A probabilistic life cycle assessment comparing greenhouse gas emissions from electric and fossil-fuelled vehicles in Australia

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1. Introduction

All Australian and New Zealand jurisdictions have set net zero greenhouse gas (GHG) emission targets by 2045/2050.

However, the Paris agreement has made clear that in order to limit the rise in global temperatures below 1.5 °C and reduce the risk of disastrous runaway climate change, the world needs to achieve at least a 50 percent GHG emission reduction by 2030, which is less than ten years away.

Road transport makes up a substantial and growing contribution to total national GHG emissions. Australia has experienced a sustained increase in total GHG emissions from road transport, as well as an increase in average real-world GHG emissions per kilometre for new passenger vehicles since 2015, mainly due to increasingly bigger and heavier passenger vehicles (TER, 2019). In addition, new Australian passenger vehicles are under-performing in relation to CO_2 emissions (and fuel economy) when compared to the USA, EU and Japan.

Battery electric vehicles (BEVs) are internationally regarded as the best solution to rapidly reduce GHG emissions from road transport. But does this hold true for the Australian on-road fleet with its own unique characteristics?

Keywords: LCA, GHG emissions, Uncertainty.

2. METHOD

TER conducted a probabilistic life cycle assessment (LCA) into fleet average greenhouse gas emission rates from both conventional fossil-fuelled (petrol, diesel, LPG, CNG) passenger vehicles (internal combustion engine vehicles or ICEVs) and BEVs in Australia, including all aspects of a vehicle's life ('cradle to grave'), i.e. vehicle production, fuel/electricity production, infrastructure, grid and charging losses, on-road usage and vehicle disposal/scrappage.

Given the complexity, localised and dynamic nature of vehicle life cycle impacts, it is important that the uncertainty in LCA results is quantified. However, the majority of international LCA studies use deterministic approaches.

This study used a probabilistic LCA approach to explicitly account for uncertainty. This is useful to determine the robustness of study outcomes and to identify which aspects of the LCA are most uncertain and warrant further targeted examination.

Figure 1 shows an overview of the various sources of information used in this study. They are discussed in detail in the full report, which can be downloaded from: https://www.transport-e-research.com/publications.

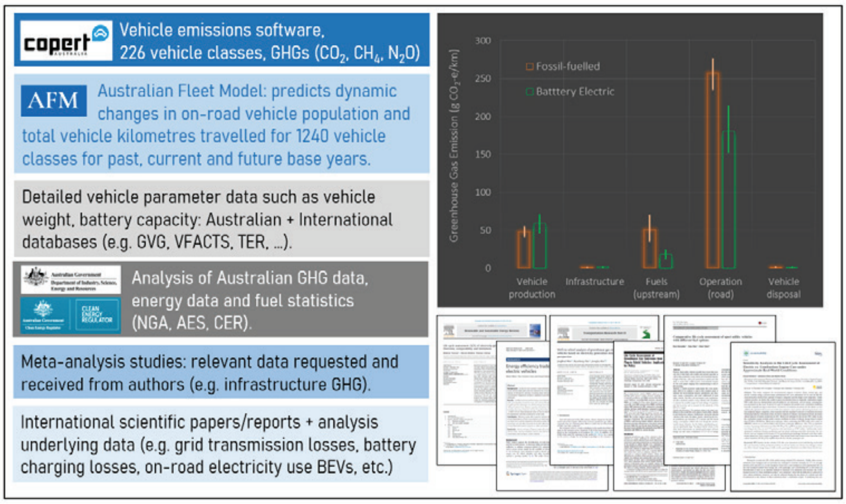
The life cycle GHG emission factors were computed with two additive models and sub-models. The study only accepted real-world emissions and energy use data.

A probabilistic analysis using uncertainty input distributions and Monte Carlo simulation was conducted to estimate the life cycle GHG emission factor probability distributions for ICEVs and BEVs. GHG emissions are normalised for distance (grams/km) for all LCA aspects to allow for comparison.

3. RESULTS

Table 1 shows life cycle specific GHG emission factors (g/km) for all LCA aspects and the two vehicle types. This table is useful to assess the relevance of different LCA aspects.

For instance, operational GHG emissions ('driving on the road') dominate total GHG emission factors for both ICEVs and BEVs (about 70 percent of total GHG emissions per kilometre). 'Infrastructure'[1] and 'vehicle disposal' (scrappage) are estimated to have a very small and negligible contribution to total GHG emission factors (< 1 percent BEV production (manufacturing) generates 25 percent higher GHG emissions per km then ICEV production. However, this is more than compensated for in 'Upstream fuels' GHG emissions[2], which are a factor of three higher for ICEVs.


copert
Vehicle emissions software, 226 vehicle classes, GHGs (CO_2, CH_4, N_2O)

AFM
Australian Fleet Model: predicts dynamic changes in on-road vehicle population and total vehicle kilometres travelled for 1240 vehicle classes for past, current and future base years.

Detailed vehicle parameter data such as vehicle weight, battery capacity: Australian + International databases (e.g. GVG, VFACTS, TER, ...).

Analysis of Australian GHG data, energy data and fuel statistics (NGA, AES, CER).

Meta-analysis studies: relevant data requested and received from authors (e.g. infrastructure GHG).

International scientific papers/reports + analysis underlying data (e.g. grid transmission losses, battery charging losses, on-road electricity use BEVs, etc.)

Figure 1. Input data sources used in this study

Vehicle type	Life cycle aspect	Unit	(Most) Plausible	Plausible minimum	Plausible maximum
ICEV	Vehicle production	g CO_2-e/km	48	42	56
	Infrastructure	g CO_2-e/km	1.1	0.3	1.9
	Fuels (upstream)	g CO_2-e/km	51	37	72
	Operation (road)	g CO_2-e/km	257	238	279
	Vehicle disposal	g CO_2-e/km	0.5	0.1	1.0
BEV	Vehicle production	g CO_2-e/km	59	47	72
	Infrastructure	g CO_2-e/km	2.0	1.5	2.6
	Fuels (upstream)	g CO_2-e/km	18	12	25
	Operation (road)	g CO_2-e/km	181	152	214
	Vehicle disposal	g CO_2-e/km	0.5	0.1	1.0

Table 1. Overview of mean fleet real-world GHG emission factors by LCA aspect

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[1] e.g. fossil-fuelled power plants, fossil fuel processing facilities and renewable energy sources such as wind farms, solar plants, hydro power, etc.

[2] These are GHG emissions due to upstream extraction, transport, production and distribution of fossil fuels (electricity generation for BEVs) or refined fossil fuels such as petrol and diesel used in ICEVs .

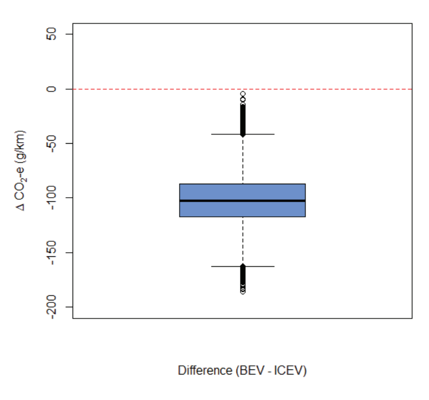

Figure 1. Box-plot showing Monte Carlo simulation results for the difference in GHG emission rate distributions of BEVs and ICEVs (2018)

The fleet average LCA GHG emission factors for Australian ICEVs and BEVs in 2018 are 362 g CO$_2$-e/km for ICEVs (95 percent confidence interval (95%CI)): 336-389 g CO$_2$-e/km) and 260 g CO$_2$-e/km for ICEVs (95%CI: 227-297 g CO$_2$-e/km) for BEVs. Figure 2 shows the results of the Monte Carlo uncertainty analysis in terms of the difference between ICEVs and BEVs (GHG emission distributions).

Accounting for variability in GHG emission factors in all relevant life cycle aspects of ICEVs and BEVs, BEVs significantly reduce average life cycle GHG emission rates for passenger vehicles with 95 percent confidence. In fact, none of the 100,000 uncertainty simulations generated a higher emission rate for BEVs as compared with ICEVs. The weight of evidence suggests that BEVs will reduce GHG emission rates with 16 percent to 40 percent (28 percent on average) for the current (2018) Australian electricity mix, which is still largely fossil fuels based.

The uncertainty analysis was repeated for two alternative scenarios.

1. For a (short-term) ‘marginal electricity’ scenario, i.e. 100 percent fossil-fuelled electricity generation to meet new demand from EV charging, BEVs will still reduce GHG emission rates between 5 percent and 29 percent (17 percent on average).
2. For a (longer-term) ‘renewable energy’ scenario, i.e. an Australian electricity mix of 5 percent coal, 5 percent gas, 30 percent hydro, 25 percent wind, 5 percent biomass and 30 percent solar, BEVs will reduce GHG emission rates with 67 percent to 82 percent (74 percent on average).

4. CONCLUSIONS

Rapid electrification of the Australian passenger vehicle fleet is a robust way to substantially reduce life cycle GHG emissions from road transport. For each BEV sold, it would immediately provide significant reductions in GHG emissions per passenger vehicle kilometre travelled. This is the case for both the current (2018) Australian electricity mix, which is still largely generated with fossil fuels, and even a 100 percent fossil-fuelled marginal electricity. Deep reductions in GHG emissions from road transport are achieved with a renewable Australian electricity grid.

It is therefore essential that BEV sales are promoted and supported (BEV subsidies rather than taxes) now to ensure that a significant level of electrification is achieved in 2030 in the Australian on-road fleet. The GHG emission benefits of electric vehicles will only increase further over time as the Australian electricity grid becomes decarbonised.

REFERENCES

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