Energy Efficiency and Conservation Authority

Life Cycle Assessment of Electric Vehicles: The environmental impact of electric vehicles, a New Zealand Perspective

Final Executive Summary

243139-00

Final | 9 November 2015

Job number 243139-00

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Executive Summary

At first glance, New Zealand seems uniquely suited to benefit from recent developments in the technology of plug-in electric vehicles (PEVs).

Broadly speaking, PEVs are vehicles that use an on-board battery to store energy supplied from an external source — typically the mains electricity grid — and an electric motor as a primary method of propulsion. This category of vehicle includes Battery Electric Vehicles (BEVs), which use only electricity, and Plug-in Hybrid Electric Vehicles (PHEVs), which have both a conventional internal combustion engine and an electric motor. PEVs are not to be confused with Hybrid Electric Vehicles, which use many of the same technological elements merely to capture efficiencies in the operation of their conventional internal combustion engine.

While the all-electric range of PEV vehicles is constrained by the amount of energy they can store in their batteries, all of the models presently on the New Zealand market are capable of meeting the transport needs of the majority of urban-dwelling New Zealanders, who drive less than 42 kilometres per day. New Zealand presently produces around 80% of its electricity from renewable sources, and is on track to meet its stated target of 90% renewable by 2025. For this reason, widespread adoption of PEV technology promises to yield significant reductions in the 'carbon footprint' of the New Zealand light transport fleet, which currently relies upon the consumption of fossil fuels.

PEVs have accordingly attracted an increasing amount of attention from motoring enthusiasts, sustainable energy advocates and utility companies; it is anticipated by industry and policy-makers alike that the number of PEVs in the light vehicle fleet will grow quickly, particularly if policy and financial commitments are made to support PEV uptake and use. It is therefore desirable to attempt to quantify what, if any, benefit this kind of investment in PEV technology would yield.

As it is commonly pointed out, it is not only the effects of motor vehicle operation that must be considered when evaluating competing technologies. For example, a low carbon footprint will count for little if the vehicle in question has an overall higher 'embodied carbon' content (that is, its manufacture requires a more carbon-intensive process), or if other impacts upon the environment or human health are unacceptable. A proper comparison will therefore take into account the impacts of the processes involved in the entire 'life cycle' of a vehicle — the so-called 'cradle-to-grave' journey of which the vehicle's operation is but a part.

Life cycle assessments (LCAs) of motor vehicle technologies have become commonplace overseas, but no such study has been undertaken for the New Zealand context. The Energy Efficiency and Conservation Authority (EECA) has therefore commissioned Arup and Verdant Vision to perform an LCA assessment of PEVs in New Zealand.

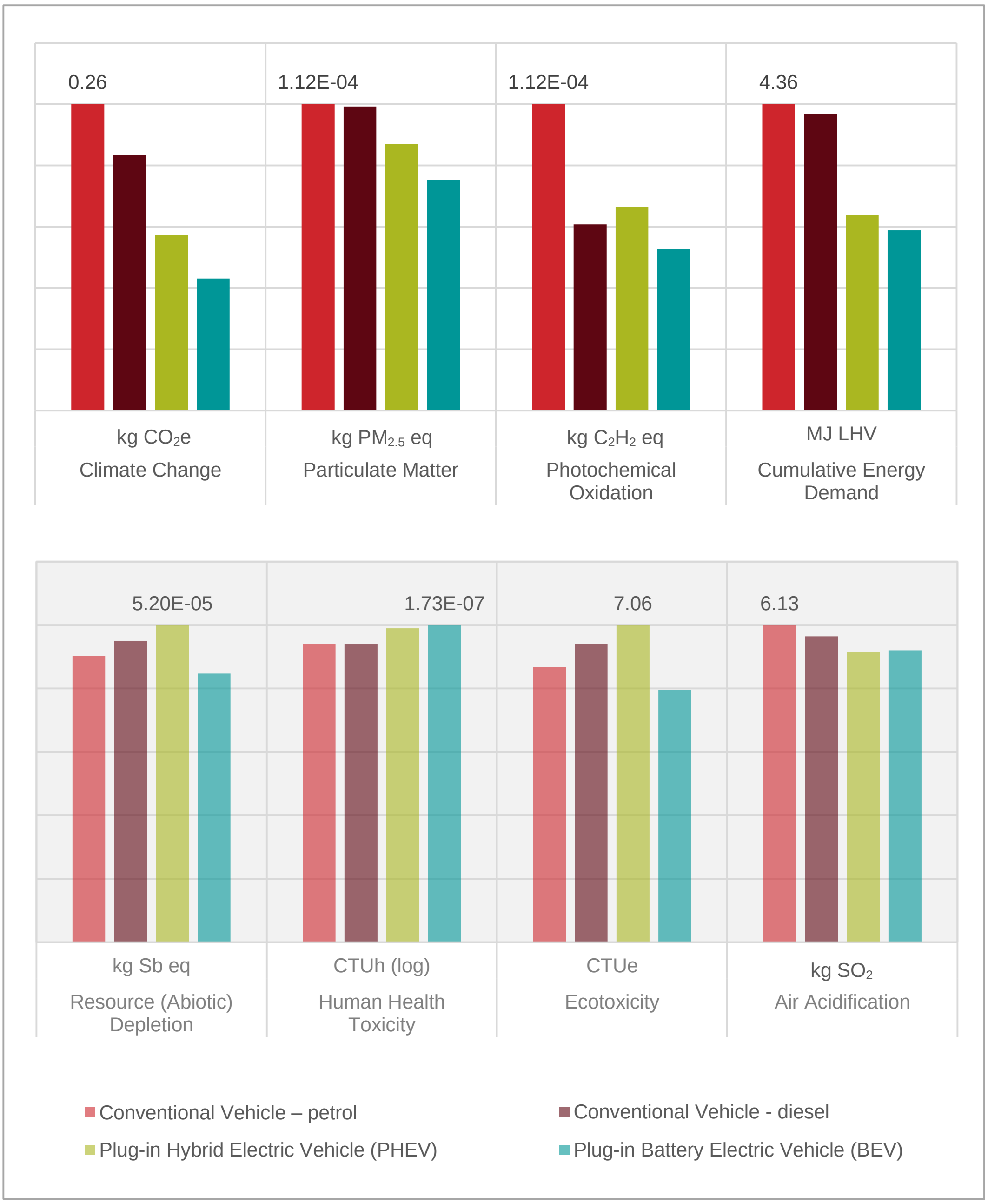
This LCA study was performed to the relevant ISO standards and peer-reviewed by an independent LCA expert. The full technical report sets out the findings of this study, along with the methodologies and assumptions applied and the uncertainties and limitations that bear upon them. Like all LCAs, and while its findings can be considered to be robust, this study is a ‘snapshot in time’, and is liable to require revision should the range and quality of the data available, or the generally accepted methods of assessing it, change. This Executive Summary provides the key findings from the report.

For the sake of the comparison, representatives of four vehicle technologies were considered: two ‘conventional’ types — a petrol and a diesel vehicle respectively — and two PEVs: a PHEV and a BEV. The study considering the impacts of every stage of the vehicle’s life: from the extraction of raw materials, the manufacture, shipping, in-use service (operation and maintenance) of the vehicle to the eventual end-of-life processes used to dispose of it.

In order to examine the life cycle impacts of each vehicle upon the environment and upon human health, eight ‘impact categories’ were examined. These were:

- Climate change (the overall impact of a vehicle technology in terms of carbon dioxide equivalent emissions);
- Particulate matter (the levels of fine particles, known to be harmful to human health, produced);
- Photochemical production (emissions that contribute to smoke and smog levels, which are known to be harmful to human health);
- Cumulative energy demand (the total energy used in the life cycle of the vehicle);
- Resource depletion (whether the production and operation of the vehicle brought about significant depletion of natural resources compared to our reserves, notably rare-earth, precious or industrial metals, and fossil fuels);
- Human health toxicity (whether the processes involved with the extraction of raw materials, vehicle manufacture, use, maintenance or end-of-life disposal produced substances that were harmful to human health);
- Ecotoxicity (as above, but considering the impact of these processes upon other organisms and ecosystems); and
- Air acidification (whether the production and operation of the vehicle leads to the emission of substances such as sulphur dioxides, nitrogen oxides and other nitrogen compounds that can lead to the acidification of water bodies and vegetation).

The following pages presents the results of the study. In the following image, the impact categories highlighted in grey signify those categories with high uncertainties associated with its results.



The study found:

- Significant reductions in emissions with global warming potential are available over the life cycle of PEVs. A reduction of carbon dioxide-equivalent (CO_2-eq) emissions approaching 60% will be realised over the full life cycle of the vehicle for a BEV compared with a petrol vehicle.

  When looking only at the electricity consumed by a BEV driven in New Zealand, a BEV will produce close to 80% less CO_2-eq emissions compared to a petrol vehicle, a figure that will only improve supposing New Zealand meets its policy targets for the reduction of the carbon intensity of electricity production. The total amount of energy used during the entire life cycle of the vehicle (cumulative energy demand) was around 40% less for the BEV than for the petrol and diesel vehicles.

- The study found that there are no significant differences across the technology types with regard to net resource depletion, although it should be noted that the levels of uncertainty in these findings was high. While it is easy enough to state with confidence the ameliorating effect on fossil fuel resource depletion of using PHEV or BEV technology, for example, it is somewhat harder to quantify the depletion of other resources, such as the minerals used in battery and electric motor manufacture. Nonetheless, it was concluded that the differences in net resource depletion were not significant, and sensitivity analysis found that improvements in battery technology (such that battery life is extended) and in the rate of recycling of the materials used in batteries and motors will improve the comparative mineral resource performance of PEVs.
- The study into resource depletion impacts also helped to dispel two myths about PEVs:
    - Whilst PEVs do contain rare earth materials in small amounts (as do most petrol and diesel vehicles), the study findings show that the resource depletion impact of rare earth metals was not a significant issue compared to other minerals or resources;
    - The lithium salts used in lithium-ion batteries for current PEVs on the market are neither a rare-earth nor even a precious metal. The study also found that the resource depletion effect of the amount of lithium in PEVs was insignificant compared to other minerals or resources.
- PEVs produce lower particulate emissions than petrol and diesel vehicles.
- Diesel, plug-in hybrid and battery electric vehicles all indicated lower smog-forming potential (photochemical oxidation) than petrol vehicles.

As with resource depletion, there was considerable uncertainty in the assessment methods used to gauge human health toxicity, eco toxicity and air acidification, which reduces the confidence of the study results in these impact categories. The results did, however, indicate that BEVs have the lowest impact for eco toxicity and air acidification, and that at any rate, human toxicity impacts were very small across all vehicles.

Overall, the comparative life-cycle assessments indicated that there are very worthwhile gains to be made by encouraging the uptake of PEV vehicle technologies in New Zealand, particularly with regard to reducing the carbon intensity of the New Zealand economy.