Case Study

Battery-electric distribution truck

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 truck. The trial was conducted using one battery-electric truck in place of three medium sized rigid diesel trucks in three different applications in Queensland.	**Energy benefit (MJ/km)**	**GHG benefit (kg CO_2-e/km)**	**Economic benefit ($/100 km)**
	73% ↑ (7.79 MJ/km)	100%↑(Green Power) 13%↑(grid)	77%↑ (off peak) ($0.30/km better) 30%↑ (peak + GreenPower) ($0.12/km better)

↑ performance better than conventional vehicle
↓ performance worse than conventional vehicle

The *Green Truck Partnership* is designed to be a forum for the objective evaluation of the merits of clean vehicle technologies and fuels by heavy vehicle operators. This report discusses the results of a trial of an electric distribution truck used in local pick-up and delivery in 2014.

1 ELECTRIC VEHICLE BASICS

Electrification of motor vehicles is gathering pace, although the concept is not new – 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 that includes:

- functional electrification, where some vehicle functions 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 (strong hybrids);
- fully electric vehicles, with drive energy from on-board batteries via an electric motor, and all on-board functions powered electrically.

Technology has progressed such that fully electric vehicles are now a viable option in some applications, albeit at high 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 truck used in this trial include a range up to 200 km and a top speed around 100 km/h, with recharging of the 80 kWh battery taking 5–6 hours.

2 TRIAL OBJECTIVE

This trial was intended to assess the difference in energy consumption of a commercially available electric distribution truck compared with a conventionally powered diesel truck.

3 METHODOLOGY

DATA COLLECTION

The trial involved an in-field comparison of one battery-electric rigid truck operating on three different urban/outer urban parcel pick-up and delivery runs around Brisbane, and three conventional (diesel) rigid trucks on the same runs. The electric truck was run for over 5,000 km over 3 months in parallel with the baseline trucks.

Table 1 shows basic details of all four trucks. In summary, the conventional diesel (baseline) trucks and the electric truck were roughly equivalent in overall size and configuration. The EV had a slightly lower payload capacity (by around 400 kg) due to the need to carry its own on-board batteries.

Table 1 Trial vehicle descriptions

Truck ID	Make/model	GVM (t)	Body
382	2012 Isuzu FRR500	10.4	Pantech
398	2007 Fuso Fighter FK617	10.4	Pantech
556	2007 Fuso Fighter FK617	10.4	Pantech
EV	Not disclosed	10	Pantech

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 trucks using data loggers.

Instead, diesel consumption was provided directly by the fleet operator (from fuel card records). Electricity consumption for the electric truck was calculated using metered data available from the recharging equipment used to recharge the electric truck and validated against the vehicle's telemetry system. The data available from the fleet and the EV supplier included:

- **DISTANCE**: kilometres travelled.
- **ROUTE CONFIRMATION**: to ensure diesel and electric trucks travelled the similar routes.
- **FUEL CONSUMPTION:** total fuel consumed (L) for the baseline (diesel) trucks.
- **ELECTRICAL ENERGY CONSUMPTION**: total electricity (kWh) used to recharge the electric truck during the period.

Energy data for the diesel and electric trucks was compared in aggregate across the entire test period (rather than on specific trips) because trip data was not available for all diesel trucks.

DATA ANALYSIS

Although quantitative measures of duty cycle were not available, normalisation of the duty cycles was achieved by running the electric truck on the same regular route runs as the conventional diesel (baseline) trucks.

A common unit was required to compare energy efficiency of the different kinds of trucks. For conventional (diesel) trucks, 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 conversions

Truck type	Fuel unit	Energy Conversion*	Energy efficiency
Diesel	L/km	X 38.6 MJ/L	MJ/km
Electric	kWh/km	X 3.6 MJ/kWh	MJ/km

**Source:* DoE 2014

4 RESULTS

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

ENERGY

Energy use intensity for the diesel trucks and the electric truck are shown in Table 3 by route. On average, the EV used only 27% of the energy required by the diesel trucks to do similar work: 2.86 MJ/km (EV) versus 10.64 MJ/km (diesel).

Table 3 Energy consumption

Run	Diesel fuel efficiency (L/km)	Diesel energy efficiency (MJ/km)	EV energy efficiency (MJ/km)
Murarrie	0.2923	11.28	2.49
Coopers Plains	0.2656	10.25	3.37
Underwood	0.2691	10.39	2.71
Average	**0.2757**	**10.64**	**2.86**

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 truck comes out far ahead as 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. Taking this into account, the battery-powered truck still emerges 13% better than the average of runs in the diesel trucks: 0.64 kg CO_2-e/km compared with 0.74, respectively.

Fleet operators can also ensure their EV produces no net emissions by purchasing 100% GreenPower accredited electricity, or by offsetting emissions with certified abatement certificates. Table 4 shows the effect of purchasing GreenPower.

Table 4 Comparison of EV emissions

Emissions intensity (kg CO_2-e/km)		
Diesel	EV (grid)	EV (GreenPower)
0.74	0.64	0

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 do not contribute to air pollution in the areas they operate, although emissions are produced at the electricity source.

ENERGY COST

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

Assuming the electric truck is charged overnight using only off-peak electricity, the energy cost can be much lower (77% lower in this analysis) than an equivalent diesel truck: 8.7 cents/km versus 38.6 cents/km.

However, if the truck 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 cost only 23.8 cents/km for the electricity used – a saving of 38% in energy costs compared with diesel.

If 100% GreenPower is used to offset the emissions, the electric truck still comes out nearly 70% ahead on energy costs if charged off-peak (11.9 cents/km versus 38.6 cents/km).

Even in the worst case for the EV (100% GreenPower and charging in peak times) the energy cost for the EV is 30% less than for the diesel truck average.

OTHER CONSIDERATIONS

Analysing energy costs is interesting but does not provide a complete comparison. Electric vehicles use a different energy source that may require different fleet management and financing approaches – for example, initial purchase cost is higher, utilisation might be limited due to driving range or recharging time, 'fuel' costs shift to the invoicing cycle for site electricity and repair or recovery personnel may need special training. On the other hand, novel financing arrangements for the truck 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 EV with lower costs for consumables (e.g. 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 EV, 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 CONCLUSIONS

The findings of this trial suggest that the use of an electric truck in place of a diesel truck in a pick-up and delivery application can provide substantial energy, cost and emissions benefits, but that these vary significantly with operating choices.

Importantly, greenhouse gas emissions for the EV in this trial were lower even when grid electricity emissions were counted. 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 EV was lower than the equivalent diesel trucks.

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 very few electric trucks are available in Australia. For operators considering a switch, the different energy source requires properly matching operating requirements with capabilities, and a whole-of-life approach to costs.

ASSUMPTIONS

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

- **DIESEL PRICE:** \$1.40/L = 3.63 c/MJ, comprising:
  - \$1.52 retail (AIP 2014), minus
  - \$0.12 fuel tax credit (ATO 2014)
- **ELECTRICITY PRICE**
  - Off-peak: 11 c/kWh = 3.06 c/MJ
  - Peak: 30 c/kWh = 8.33 c/MJ
  - GreenPower(2014): extra 4 c/kWh (1.11 c/MJ)
  - Greenhouse emissions intensity (DoE 2014):
- **DIESEL:** 69.81 kg CO_2-e/GJ
- **ELECTRICITY:** 0.81 kg CO_2-e/kWh = 225 kg CO_2-e/GJ.

REFERENCES

Australian Institute of Petroleum 2014, *Average weekly retail prices for diesel fuel – week ending Sunday 5 October 2014* www.aip.com.au/pricing/retail/diesel/index.htm

Australian Taxation Office 2014, *Fuel tax credits for business*, Australian Government www.ato.gov.au/uploadedFiles/Content/ITX/downloads/BUS18875n14584.pdf

Department of Environment 2014, *National Greenhouse Accounts Factors*, July 2014

Greenpower 2014, *Costs,* www.greenpower.gov.au/Homes/Costs/

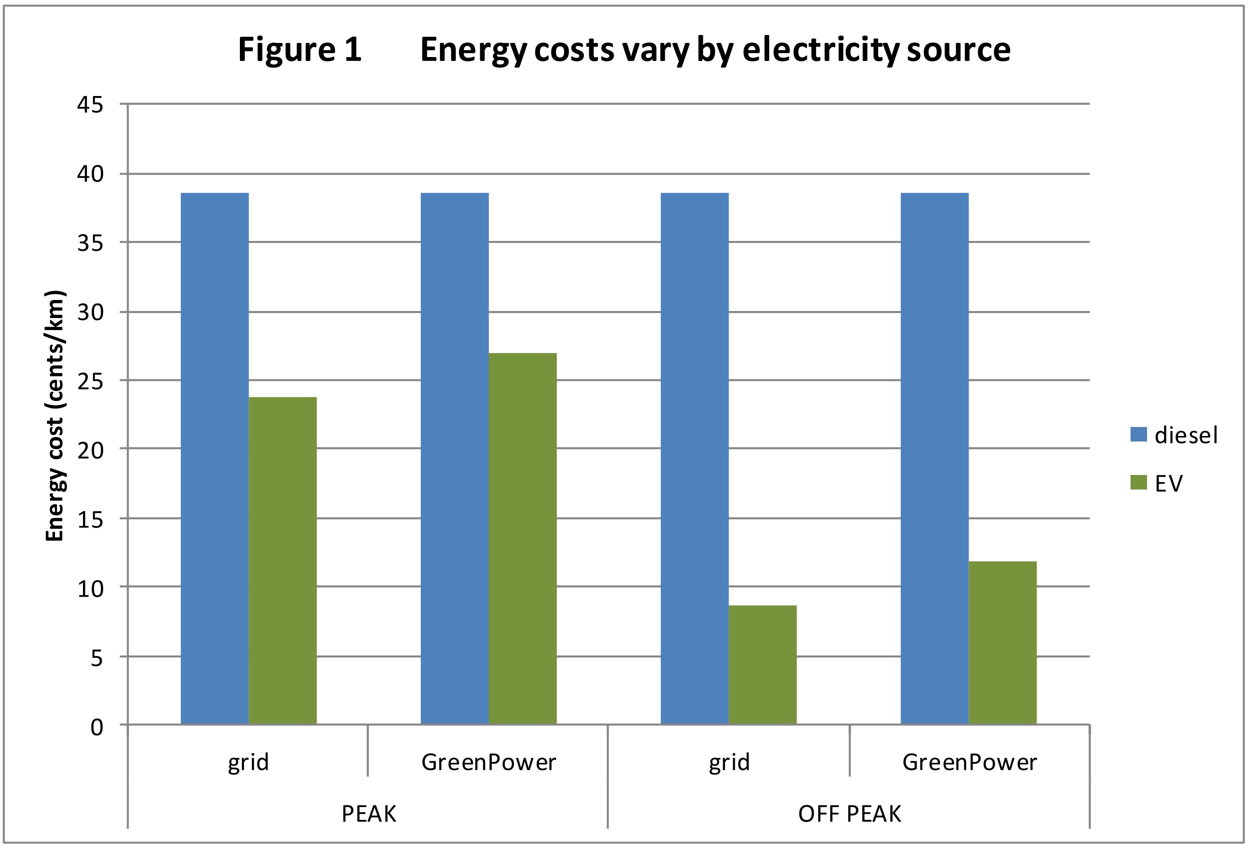
Figure 1 Energy costs vary by electricity source
Energy cost (cents/km)
45
40
35
30
25
20
15
10
5
0
grid
GreenPower
grid
GreenPower
PEAK
OFF PEAK
diesel
EV