

Case Study

LIQUEFIED NATURAL GAS (HIGH PRESSURE DIRECT INJECTION)



TRIAL SUMMARY

The objective of this trial was to assess the fuel efficiency and GHG emissions outcomes of an LNG powered vehicle High Pressure Direct Injection (HPDI) technology relative to a conventional diesel vehicle. The trial involved an assessment of B-doubles operating in linehaul applications in regional Victoria.

**Fuel benefit
(L/100 km)**

0.18 DLE ↑

**GHG benefit
(g/km CO₂-e)**

273 ↑

**Economic benefit
(\$/100 km)**

22.81 ↑

↑performance better 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 liquefied natural gas (LNG) trial conducted under the program in 2011.

1 HIGH PRESSURE DIRECT INJECTION (HPDI) LNG VEHICLES

In its pure form, natural gas is cheaper than diesel and when considered in terms of energy equivalence produces lower GHG emissions than diesel.

The practical realisation of these potential benefits, however, is dependent upon the combustion efficiency of gas engine technologies relative to diesel engine technologies. Some gas engine technologies are more energy efficient than others, leading to the inevitable conclusion that the net environmental and economic outcomes of using natural gas over diesel vary according to the nature of the vehicle technology that is deployed.

HPDI technology is considered by many in the industry to provide the greatest economic and environmental outcomes owing to a constant diesel substitution rate of 95% and the maintenance of the compression ignition regime used by conventional diesel engines.

These benefits, however, come at a higher cost, with HPDI vehicles generally costing 40% more than an equivalent diesel powered prime mover. Past trials have also revealed that the annual repair and maintenance costs of HPDI vehicles can be slightly higher than those of conventional diesel vehicles.

2 TRIAL OBJECTIVE

The purpose of this trial was to quantify the fuel saving and GHG outcomes of HPDI vehicles relative to conventional diesel vehicles in order to assess the performance of an LNG vehicle (HPDI technology) compared to a conventional diesel vehicle in terms of the impacts on GHG emissions and fuel costs.

3 METHODOLOGY

DATA COLLECTION

The trial involved an in-field assessment of an LNG linehaul vehicle (HPDI) relative to an equivalently configured diesel vehicle. The vehicles were B-double dairy tankers running like routes between rural and metropolitan Victoria. The vehicles were operated simultaneously over a six-week period.

During the trial period, data loggers were used to collect drive cycle data relating to the operation of each vehicle to ensure validity of the fuel comparison. The data collected by the loggers during the course of the trial included:

- **FUEL CONSUMPTION:** total fuel consumed in a daily period.
- **FUEL ECONOMY:** daily fuel economy (km/L).
- **DISTANCE:** kilometres travelled.
- **IDLE TIME:** time spent at idle.
- **ENGINE LOAD:** percentage of time spent at a given engine load.
- **AVERAGE SPEED:** average speed (km/h).
- **STOPS:** number of stops per kilometre travelled.

DATA ANALYSIS

Key descriptors considered in this analysis included engine load, average speed and drive fuel economy. This data was used to assess the average performance of vehicles throughout the trial, and identify any periods where the operation of the two vehicles was considered to be sufficiently different to warrant exclusion of related fuel consumption data. Once the data validation process was completed, the fuel efficiency performance of the LNG vehicle was compared with the diesel vehicle. The results of this comparison are discussed in Section 4.

In order to ensure the validity of the fuel consumption comparison, the duty cycles of both vehicles were compared by considering the engine load and average speed descriptors collected during the course of the trial. Given that these vehicles were performing linehaul tasks, the two descriptors were considered to provide a solid methodology for assessing consistency of vehicle operation.

Although both vehicles performed identical runs, engine load is essentially a measure of how hard the engine is working and is measured as a percentage of a theoretical maximum loading developed by the vehicle manufacturer. This parameter can be influenced by a number of factors including vehicle speed, acceleration patterns, vehicle payload, road terrain, transmission design and even weather conditions. Comparison of the engine load profiles for both vehicles revealed some differences in the engine load profile, as shown in Figure 1.

Interestingly, the analysis revealed an offset in the load profile for the LNG vehicle (i.e. same shape, but a higher proportion of time at higher engine load). In simple terms, this shows the LNG engine was working harder and therefore likely to have consumed more fuel than if the engine load had been the same.

This variation is most likely to be attributable to the fact that the different fuels require slightly different combustion settings and hence yield slight differences in engine load for similar vehicle operation.

In order to ensure that the difference was merely one of technology and not vehicle application, a second comparison was undertaken by considering the average speed profiles of the vehicles. This analysis, presented in Figure 2, shows a good correlation between the speed profile of the LNG vehicle and the speed profile of the diesel comparison vehicle.

Given the results of the engine speed comparison, the direct comparison of the fuel consumption results was deemed to be valid.

4 RESULTS

Comparison of the fuel consumption results reveals that the fuel costs for the LNG vehicle were 45% lower than the diesel vehicle (Figure 3). It should be noted that this comparison was derived using indicative fuel costs for LNG and diesel at the time of the trial.

Analysis of the GHG performance (Figure 4) reveals that the GHG emissions generated by the LNG vehicle were 22% lower than the diesel vehicle.

Fuel consumption could not be compared on a volumetric basis, but when considered on an energy equivalence basis the energy consumption of the LNG vehicle was found to be slightly lower than that of the diesel vehicle. This difference, however, is considered to be largely insignificant.

5 CONCLUSION

The findings of this trial suggest that the use of LNG in HPDI engines delivers fuel cost savings in the vicinity of 45% for typical diesel and LNG prices in Australia. It should be noted, however, that the economic outcomes over the life of the vehicle need to assess these fuel savings in light of the higher capital cost of these vehicles and any variation in repair and maintenance costs.

In terms of comparative GHG emissions, the LNG powered HPDI vehicle delivered GHG savings in the vicinity of 22%, which is roughly equivalent to a saving of 273 g CO₂-e/km.

Figure 1
Comparison of vehicle engine load
across baseline and trial periods

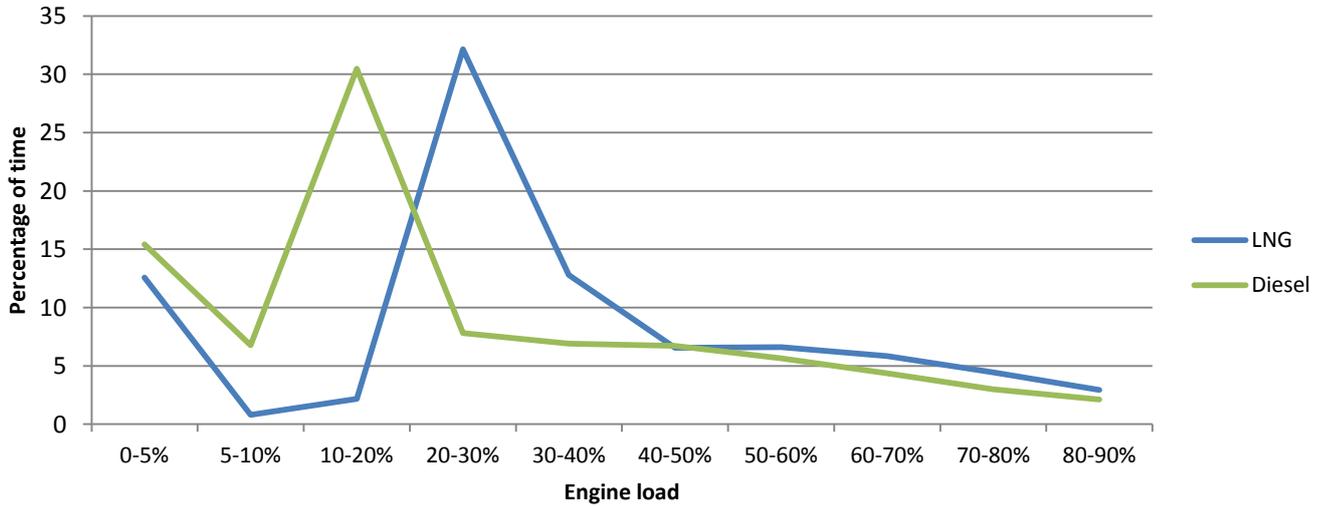


Figure 2
Comparison of vehicle average speed
across baseline and trial periods

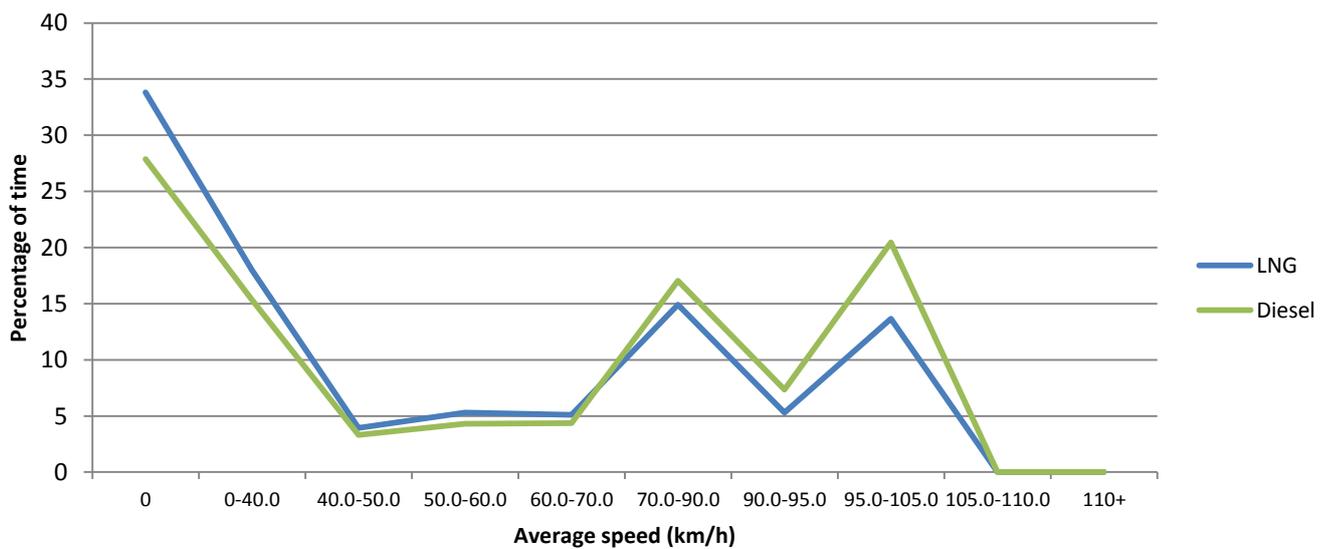


Figure 3
Comparison of LNG and diesel fuel costs

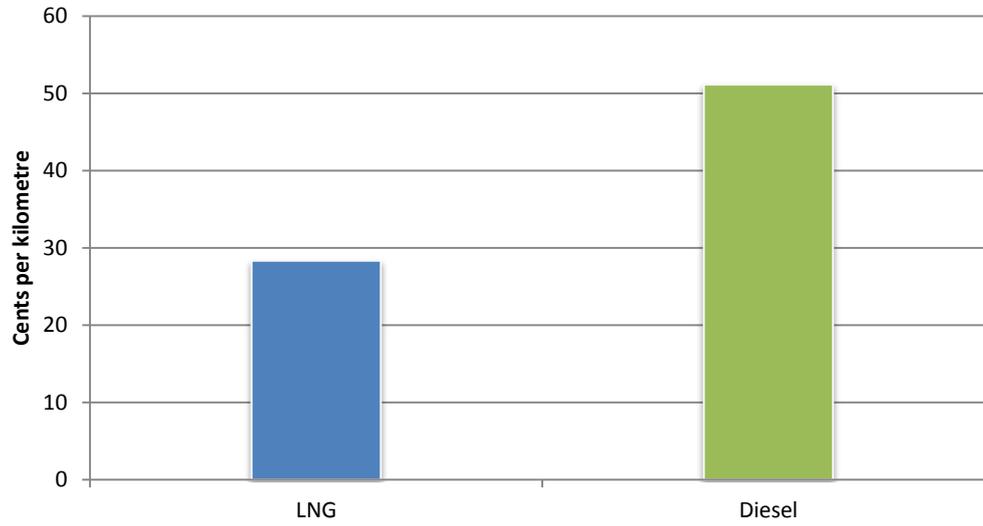


Figure 4
Comparison of LNG and diesel GHG emissions

