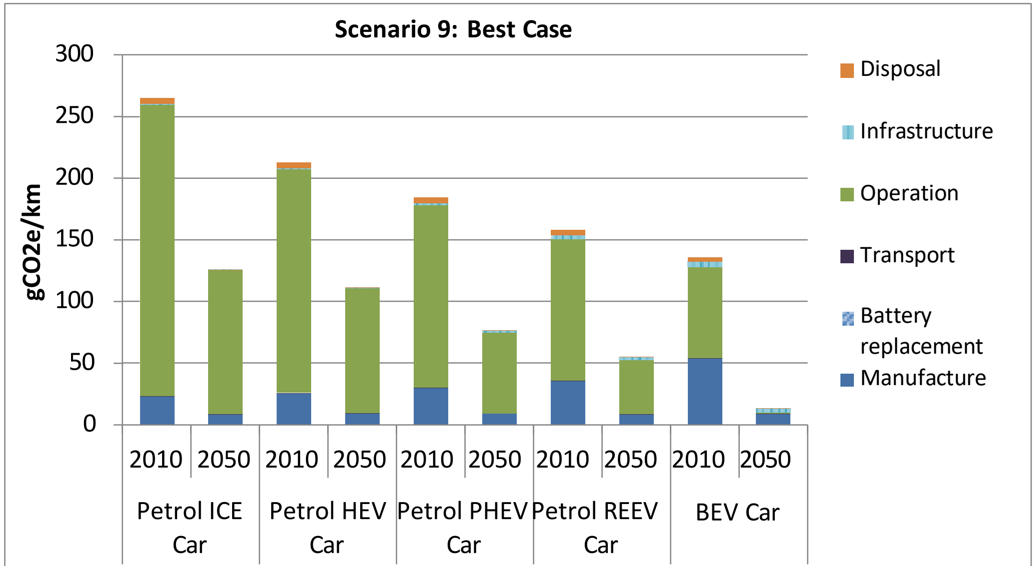
Base case scenario for cars:

Split of LCE for different powertrains for 2010 and 2050

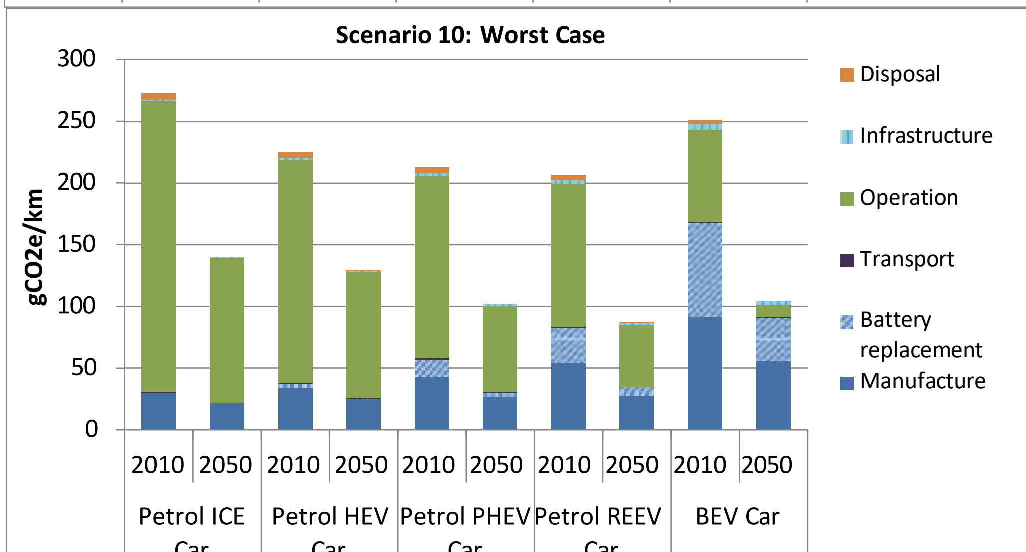


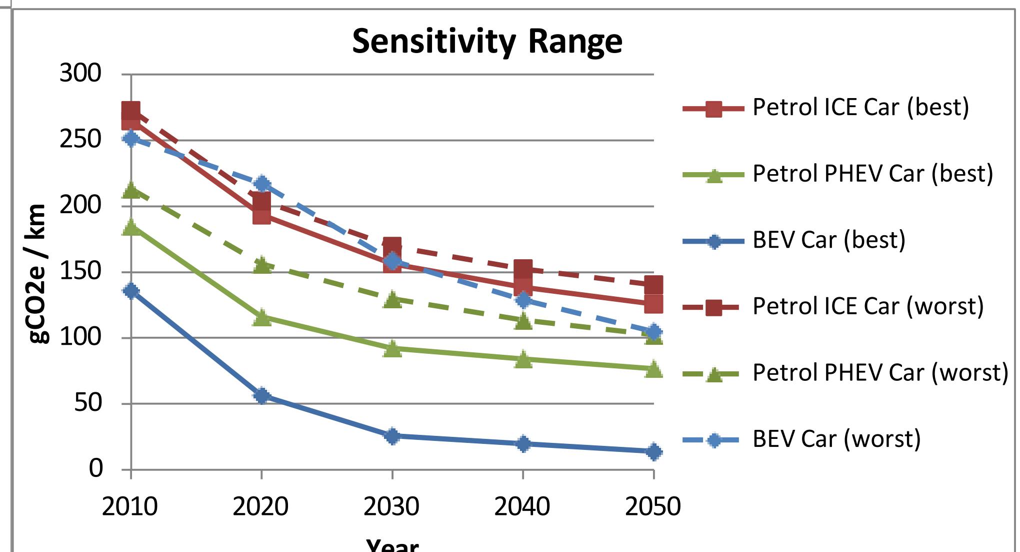
Sensitivity analysis for cars:

Best Case and Worst Case



- Battery developments are critical to achieve the maximum savings potential (2050:-90%)
- Worst case BEVs show only 26% reduction on base ICE in 2050 (at current biofuel levels). BUT battery replacement unlikely under current lifetime km assumptions versus current manufacturer warranties
- BEVs show 55% improvement over Petrol ICE in 2050 for more realistic alternate worst case + high lifetime km scenario (16,000 mi/yr = 57 g/km LCEs for BEVs)





Summary and Conclusions:

Part 1 –

Base scenario for 2010 shows that operational GHG emissions over lifetime of vehicle decrease in the following order ICE > equivalent HEV > PHEV > REEV > BEV

- Sensitivity analysis highlighted battery developments are critical to achieve the max. GHG savings for BEVs (and REEVs, PHEVs to a lesser extent):
  - Improvements in battery cycle/lifetime to minimise the likelihood of replacements
  - Improvements in battery energy density to reduce material use
  - Improvements in recycling practices to generate savings through recovered materials
  - Regional (UK/European) battery production to minimise GHG
  - Improvements in battery manufacture GHG intensity (i.e. production energy and materials)
- BUT in worst case scenario with high lifetime km (+one battery replacement), BEVs still have ~55% reduction on equivalent ICE by 2050 (at current UK average biofuel levels)
- Future NonUK emissions share unlikely to increase much for ICE (~9%) and PHEV (~18%), but could increase significantly for BEV (currently 41%, potentially rising to 66% by 2050). (Primarily from significant reduction in operational, other UK elements)
- Recharging infrastructure more uncertain; a small but likely still significant component (>3% for BEVs in 2010), but could be potentially more significant in the longer term.

Summary and Conclusions:

Part 2 – Potential implications for policy and businesses

- Publication of industry LCA studies would help facilitate understanding

  ⇒ Ideally need to track vehicle LCA in a more consistent basis before could even think about whether/how a regulatory approach might be adopted (or not)

- Future vehicle CO_2 regulations should likely at least factor in WTW emissions

- Recommendations from Ricardo (2011) report for LowCVP are still relevant:
  - Consider a new CO_2 metric based on the GHG emissions emitted during vehicle production [tCO2e] *(and more tightly define scope/specification for this)*
  - Consider targets aimed at reducing the life cycle CO2 [tCO2e]
  - Consider the fiscal and regulatory framework in which vehicles are sold, used and disposed

- Need to develop a better understanding of battery production emissions and impacts of technology development and ensure future developments do significantly reduce battery production/disposal emissions

- Further research is also needed to quantify the relative impacts of different infrastructure types/mixes, and the likely 2050 requirements