Transport Roads & Maritime Services

GREEN TRUCK PARTNERSHIP

Case study

Battery-electric distribution van

Trial summary

This trial sought to quantify the difference in energy requirements and emissions of using an electric vehicle in place of a conventional diesel van. The trial was conducted using a small battery electric van in place of a medium sized van in a set mail distribution run in Melbourne.

Energy benefit (MJ/km)	GHG benefit (g CO_2 e/km)	Economic benefit ($/100 km)
77%↑	100%↑ (GreenPower)	62%↑ (GreenPower)
	24%↑ (Grid)	77%↑ (Grid)

↑ performance better than conventional vehicle

↓ performance worse than conventional vehicle

MJ/km	= megajoules per kilometre
g CO_2 e/km	= grams per kilometre of carbon dioxide emission
$/100 km	= dollars per 100 kilometres
%	= per cent

The *Green Truck Partnership* is designed to be a forum to objectively evaluate the merits of clean vehicle technologies and fuels by heavy vehicle operators. This report discusses the results of a trial of an electric van used in a mail run in 2015 (trial) and 2016 (baseline).

1 Electric vehicle basics

Electrification of motor vehicles is gathering pace, although the concept is not new – electronic vehicles (EVs) were on US roads in the early 1900s. However, limitations in battery chemistry, materials science and power controls have prevented the technology taking hold to date.

Recent advances in these technologies have allowed increasing electrification of vehicle functions, covering a spectrum including:

- functional electrification, where some systems and accessories (power steering, air conditioning) become electrically powered to reduce parasitic losses of engine power
- hybrids that store energy recovered during braking to power accessories (mild hybrids) or to accelerate the vehicle (full hybrids)
- fully electric vehicles, with drive energy taken from on-board batteries via an electric motor, and all functions powered electrically.

Technology has progressed such that fully electric vehicles are now a viable option in some applications, albeit at higher up-front cost and with some operational compromises.

This has important implications for freight vehicles. Over the longer term, electric vehicles are likely to disrupt traditional supply chains for fuels, motor vehicles, and electricity itself. But in the near term, the most viable applications for EVs in the freight industry will be limited to depot-based operations that do not require a long driving range, and with consistent and predictable routes.

The performance characteristics of the van used in this trial include a 650 kilograms (kg) payload, with 22 kilowatt-hour (kWh) lithium-ion battery feeding the 44 kW / 226 Newton-metre (Nm) electric motor, capable of accelerating the van to 50 kilometres per hour (km/h) in 5.5 seconds. European driving cycles give an official range of 170 kilometres, however real-world scenarios range from 80 to 125 kilometres. [1]

Electric van used in trial.

2 Trial objective

This trial was intended to assess the difference in energy consumption of a trial electric van compared with a conventionally powered diesel van. The electric van was specifically provided by the vehicle manufacturer for the purposes of evaluating the suitability of the concept.

3 Methodology

3.1 Data collection

The trial involved an in-field comparison of one electric van operating in an urban parcel pick-up and delivery service around Port Melbourne; and a conventional (diesel) van on the same run.

The electric van was driven for over 3,700 kilometres over three months, of which 1,300 kilometres was in the specific test run. The baseline diesel van covered more than 2,700 kilometres over two months, of which an estimated 900 kilometres was on the same specific test run as the electric van.

The set delivery route was 64 kilometres in length, and the electric van was recharged every night at the dedicated recharger installed at the depot. The diesel van was refuelled at a typical forecourt, offsite; however, the proximity to the depot makes the increase in distance negligible.

In this operation, payload varies according to the time of year, with the peak before Christmas. The electric van was logged from May to July, while the baseline van was logged in April and May the following year. The electric van is slightly smaller in size and payload capacity than the diesel baseline van, however the electric van had enough capacity to handle the same task, without requiring a secondary trip back to the depot. The larger size of the diesel baseline van was to ensure peak periods could also be accommodated.

The nature of the operations and the timing of the trial meant that the fuel data and duty cycle characteristics were not able to be recorded directly from the vans using data loggers.

Instead, diesel consumption was provided directly by the fleet operator (from fuel card records). This data included:

- DISTANCE: kilometres travelled, via odometer differences (km)
- FUEL CONSUMPTION: total fuel consumed in litres (L).

A secondary layer of data was gathered via hand written motor vehicle running sheets, which logged date, duty runs, odometer, and fuel litres.

Electricity consumption for the electric van was calculated using metered data available from the recharging equipment used to recharge the electric van. The data available from the fleet and the EV supplier included:

- DATE: start and stop dates for the recharge
- ELECTRICAL ENERGY CONSUMPTION: total electricity in kilowatt-hour (kWh) used to recharge the electric van during the period.

GPS data was also collected, and for the electric trial period was cross referenced with data for

- DATE: start and stop dates for the vehicle
- DISTANCE: kilometres travelled (km).

These two data sets were correlated to give an average electric vehicle efficiency in watt-hours per kilometre (Wh/km) for each day.

Diesel energy data could be analysed only in aggregate form over the entire period, however the electrical data could be analysed on a trip-by-trip level, as well as aggregate.

3.2 Data analysis

Although quantitative measures of duty cycle were not available, normalisation of the duty cycles was assumed because the electric van was used on the same set delivery run as the conventional diesel (baseline) van.

A common unit was required to compare energy efficiency of the different kinds of vans. For conventional (diesel) vans, diesel litres are normally used as a surrogate energy measure. But electric vehicle energy use is typically tracked by electricity units such as kilowatt-hours (kWh).

To ensure direct energy efficiency comparisons could be made, both measures were converted to the common energy unit of megajoules (MJ). Table 2 shows the base units and conversion factors for these calculations. Other assumptions and factors are detailed at the end of the report.

Table 2: Energy consumption

Van type	Fuel unit	Energy conversion [4]	Energy efficiency
Diesel	L/km	X 38.6 MJ/L	MJ/km
Electric	kWh/km	X 3.6 MJ/kWh	MJ/km

Some of the electric van charge data had to be corrected or removed due to the nature of the charging regime and equipment.

The electric van was typically left to charge over the weekend, and it was found that considerably more energy was consumed over these days, possibly as a result of over-charging or repeated attempts to charge.

Whatever the cause, the weekend charge data was excluded as it was considered a phenomenon associated with imperfect charging, as opposed to a genuine reflection of energy consumption by the battery during the van’s running.

4 Results

The most relevant issues for this case study are energy use, emissions and energy cost.

4.1 Energy

The energy intensity of the electric van showed considerable variation from trip to trip, even with weekend charge data excluded. There were 21 data points, and the most efficient day (min) was 174 Wh/km, while the least efficient (max) was 329 Wh/km. The average was 262 Wh/km, with a standard deviation of 39 Wh/km. This average was used for comparative purposes.

By contrast, the diesel van covered 2,746 km with 292 litres, giving an efficiency of 9.4 km/L.

On that basis, the electric van used an average 77 per cent less energy than the diesel van to do similar work: 0.94 MJ/km (electric van) versus 4.10 MJ/km (diesel). Energy use intensity for the diesel van and the electric van are shown in Table 3, with the electric van's units converted to diesel litre equivalent (DLE).

Table 3: Energy consumption with different units

Van type	MJ/km	Wh/km	km/L (DLE)	L/100km (DLE)
Diesel	4.10	1138	9.4	10.6
Electric	0.94	262	40.9	2.4
Benefit		77%		

4.2 Emissions

The *Green Truck Partnership* approach to calculating greenhouse gas emissions is to include only tailpipe (or vehicle exhaust) emissions. On that basis, the electric van comes out far ahead - it has no tailpipe emissions.

But critics of electric vehicles argue that they simply transfer the emissions from the vehicle tailpipe to the smokestack at the power station. In addition, major emitters of greenhouse gases need to report (under NGER legislation) emissions from fuel combusted and from purchased electricity. For that, the different emissions intensities of diesel and electricity need to be taken into account, with coal-based (grid) electricity producing significantly more emissions per unit of energy generated.

Australia's electrical grid varies in the generation technology, and as such the amount of carbon emitted per unit of energy generated. Victoria, for example, has the worst emissions intensities in Australia, with its old brown coal dominated power stations emitting 1.13 kg of CO_2e/kilowatt-hour (CO_2e/kWh). Victoria emits over nine times the carbon emissions of Tasmania's clean hydroelectric-dominated power stations for every unit of electricity produced (0.12 kg of CO_2e/kWh).

For a fair analysis of the Australian market, the average emissions intensity of the national electric market (NEM) was used, averaging Queensland, NSW, Victoria, SA, and Tasmania). The NEM average is currently rated at 0.83 kg CO_2e/kWh [4].

Taking this into account, the battery-powered van powered with regular grid electricity emerged 24 per cent better than the diesel powered van: 0.22 kg CO_2e/km compared with 0.29, respectively.

Fleet operators can also ensure their electric vehicle produces no net emissions by powering their vehicle from renewable energy: by purchasing 100 per cent GreenPower accredited electricity, or by offsetting emissions with certified abatement certificates, or by generating their own electricity, for example through solar photovoltaic panels. Table 4 shows the effect of these renewable energy sources on emissions.

Table 4: Comparison of electric van emissions using National Energy Market (NEM) intensity

Emissions intensity (kg CO_2e/km)		
Van Type	**Grid**	**GreenPower**
Diesel	0.29	0.29
Electric	0.22	0
Benefit	24.4%	100%

It is worth noting that emissions from diesel and petrol powered vehicles can also be reduced with certified offsets.

Demonstrating the effect of large differences in emissions intensity between states, Figure 2 shows the results using these different factors.

It should be noted that electric vehicles also hold a major advantage over diesel vehicles in terms of urban air pollution. They produce no tailpipe emissions, so they do not contribute to air pollution in the areas they operate, although emissions are produced at the electricity source.

4.3 Energy cost

The relative cost saving or penalty of an electric vehicle is highly sensitive to the prices an operator pays for diesel and electricity. This is shown in Figure 1.

Assuming the electric van is charged overnight using only off-peak electricity, the energy cost can be much lower (77 per cent lower in this analysis) than an equivalent diesel van: 2.9 cents per kilometre (c/km) versus 12.4 c/km.

However, if the van batteries are discharged and it needs to be charged during the day using peak electricity rates, the electricity cost increases substantially. But even at the peak tariff used in this analysis, it still costs only 7.9 cents/km for the electricity used – a saving of 36 per cent in energy costs compared with diesel.

If 100 per cent GreenPower is used to power the van, the electric van still comes out 62 per cent ahead on energy costs if charged off-peak (4.7 c/km versus 12.4 c/km). And even in the worst case for the electric vehicle (100 per cent GreenPower and charging in peak times) the energy cost of 9.7 c/km for the electric vehicle is 22 per cent less than for the diesel van average.

In practical terms, assuming an annual mileage of 15,000 kilometres, the electric vehicle could have saved up to $1,431 per year in energy costs. Over a seven year asset life (and no discount rate) this translates to a total energy saving of over $10,000 if charged off-peak.

Prices for electricity and fuel vary by location and time, with fuel prices also dependent on overseas oil markets. To illustrate the variability of savings, Figure 3 can be used to calculate energy savings based on different diesel and electricity price scenarios.

Depending on the price of electricity (x-axis), and the price paid for diesel (three scenario lines in the graph), the likely energy cost saving can be interpreted from the y-axis. This percentage (y-axis) simply represents the cents/km saving in energy costs when running on electricity compared with a diesel baseline.

Table 5: Comparison of energy costs

	Off-peak (c/km)		Peak (c/km)	
Van type	**Grid**	**GreenPower**	**Grid**	**GreenPower**
Diesel	12.4	12.4	12.4	12.4
Electric	2.9	4.7	7.9	9.7
Benefit	77%	62%	36.7%	22%

4.4 Other considerations

Analysing energy costs is interesting but does not provide a complete comparison. Electric vehicle use a different energy source that may require different equipment, fleet practices and financing approaches. For example, initial purchase cost is higher; utilisation may be limited by driving range or recharging time; charging equipment may be required; “fuel” costs become electricity costs; and maintenance staff may need special training.

On the other hand, novel financing arrangements for the van or just the battery might reduce or defer the capital cost while reducing the perceived risk of battery ownership/replacement.

Service schedules will be much simpler on the electric vehicle with lower costs for consumables (eg brakes, engine oil, filters). These differences were not considered in the analysis due to the short duration of the trial.

For an operator considering an electric vehicle, all costs and how they are structured will need to be understood and compared. A fit-for-purpose assessment should also be provided by the supplier to ensure operating requirements such as driving range, payload and service life are met.

5 Conclusion

The findings of this trial suggest that the use of an electric van in place of a diesel van in a mail run application can provide substantial energy, cost and emissions benefits; but that these could vary significantly with operating choices.

Importantly, greenhouse gas emissions for the electric van in this trial were lower even when the vehicle was charged with grid electricity. Offsetting fleet emissions or purchasing accredited GreenPower would reduce these to zero.

Under all the scenarios analysed in this trial, including purchase of GreenPower and peak-time charging, the energy cost for the electric van was lower than the equivalent diesel van.

Other operating costs were not considered in this trial but could have a significant effect (positive or negative) on the whole-of-life costs. These will vary with supplier and vehicle utilisation.

At this time (2016-17) very few electric vehicles are available in Australia. For operators considering a switch, the different energy source requires a careful matching of operating needs with capabilities, and a whole-of-life approach to costs.

5.1 Assumptions

Several assumptions were applied to the energy calculations and financial analysis, including:

- DIESEL PRICE: $1.17/L 2 = 3.03 c/MJ [2]

Note: the Australian Tax Office (ATO) fuel tax credit is not applicable for light vehicles of 4.5 tonne GVM or less. [3]

- ELECTRICITY PRICE
  Off-peak: 11 c/kWh = 3.06 c/MJ
  Peak: 30 c/kWh = 8.33 c/MJ
  GreenPower: extra 7 c/kWh (1.9 c/MJ) [5]

Greenhouse emissions intensity:

- DIESEL: 70.2 kg CO2-e/GJ 4
- ELECTRICITY (NEM): 0.83 kg CO2-e/kWh = 231 kg CO2-e/GJ [4]

6 References

1. Car Advice 2014, Renault Kangoo Z.E. – Electric vans join Australia Post fleet in 12-month trial
2. Australian Institute of Petroleum 2016, *Average weekly retail prices for diesel fuel – week ending 5 June 2016*
3. Australian Taxation Office 2016, *Fuel Tax Credits*, Australian Government

4. Department of Environment 2015, *National Greenhouse Accounts Factors*, August 2015

5. Greenpower 2016, *Costs*, *www.greenpower.gov.au/Homes/Costs/*

Figure 1: Energy costs vary by electricity source

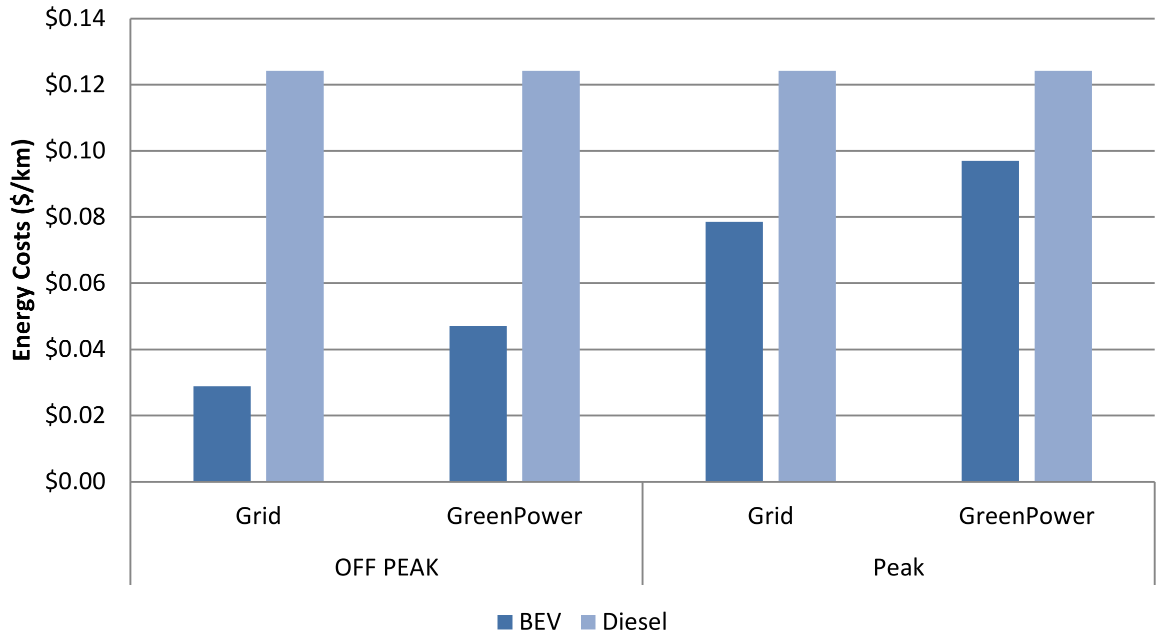


Figure 2: Carbon benefit from using BEV van with regular grid power

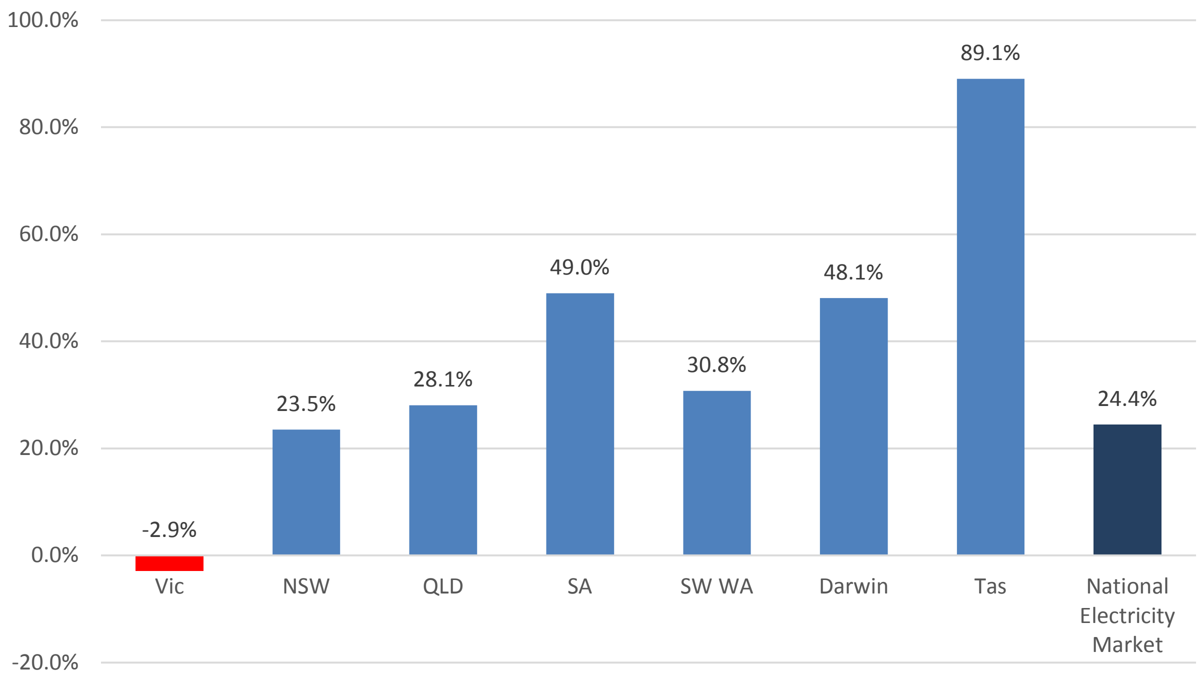
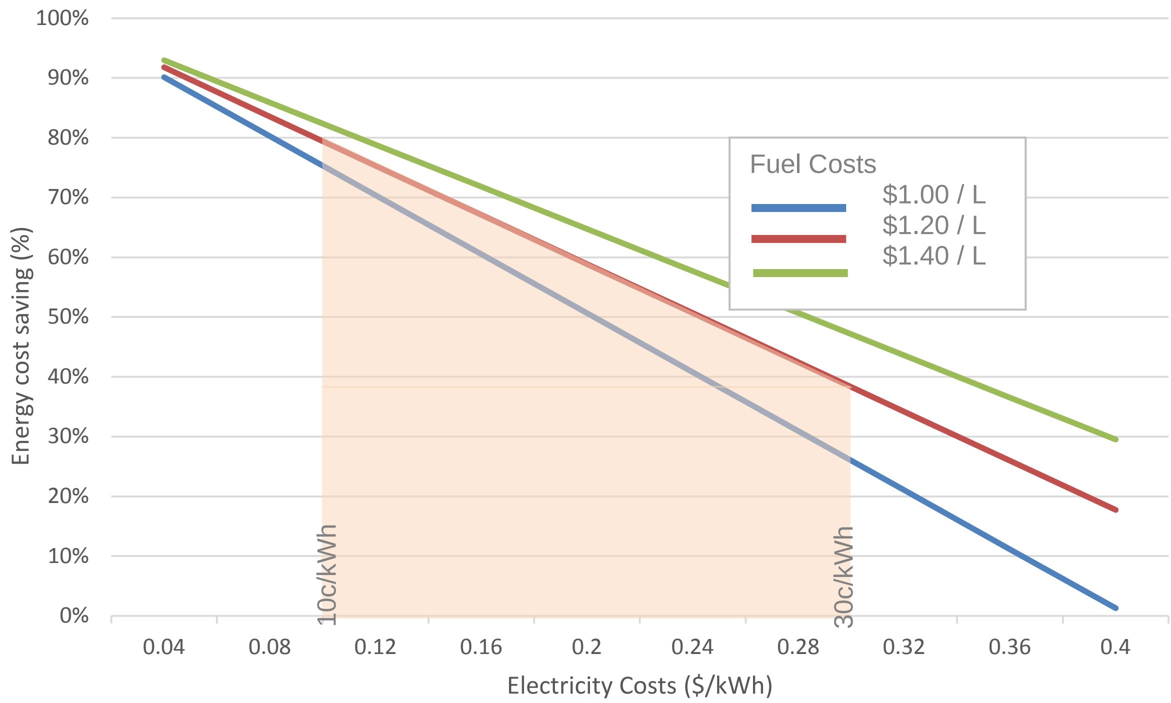


Figure 3: Energy cost saving for various electricity and fuel prices



7 Document control

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