Fuel Efficiency Trial

Company: Butler Freight Services Pty Ltd
Industry: Freight Transport
Application: Heavy Truck
Fuel: Enezol Energize Diesel
Report Date: August 23, 2022

Enezol

Objective:

ABMARC (http://www.abmarc.com.au), Australia's premier independent, third-party transport and emissions consultancy, was engaged by our Australian fuel distribution partner, Refueling Solutions (http://www.rfs.com.au) to perform chassis dynamometer tests on a heavy-duty truck for the purposes of determining the fuel consumption benefits of using Enezol Energize Diesel Fuel (ENEZOL) compared to regular diesel fuel.

Test Overview:

A chassis dynamometer located at the Automotive Centre of Excellence, Docklands, Victoria, was used to simulate road loads. Fuel consumption measurements were obtained by using a Coriolis mass flow meter in conjunction with a heat exchanger for fuel temperature conditioning.

The CUEDC simplified drive cycle was used for this assessment, representing city, rural and highway driving conditions.

The road load model applied by the chassis dynamometer simulated a gross vehicle mass of 25,000 kg and aerodynamic and road friction characteristics that are typical for real world driving of the test vehicle and trailer.

The test vehicle was selected by RFS in conjunction with their client Butler Freight Services from their in service fleet. The truck selected was a 2017 Scania P440 prime mover with 12.7 Litre DC13 engine, Scania Overdrive 14 Speed and Scania tandem rear axles. The vehicle presented for the initial test had approximately 220,000 km and had been operating almost exclusively on regular diesel.

Test Sequence:

1. Regular Diesel test on Chassis Dynamometer
2. Engine Conditioning with Enezol Energize Diesel in field
3. Enezol Energize Diesel Fuel test on Chassis Dynamometer

Summary of Results:

Improvements in fuel consumption were observed when using Enezol Energize Diesel instead of regular diesel fuel. Drive cycle testing representing long haul transport, showed a fuel improvement of **4.6%**.

Drive cycle testing representing city transport, showed a fuel improvement of **13.00%**.

Engine idle testing showed a fuel improvement of **50.45%**.

TESTING OVERVIEW

ABMARC was engaged to perform chassis dynamometer tests on a heavy-duty truck for the purposes of determining, with statistical significance, what fuel consumption benefit can be attributed by using Enezol Energize Diesel.

The test program was designed to measure the difference in fuel consumption to demonstrate the potential savings in the real world.

The test vehicle chosen by RFS is representative of a typical heavy-duty truck combination used by operators in Australia. The vehicle was drawn from normal service, with no modifications, ensuring it is a typical heavy truck operating in Australia.

The lubricants used in the vehicle during the testing are approved by the OEM for use in the engine, transmission and axles.

Figure 1. Test vehicle installed on dynamometer

The emphasis throughout the test program was on measurement repeatability, so that small differences between the fuel consumption could be discriminated. The fuel mass flow meter was tested and verified by ABMARC as having repeatability characteristics that are suitable for this purpose.

TEST VEHICLE DATA

Make	Scania
Model	P440 6x4
VIN	YS2P6X40005475875
Date of Manufacture	September 2017
Vehicle Registration	1KS 9VP
ADR Category	NC
ADR Approval Number	32929
Gross Vehicle Mass	25,900 kg
Engine	Scania DC13 12.7 Litre In-Line 6 324kW (440HP) at 1900 rpm 2300Nm (1696 ft-lb) at 1000 ~ 1300 rpm
Transmission	Scania GRSO905R 12 + 2 Speed
Front Axle	Scania AM470
Tandem Rear Axles	Scania ADA 1100 Axle housings Scania RB662/R660 Differentials Ratio 3.42 with power divider and differential locks
Odometer reading	229,961 km

Figure 2. Test vehicle

TESTING SETUP AND METHODOLOGY

Laboratory testing using a chassis dynamometer provided controlled testing conditions, offering the greatest chance of determining differences in fuel consumption. A series of tests were performed, enabling the fuel consumption benefits to be assessed fairly and to provide a statistical confidence interval for the average results obtained.

A comprehensive testing program consisting of multiple repeats of the same drive cycles with the vehicle starting from a warm condition. The number of repeat tests performed was designed to achieve a high confidence interval, based on previous test experience.

The impact of different fuels was assessed based on average fuel consumption in transient and steady state conditions, simulating driving a heavy-duty truck in the Australian environment.

TEST FACILITY DETAILS

Test Facility Name	Kangan Institute Automotive Centre of Excellence (ACE)
Location	1 Batmans Hill Drive, Docklands, VIC 3008, Australia
Dynamometer	Froude Hofmann 2WD, heavy-duty vehicle 2.5m diameter, single roller 522 kW maximum absorbed power
External vehicle cooling fan	Fixed flow rate (not proportional to vehicle speed)
Temperature control of test chamber?	No

KEY MEASUREMENTS

All measurements were recorded at a frequency of 2 Hz

Fuel Consumption	Mass flow rate (kg/h) measured using two Micro Motion Elite Coriolis mass flow meters. Total fuel consumed in each test is determined by integrating the mass flow rate data using a trapezoidal method.
Fuel Temperature	Via Coriolis fuel flow meter
Vehicle On-Board Diagnostic (OBD) Data	Via the vehicle SAEJ1939 OBD communications protocol
Vehicle Speed	Actual vehicle and demand vehicle speed (dynamometer)

FUEL CONSUMPTION MEASUREMENTS

The fuel measurement system was connected to the following fuel lines:

1. Fuel flow to the engine
2. Fuel return from the engine

This allowed the net fuel consumption to be measured with two fuel flow meters. Typically, a single flow meter is used for ABMARC's fuel consumption testing, however this vehicle appeared particularly sensitive to changes in the fuel system setup and a dual flow meter setup was utilized.

Figure 3. Fuel Flow meter set-up

DYNAMOMETER SETUP

The table below details the road load coefficients that were applied to the dynamometer.

These are the values used by the (US) National Vehicle & Fuel Emissions Chassis dynamometer (US EPA, 2017) to simulate a prime mover with similar aerodynamics to the test vehicle towing a trailer with a 27-tonne gross vehicle mass. The coefficients are used to determine the rolling friction and aerodynamic friction to be applied by the dynamometer

F0 (N)	1546.0
F1 (N/km/h)	0.0
F2 (N/km/h2)	0.4306

To simulate the test vehicle towing a laden trailer and provide the most realistic indication of fuel consumption in the real world, the maximum inertia possible was simulated by the dynamometer while minimizing tire slippage on the rollers.

The simulated vehicle inertia was reduced from the initial 27,000 kg to 25,000 kg to reduce tire slippage on the dynamometer. This represented the gross vehicle mass simulated throughout the fuel consumption test.

Vehicle Inertia (kg)	25,000

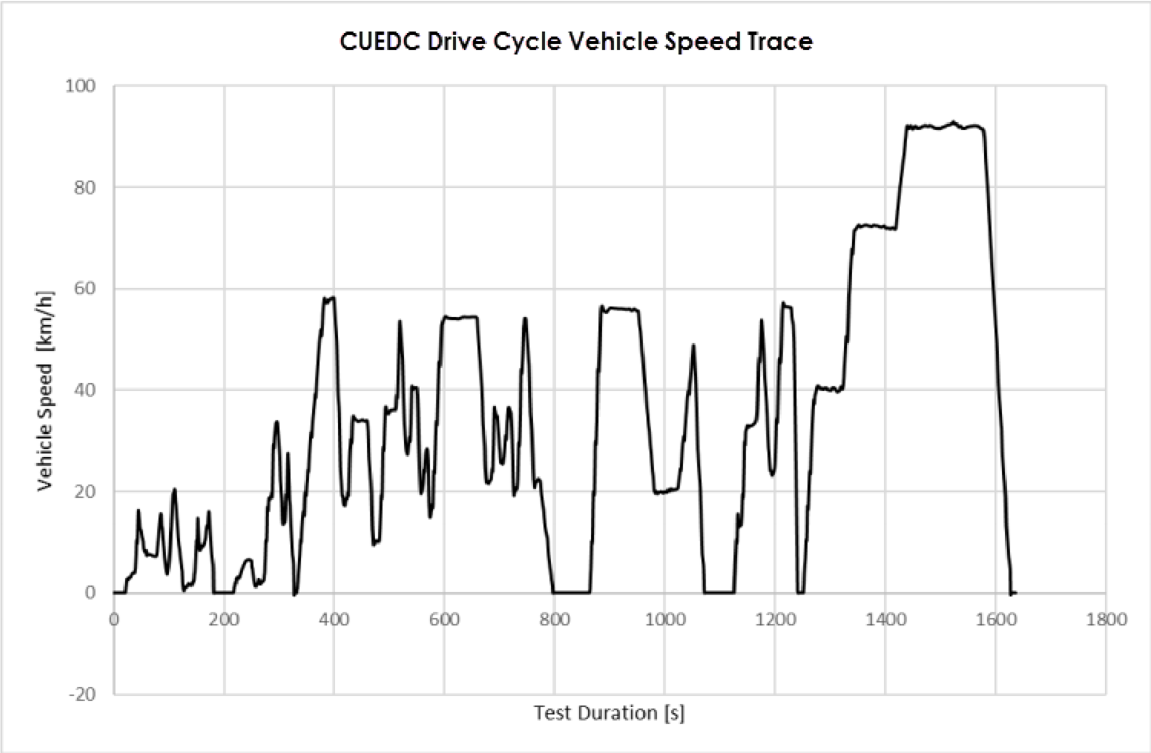
TEST PREPARATION

- The truck was delivered to the test facility after servicing by Butler Freight
- Prior to testing, fault codes were checked via the vehicle’s OBD system. No faults relating to the emission system or engine operation were found to be active.
- Vehicle tire pressures were checked and set to 85 psi, before running a dynamometer coast down and calibration with the vehicle removed from the rollers.
- Prior to running the main tests for each fuel, the vehicle was warmed up, ensuring that engine oil had reached at least 90 °C.
- Vehicle warm-up consisted of a combination of driving at steady-state speeds and driving the dynamic drive cycle.
- During all tests the cabin air conditioning (A/C) remained switched off.
- To aid repeatability, a professional test driver with experience in fuel consumption and emissions testing was used for the dynamic drive cycle tests.

TESTS PERFORMED

The CUEDC - Simplified Composite Urban Emissions Drive Cycles, was used to simulate driving in Australian traffic conditions, covering a variety of speeds and realistic acceleration/braking conditions encountered.

The following chart shows the dynamic drive cycle vehicle speed trace:



The drive cycle has the following characteristics:

Duration	1700 s (28 min)
Total Distance	15.6 km
Maximum Speed	92 km/h
Average Speed	32 km/h

To obtain statistical confidence level for the results, 8 test runs of the drive cycle were performed for each fuel configuration. The last 4 tests for each fuel were used for analysis. This level of vehicle conditioning is required to ensure the axle oil is fully warm and does not impact results.

EVALUATION RESULTS

Fuel Consumption

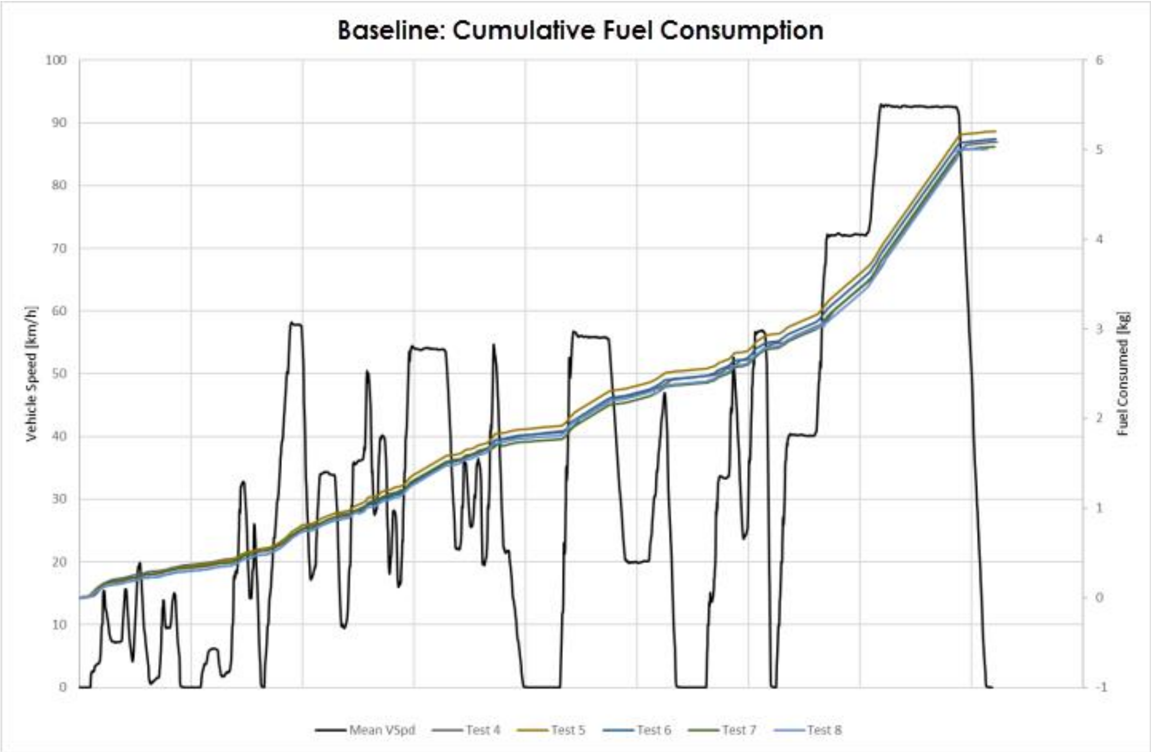
The drive cycle test results representing long-haul transport, showed a 4.6% reduction in fuel consumption using ENEZOL compared to using regular diesel fuel.

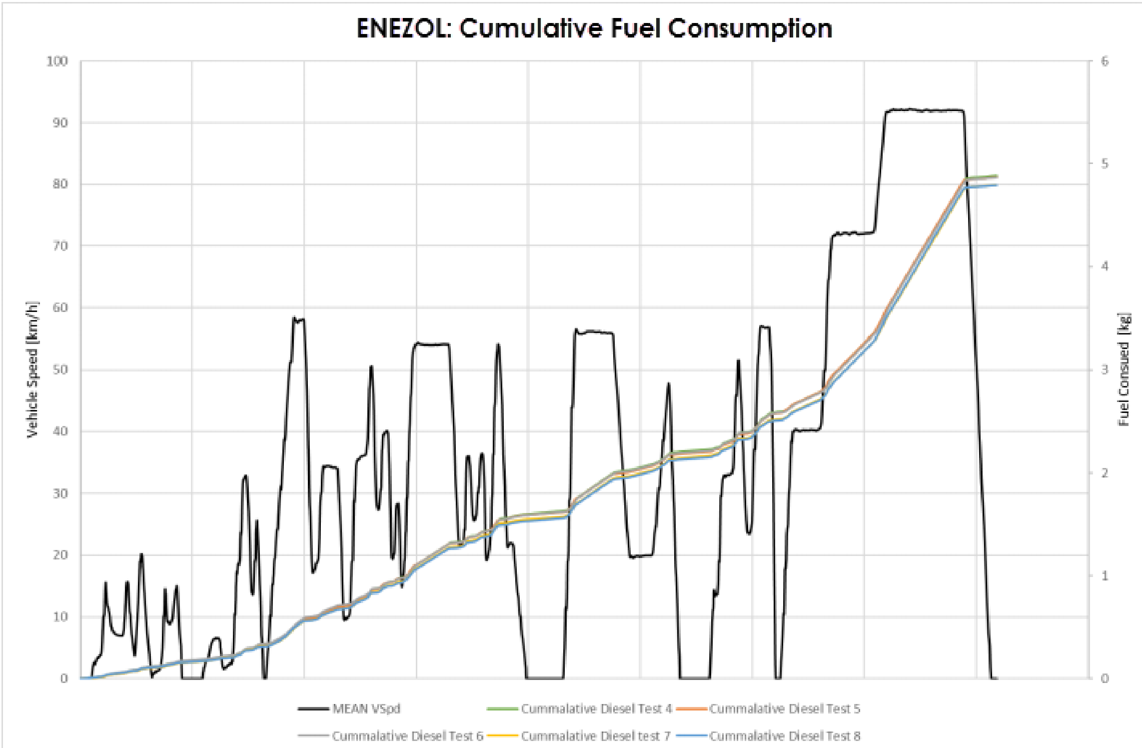
The drive cycle test results representing city transport, showed a 13.00% reduction in fuel consumption using ENEZOL compared to using regular diesel fuel.

Furthermore, by analyzing the engine idling fuel consumption data, a 50.45% reduction in idling fuel consumption was observed, using ENEZOL compared to using regular diesel fuel.

There is a 95% confidence that these fuel consumption reductions can be attributed to using Enezol Energize Diesel compared to regular diesel fuel.

To demonstrate the repeatability of fuel measurement throughout each drive cycle, the following two charts show the fuel consumption as a cumulative value for regular diesel fuel and ENEZOL respectively.




ENEZOL: Cumulative Fuel Consumption
Vehicle Speed [km/h]
Fuel Consued [kg]
100
90
80
70
60
50
40
30
20
10
0
6
5
4
3
2
1
0
MEAN VSpd
Cummalative Diesel Test 4
Cummalative Diesel Test 5
Cummalative Diesel Test 6
Cummalative Diesel test 7
Cummalative Diesel Test 8

FURTHER ANALYSIS

With Enezol Energize Diesel fuel showing significant performance improvements at engine idle speeds, we investigated what effect this could have on total fuel consumption.

Our findings indicate engine idle fuel consumption has a sizeable impact on total fuel consumption and carbon emissions. The following table contains conservative estimates of daily engine idling across a range of heavy vehicle types:

Vehicle Type	Daily Operation	Total Daily Idle	Total Daily Idle Time	Idle Fuel Consumption per hour (GPH)	Total Daily Idle Fuel Consumption
Transit Bus	9.04 hrs	40.86%	3.69 hrs	0.8	2.95 gallons
Refuse	5.19 hrs	48.04%	2.49 hrs	0.8	1.99 gallons
Single-Unit Short-Haul	3.07 hrs	33.80%	1.03 hrs	0.8	0.82 gallons
Combo-Unit Short-Haul	6.55 hrs	32.76%	2.14 hrs	0.8	1.71 gallons
Combo-Unit Long-Haul	9.64 hrs	27.86%	2.68 hrs	0.8	2.14 gallons

Table source: EPA & National Renewable Energy Laboratory - US Dept. of Energy

Furthermore, the US Department of Energy estimates close to 1 billion gallons of diesel fuel are burned by long haul trucks in the US each year, simply from idling.

This results in the emission of approximately 11 million tons of carbon dioxide, 55,000 tons of nitrogen oxides and 400 tons of particulate matter annually in the US.

Taking action to reduce engine idle fuel consumption can significantly reduce carbon emissions, as well as provide financial savings to vehicle operators.

Enezol Weighted Fuel Savings

Enezol Energize Diesel fuel demonstrated reductions in fuel consumption in real-world driving conditions.

By analyzing fuel consumption at idle and across various dynamic vehicle conditions, we find overall fuel savings for city driving conditions and long haul driving conditions, better than the performance figures measured above.

This is because idle time represents a sizeable percentage of daily use, across a range of heavy vehicle types.

To illustrate this point, the following examples isolate engine idle fuel consumption from total fuel consumption and then present the combined savings as a weighted total.

For fuel savings calculations, the established Enezol Energize Diesel performance figures are used: 50.45% fuel savings rate for idle, 13.00% fuel savings rate for city transport and 4.6% fuel savings rate for long haul transport.

City Transit Bus Example

Annual Fuel Consumption using standard diesel fuel per bus:

Total Idle Time	Idle Fuel Rate per Hour	Idle Fuel Used	Drive Fuel Used	Total Fuel Used
971 hours	0.8 gallons	776.8 gallons	6653 gallons	7429.8 gallons

Data sources: EPA, US Dept of Energy & Winnipeg Transit

Annual Fuel Consumption using Enezol Energize Diesel per bus:

Idle Fuel Used	Drive Fuel Used	Total Fuel used	% Fuel Savings
384.90 gallons	5788.11 gallons	6173.01 gallons	16.92%

Refuse Truck Example

Annual Fuel Consumption using standard diesel fuel per truck:

Total Idle Time	Idle Fuel Rate per Hour	Idle Fuel Used	Drive Fuel Used	Total Fuel Used
960 hours	0.8 gallons	768 gallons	7232 gallons	8000 gallons

Data sources: EPA, US Dept of Energy, Waste Management Inc

Annual Fuel Consumption using Enezol Energize Diesel per truck:

Idle Fuel Used	Drive Fuel Used	Total Fuel used	% Fuel Savings
380.54 gallons	6291.84 gallons	6672.38 gallons	16.60%

Long Haul Truck Example

Annual Fuel Consumption using standard diesel fuel per long haul truck:

Total Idle Time	Idle Fuel Rate per Hour	Idle Fuel Used	Drive Fuel Used	Total Fuel Used
1800 hours	0.8 gallons	1440 gallons	15909 gallons	17349 gallons

Data sources: EPA, US Dept of Energy, American Trucking Associations

Annual Fuel Consumption using Enezol Energize Diesel per long haul truck:

Idle Fuel Used	Drive Fuel Used	Total Fuel used	% Fuel Savings
713.52 gallons	15177.19 gallons	15890.71 gallons	8.41%

CONCLUSION

A heavy-duty on-road truck was drawn from normal service within Australia and prepared for chassis dynamometer testing under controlled conditions.

Repeatable fuel consumption measurements were obtained from multiple tests using a CUEDC drive cycle representing congested, city and highway/freeway driving in real-world Australian city traffic conditions.

By precisely measuring the fuel consumption with a 95% confidence, the following is concluded:

1. For long haul transport, a 4.6% reduction in fuel consumption was achieved using Enezol Energize Diesel fuel.

2. For city transport, a 13.00% reduction in fuel consumption was achieved using Enezol Energize Diesel fuel.

3. In engine idling conditions, a 50.45% reduction in fuel consumption was achieved using Enezol Energize Diesel fuel.

Furthermore, by analyzing fuel consumption at idle and across various dynamic vehicle conditions, we find the Enezol weighted fuel savings for city driving conditions and long haul driving conditions are better than the performance figures mentioned above.