Life-Cycle Assessment for Hybrid and Electric Vehicles

"Beyond the Tailpipe" LowCVP Annual Conference 2013

Nikolas Hill
Knowledge Leader – Transport Technology and Fuels
Ricardo-AEA

11th July 2013

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Overview

- Life-Cycle Assessment in the automotive sector and significance for hybrid and electric vehicles
- Project for CCC on LCE (life cycle emissions) for future low carbon technologies:
  - Scope and objectives
  - Lifecycle stages and range of values in the literature
  - Baseline assumptions for future LCE calculation tool
  - Key results from the analysis
  - Summary and conclusions
- Overall potential implications for policy and businesses

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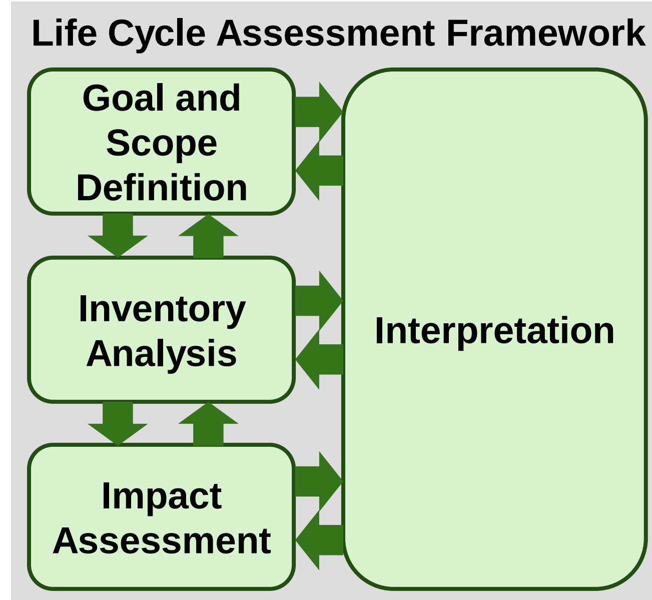
LCA Methodologies

Part 1: Use of LCA in the automotive sector

- Current tailpipe CO_2 metric insufficient to compare impacts of hybrid and electric vehicles due to upstream fuel/vehicle production GHG
- ⇒ Life Cycle Assessment (LCA) is key for future vehicle technology and fuel comparisons
- Well-to-wheel (WTW) is the specific LCA used for transport fuel/vehicle systems (but limited to the fuel itself) – used for biofuels in particular



- LCA ISO (14040/14044) standards only provide general guidelines ⇒ different models, methodologies and assumptions are often used
- Many OEMs conduct ISO compliant/high quality LCA studies of their vehicles as part of their Environmental Management strategies
- Several OEMs publish the results from their LCA, but it is not clear if different OEMs use the same set of assumptions or input data sets

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)

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- Previous CCC advice include 'low-carbon' technologies which reduce emissions at point-of-use relative to counterfactual
- Ricardo-AEA undertook an analysis considering lifecycle emissions (LCEs) for various technologies in several sectors, going beyond the point-of-use to provide estimates from the current situation out to 2050
- NOT a detailed LCA: objective was to provide estimates (from existing studies) of current LCEs for UK circumstances and project to 2050
- Current LCEs are broken down into relevant categories to allow:
  a) Investigation of the influence of key geographical parameters on overall emissions
  b) Separation of these emissions into UK and non-UK emissions
  c) Exploration of sensitivities for key components and scenarios on how these emissions might be reduced
- Work involved a literature review and development of spread sheet calculation tools for the different technology areas
- Future impacts of biofuel use excluded from analysis (set at 2012 mix)

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The road vehicle lifecycle

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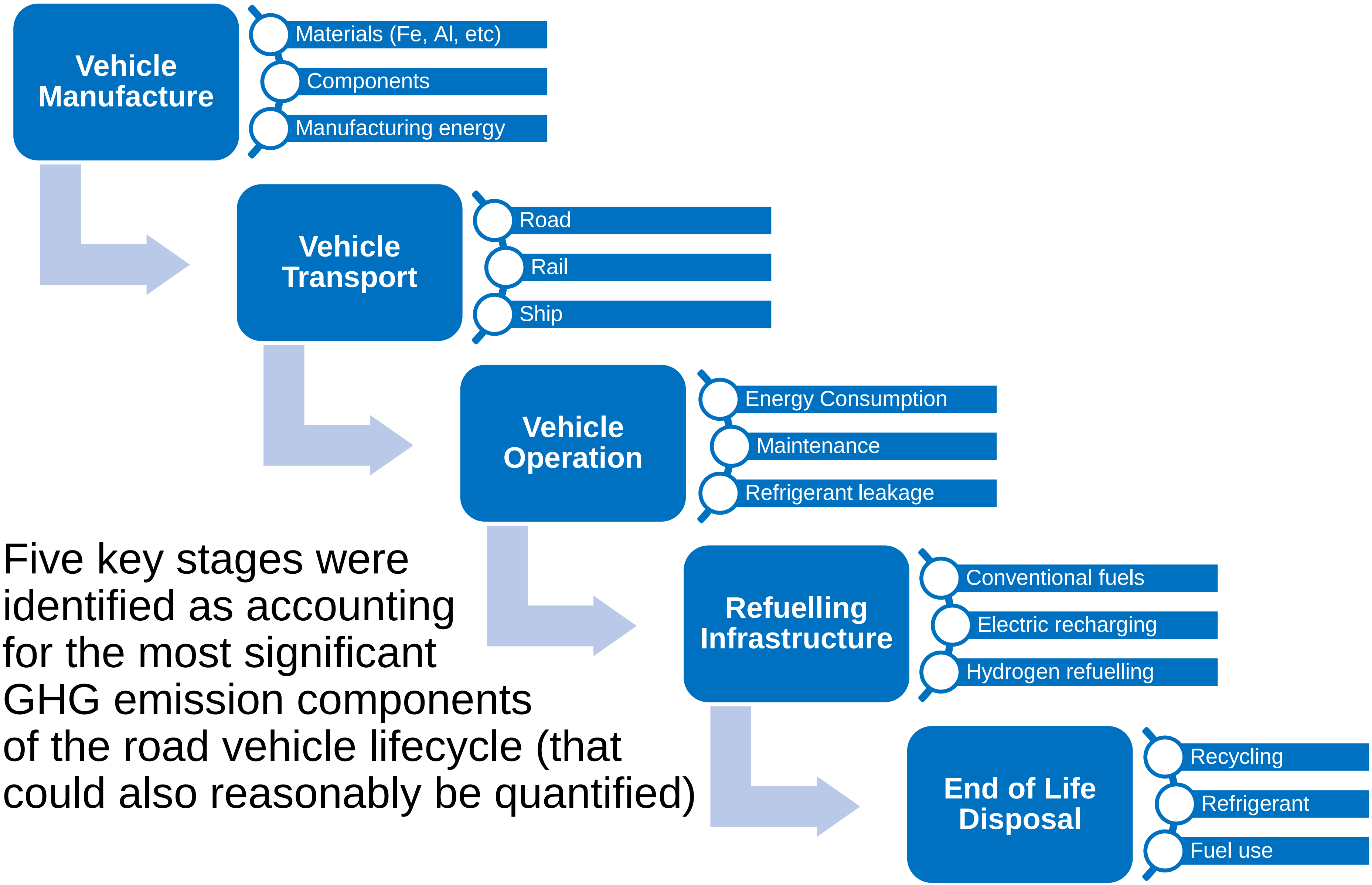

- Five key stages were identified as accounting for the most significant GHG emission components of the road vehicle lifecycle (that could also reasonably be quantified)

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Range of overall LCEs in the literature
Road transport technologies

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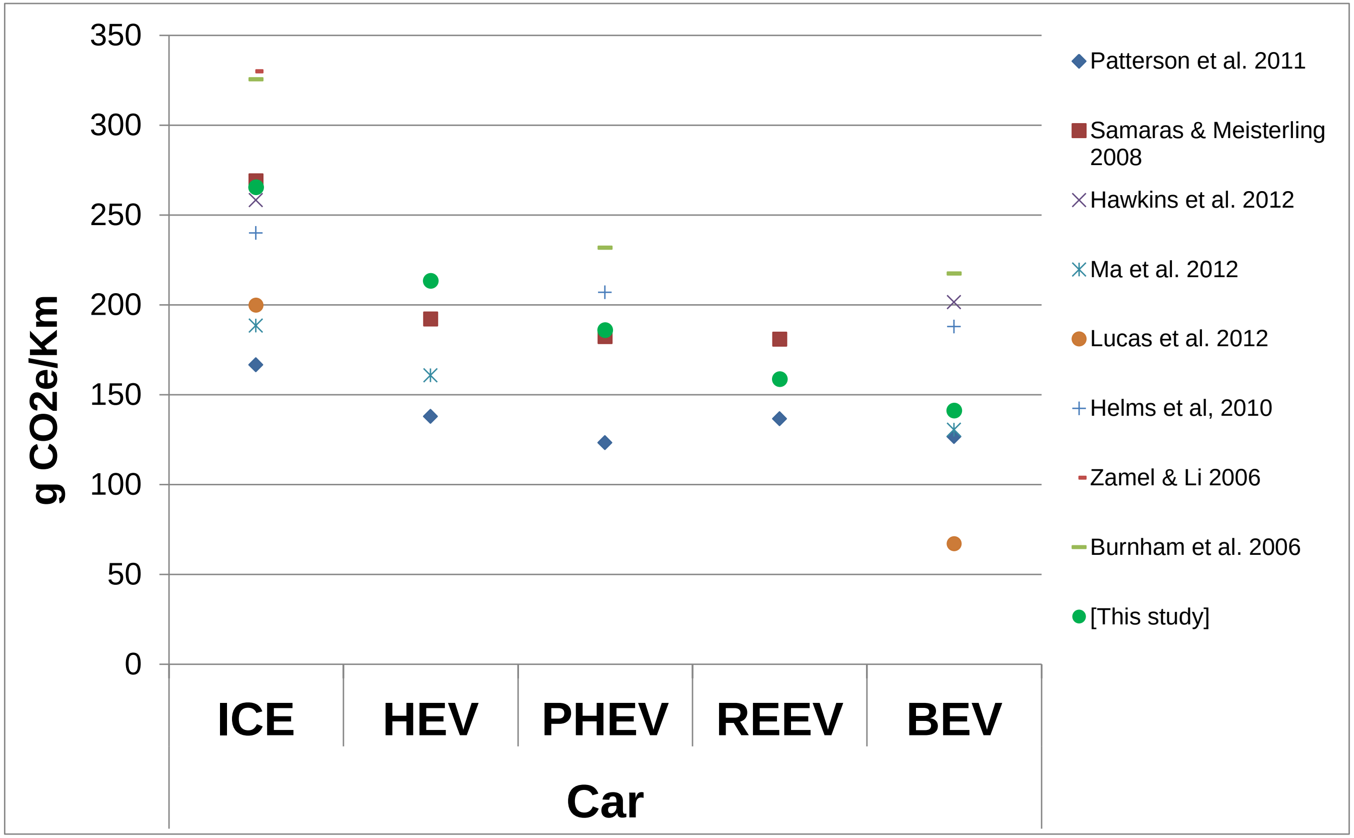

- Wide range of studies identified and preliminarily screened for suitability
- Studies selected to be taken forward for further analysis included some or all of the following elements:
  - ✓ Compared as many technologies as possible
  - ✓ Provided sufficient detail/ breakdown for the analysis
  - ✓ 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)

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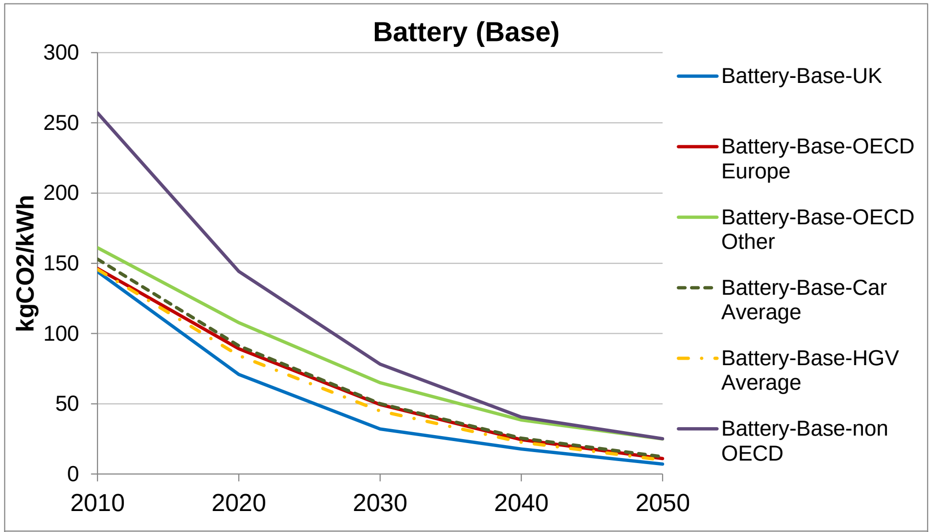
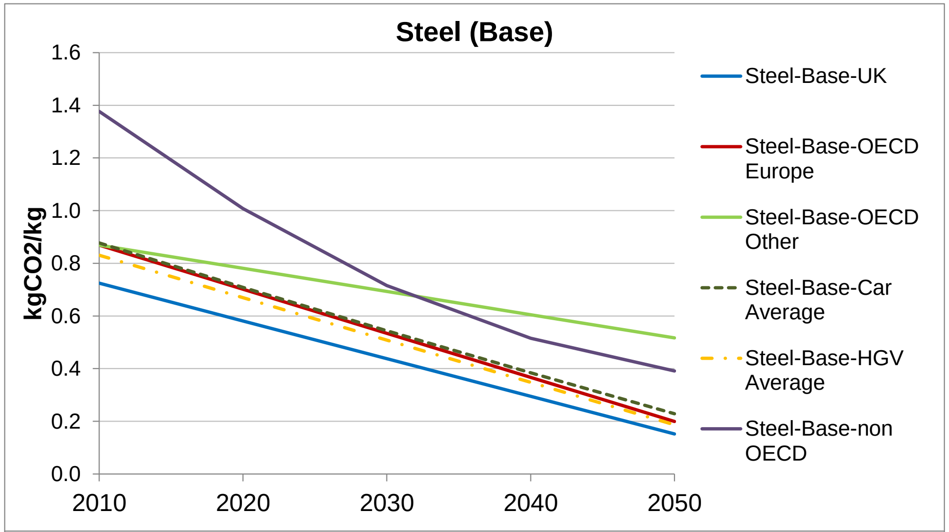
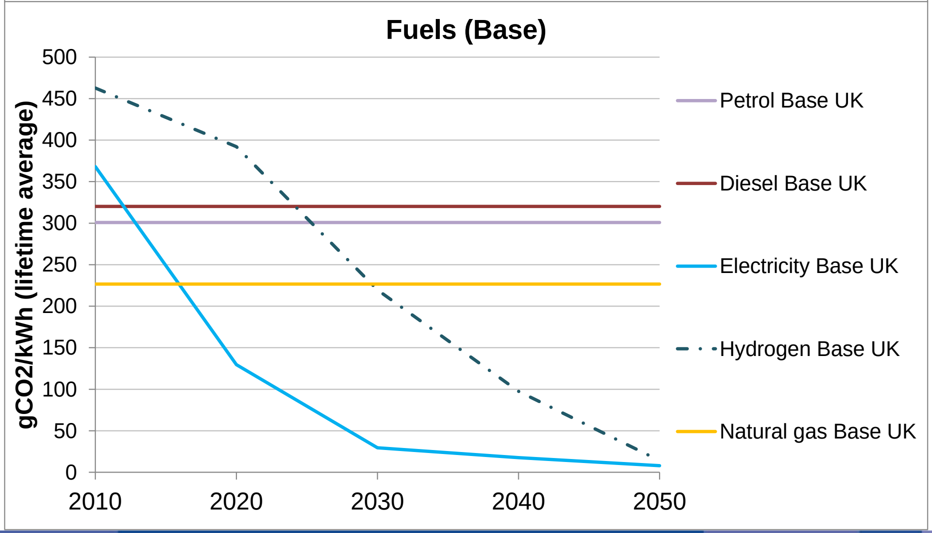
Base case scenario assumptions:

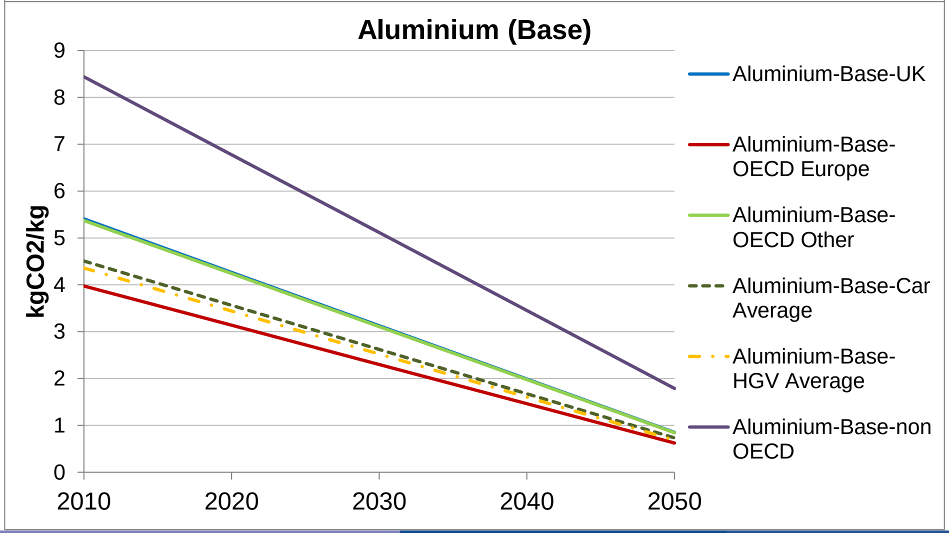
Energy and materials intensity trajectories, vehicle characteristics

- 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









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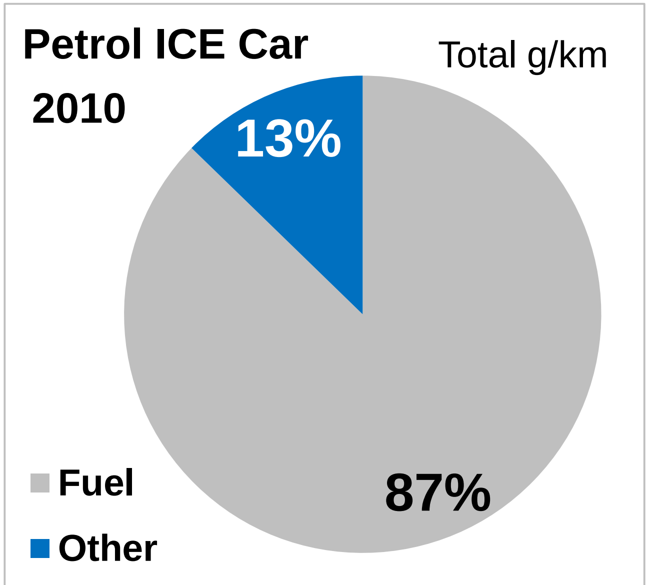
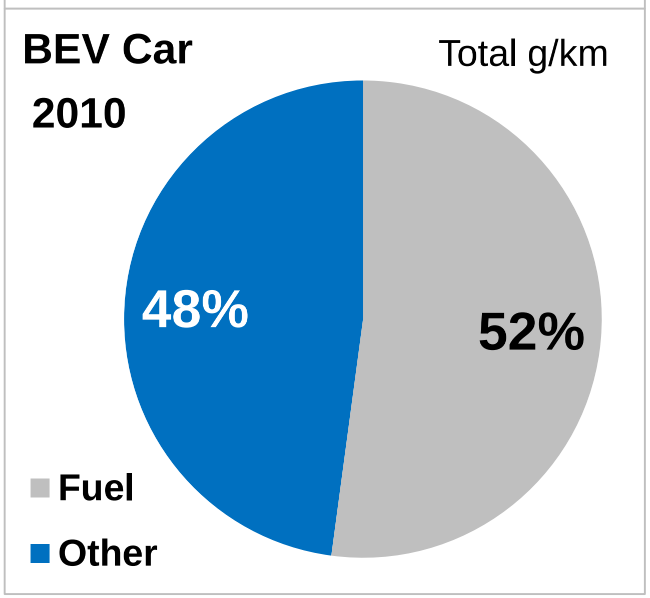
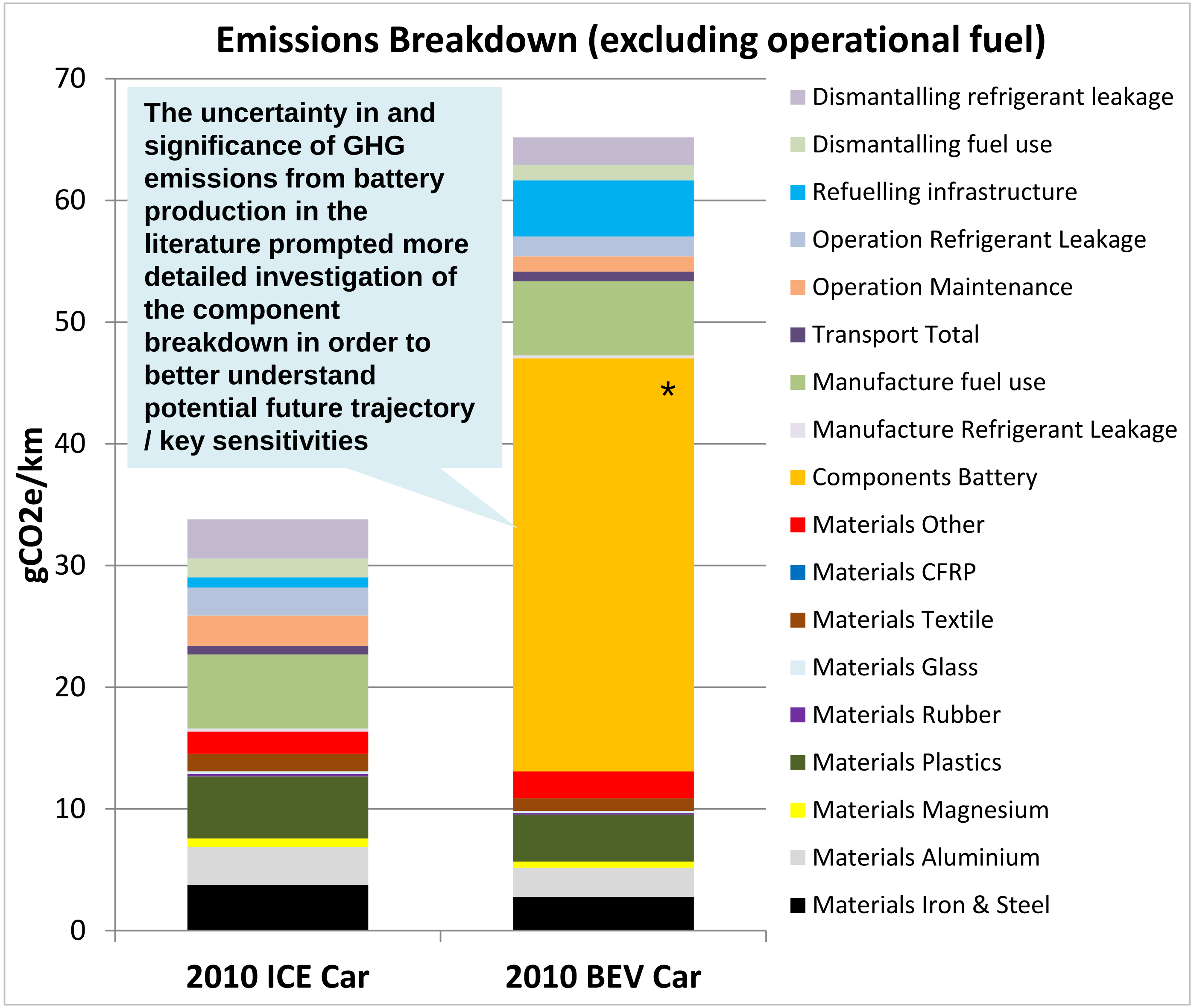
Breakdown of LCEs from the developed model:

Detailed split for 2010 Petrol ICE and BEV cars

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







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Breakdown of LCEs from the developed model:

Future trajectory of detailed split for BEV cars (baseline)

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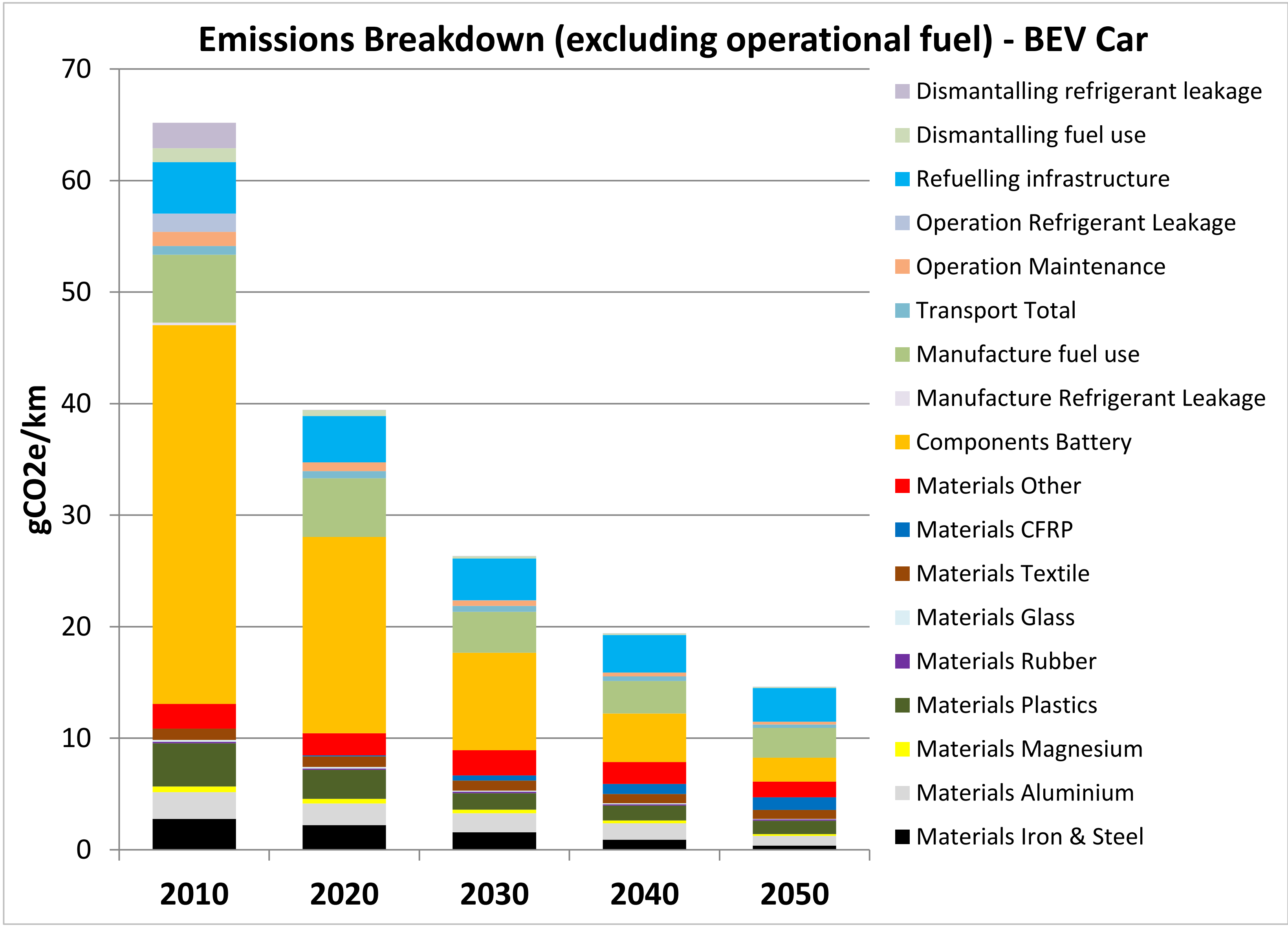
- Significance of batteries in overall LCE footprint of BEVs is anticipated to decrease significantly in the long term under the base case:
- Battery GHG reduction due to:
  - i. Reduced battery weight (/materials);
  - ii. Decarbonised manufacturing energy
  - iii. Improved recycling
  - iv. Reduced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



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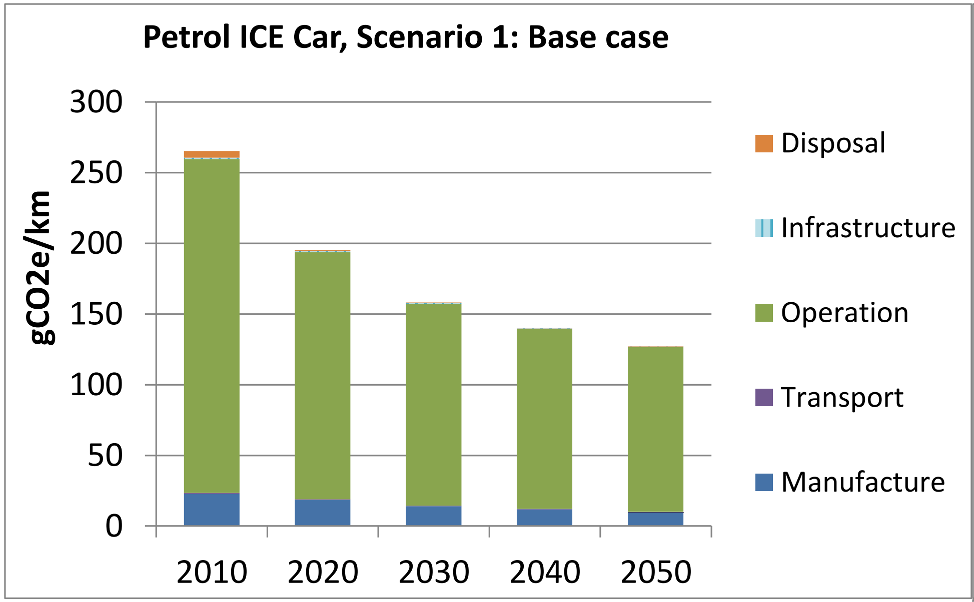
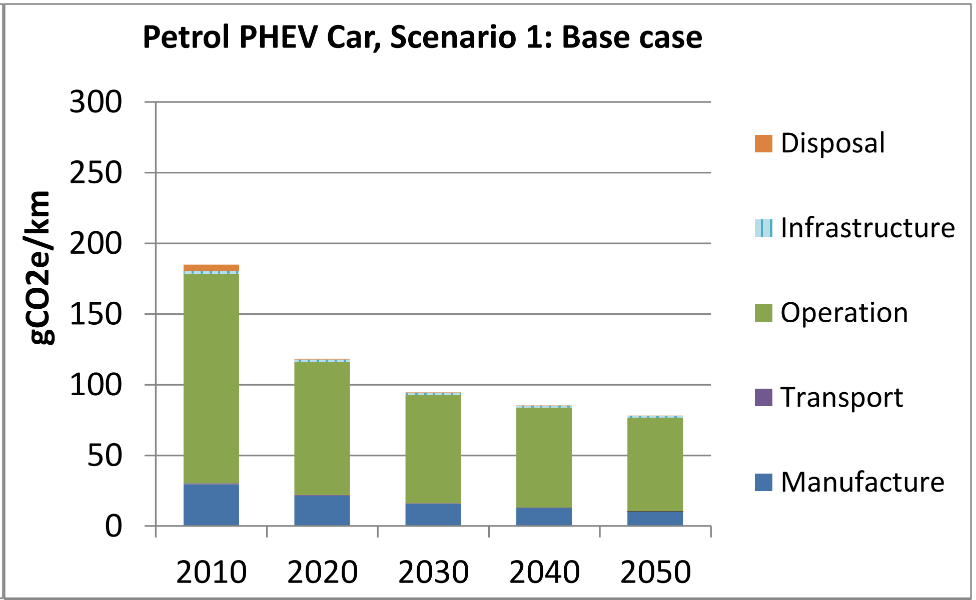
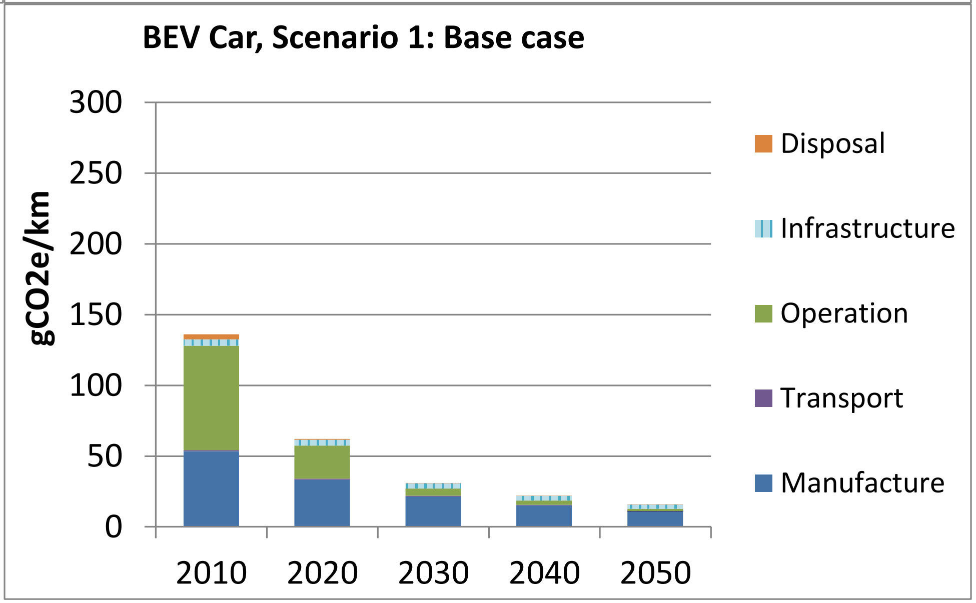
Base case scenario for cars:
Breakdown by lifecycle stage





- 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



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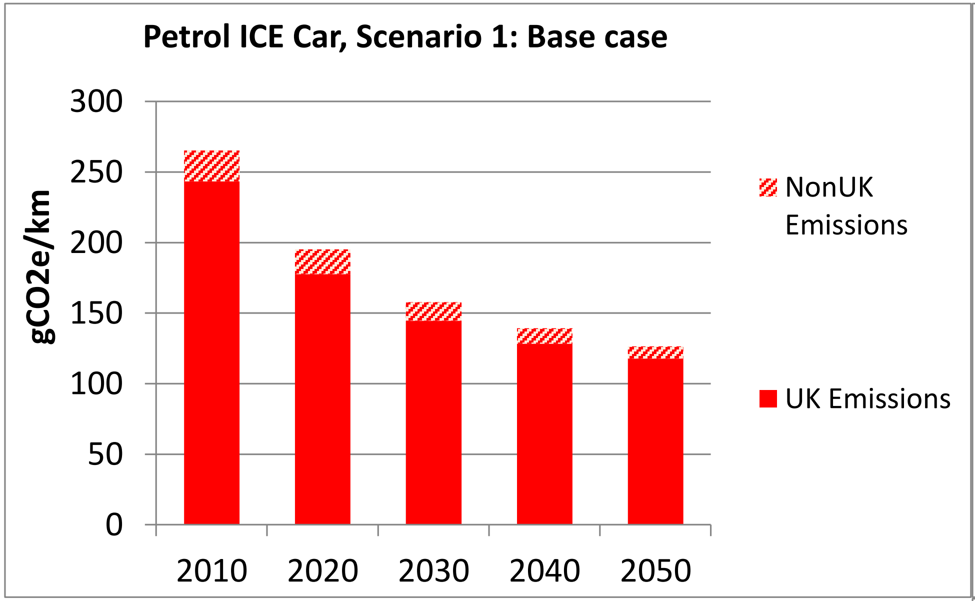
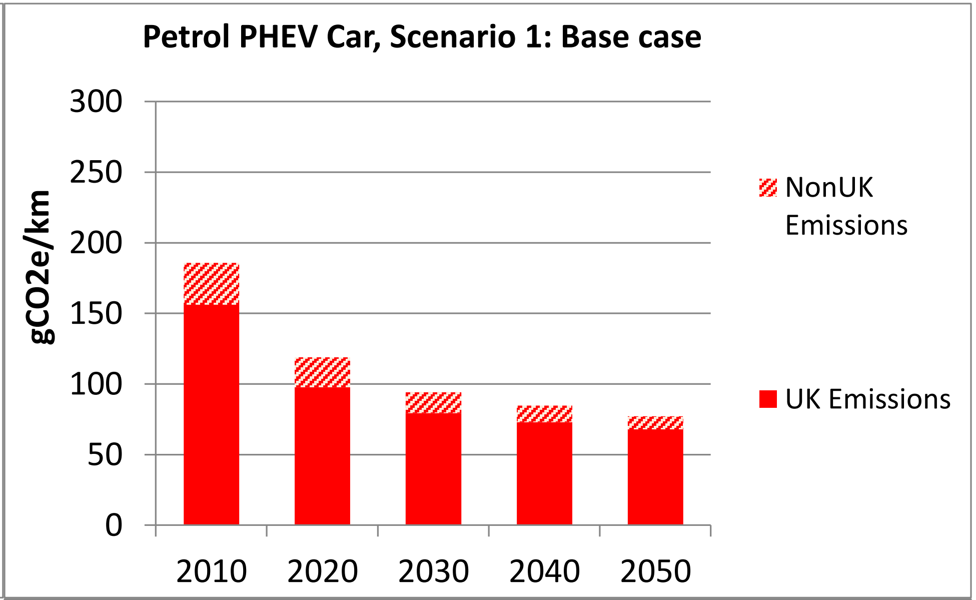
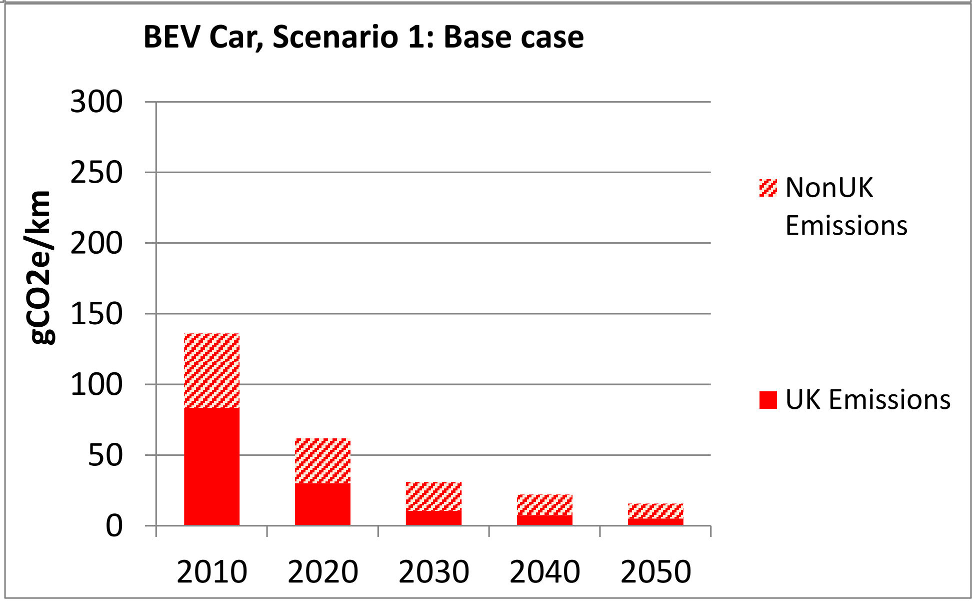
Base case scenario for cars:
Emissions in the UK vs overseas





- 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 operational LCE)



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Base case scenario for cars:

Split of LCE for different powertrains for 2010 and 2050

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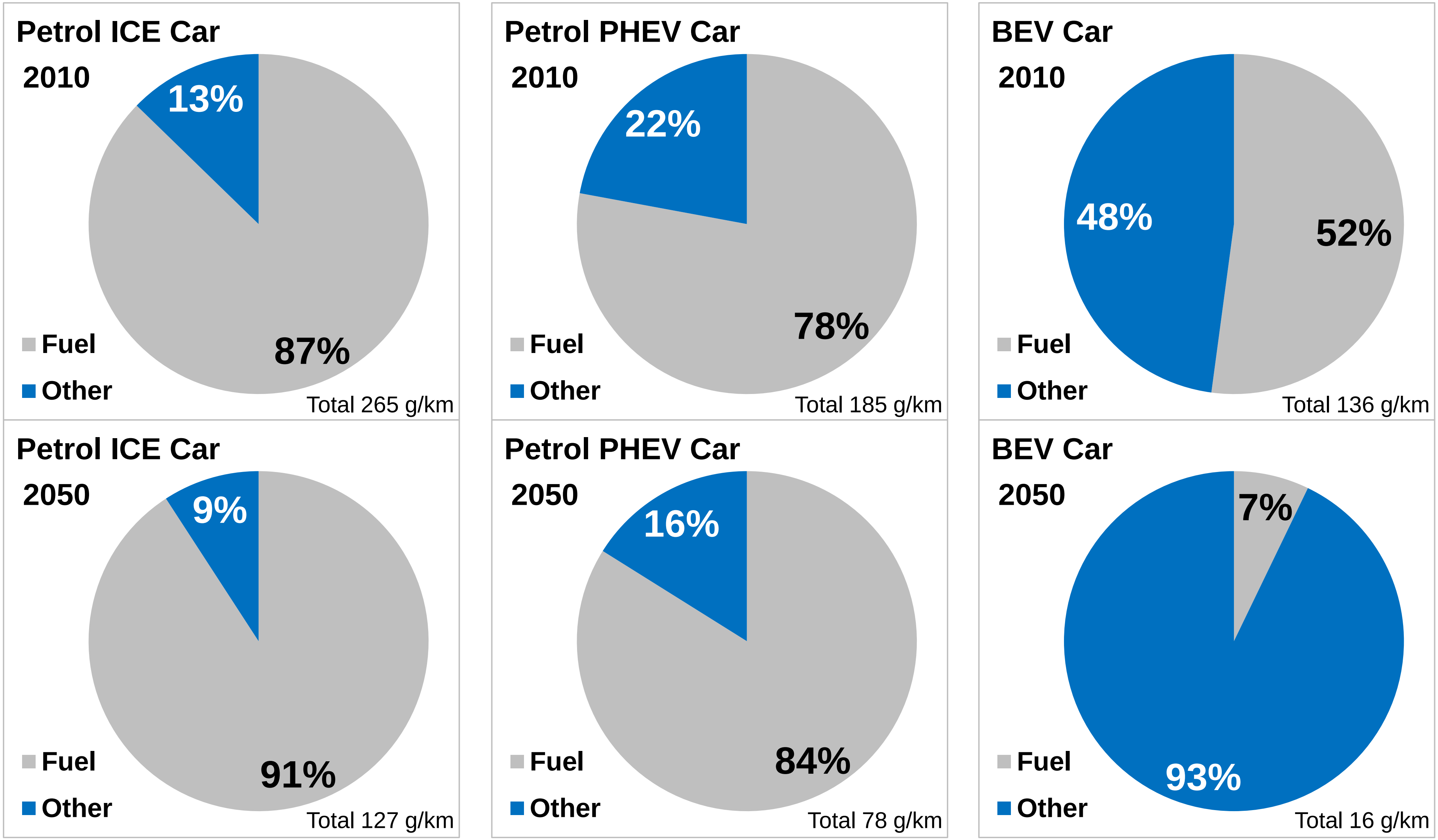

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Sensitivity analysis for cars:
Best Case and Worst Case

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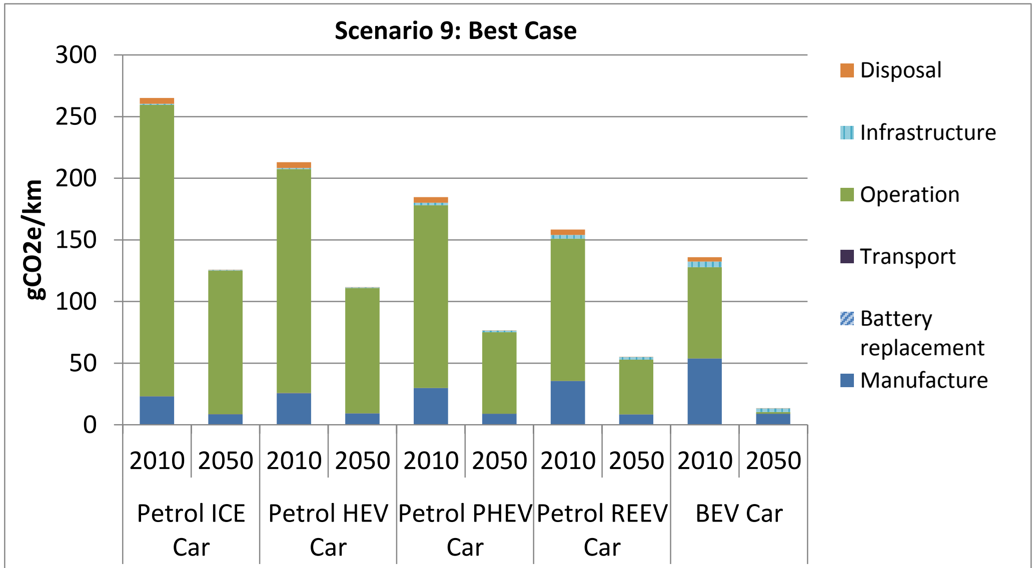
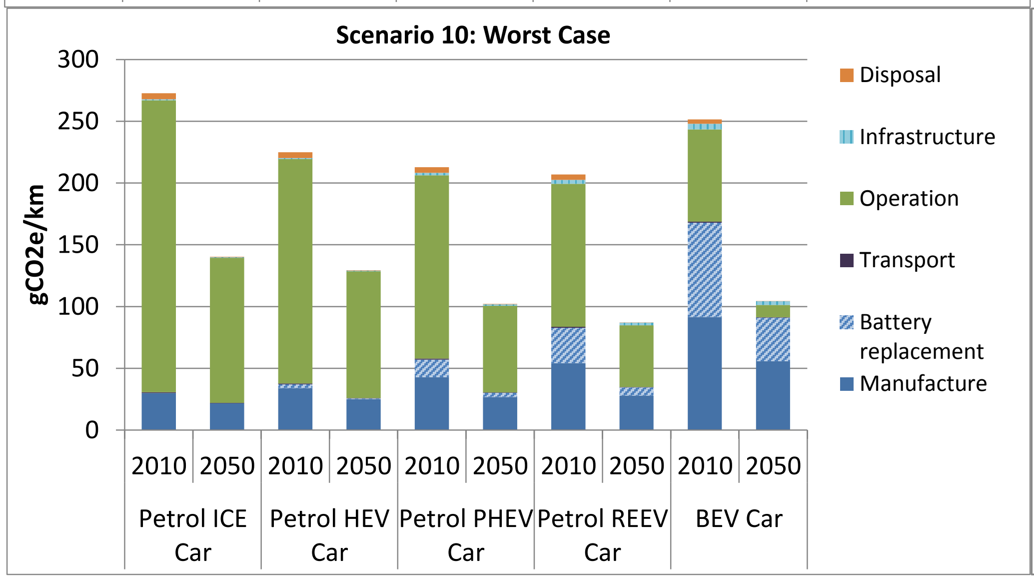
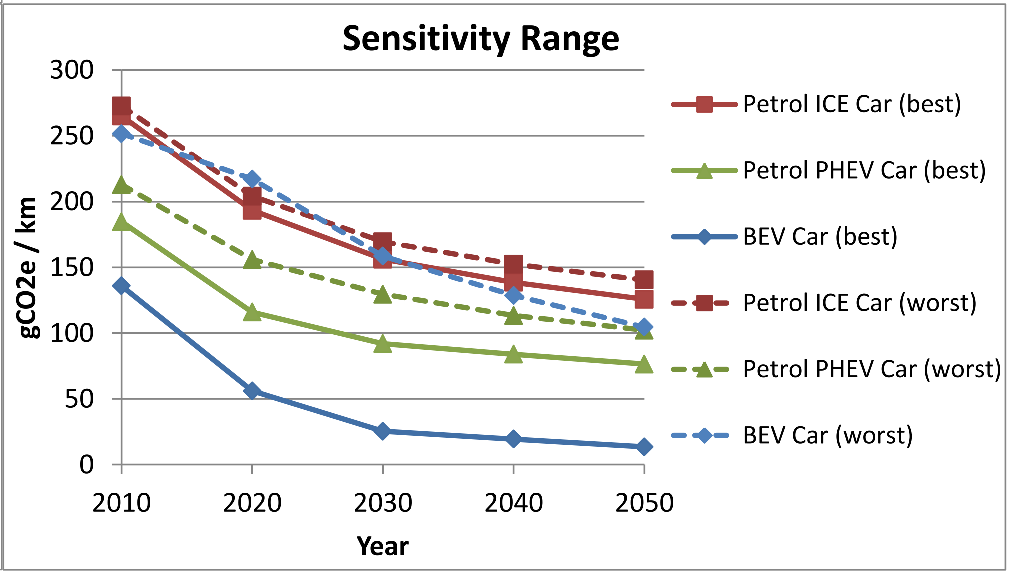


- Battery developments are critical to achieve the maximum savings potential (2050:-90%)
- Worst case BEVs show only 26% reduction on base ICE in 2050 (at current biofuel levels). BUT battery replacement unlikely under current lifetime km assumptions versus current manufacturer warranties
- BEVs show 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)





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Summary and Conclusions:
Part 1 – From Ricardo-AEA study for CCC

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- 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.

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Summary and Conclusions:
Part 2 – Potential implications for policy and businesses

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- 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

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Further information

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For further information see full study report available from CCC's website at:

http://www.theccc.org.uk/wp-content/uploads/2013/04/Ricardo-AEA-lifecycle-emissions-low-carbon-technologies-April-2013.pdf

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Nikolas Hill
Knowledge Leader – Transport Technology and Fuels

Ricardo-AEA Ltd
Gemini Building,
Fermi Avenue,
Harwell, Didcot,
Oxfordshire,
OX11 0QR,

T: +44 (0)1235 753522
E: nikolas.hill@ricardo-aea.com
W: www.ricardo-aea.com

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