Newcastle City Council Biodiesel Trial

Emissions Testing Program

Final Report

December 2004

Vehicle Emissions Management
Roads and Traffic Authority
Centennial Plaza
260 Elizabeth Street
Surry Hills 2010

Table of Contents

EXECUTIVE SUMMARY

This report presents the results of exhaust emission, fuel consumption and power tests on twelve diesel engine vehicles from Newcastle City Council using diesel, filtered diesel and biodiesel fuels.

The fuel used as the reference for this program was regular automotive diesel (less than 500ppm sulphur). The filtered diesel tested was also regular automotive diesel. The biodiesel fuel tested was a B20 blend (20% biodiesel and 80% diesel).

The twelve vehicles used included light duty four-wheel drives, light and medium duty trucks and garbage collection vehicles. The gross mass of the test vehicles ranged from 2.73 tonnes to 24 tonnes and they were all built between 1993 and 2002.

The vehicles were tested using the dynamometer test method and equipment specified in the National Environment Protection (Diesel Vehicle Emissions) Measure for in-service vehicles – the DT80 test. Measurements of smoke opacity, particulate matter (PM), oxides of nitrogen (NOx), carbon dioxide (CO2) and power at 80 kph were taken. Fuel consumption was calculated from the CO2 results using the carbon balance method. The results of tests using regular automotive diesel, filtered diesel and B20 biodiesel were compared.

For filtered diesel it was found that there was no significant affect on exhaust emissions, fuel consumption and power at 80 kph.

For B20 biodiesel fuel it was found that significant reductions were achieved for:

- Smoke (30%)
- PM emissions (39%)

B20 biodiesel fuel had no significant affect on NOx and CO2 emissions, fuel consumption and power at 80 kph.

The benefits for B20 biodiesel fuel are consistent with other research reported by the United States Environment Protection Agency (US EPA). The US EPA reported that there are definite benefits for smoke and PM emissions with the use of B20 biodiesel.

1.0 INTRODUCTION

This report describes a project, which was designed to evaluate the effect on exhaust emissions of diesel engine vehicles operated by Newcastle City Council if the fuel they use is changed from diesel fuel to a mixture of biodiesel and diesel.

2.0 BACKGROUND

Diesel vehicles make a disproportionately high contribution to air pollution from the transport sector. Emissions from diesel vehicles have the potential to cause adverse health effects and detract from urban amenity.

Fuel quality has been shown to have a significant effect on the emissions of a diesel vehicle. Biodiesel may offer both greenhouse and air quality benefits when used in combination with diesel or alone.

Newcastle City Council propose operating their fleet of diesel cars, trucks and plant on biodiesel rather than the diesel fuel, which is presently used. The Council received funding from the NSW Department of Environment and Conservation for a trial, which was primarily intended to demonstrate the practicality of operating their fleet on a mix of 20 percent biodiesel and 80 percent diesel (B20). With funding support from the Federal Government through the Department of the Environment and Heritage, the Roads and Traffic Authority (RTA) have provided emissions testing services to enable a comparison of the emissions performance of the fuels to be made

A recent paper by the United States Environment Protection Authority[1] has also reported on the results of testing of biodiesel and it is understood these test results have informed the Newcastle City Council decision to use B20 rather than other biofuel blends.

Newcastle City Council were also interested in the emissions benefits that may be obtained by passing fuel through a fine filter before it is used. Literature provided to Council officers by filter manufacturers, Filter Technology indicated that the Council could reduce fuel usage and reduce exhaust emissions by installing in-line filtering at the bowser. The Council proposed testing the effect of this filtration process on diesel and on biodiesel.

3.0 PROJECT DESIGN

The emissions testing program was designed to establish the effects on tailpipe emissions of oxides of nitrogen (NOx), particulate (PM), smoke (opacity) and carbon dioxide (CO_2) emissions if filtered diesel or B20 biodiesel, rather than diesel, is used in the Council's vehicle fleet. Some measurements were also made to assess the effect of the fuel change on fuel consumption (FC) and maximum power at 80 kilometres per hour.

The impact of the fuel change on engine and fuel system wear, engine life and operability or noise or odours is outside the scope of the emission testing program.

In this test program it was proposed to use regular automotive diesel as the reference fuel and to use the B20 blend supplied by the successful proponent in the Council's tender process.

[1] A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions EPA420-P-02-001 October 2002

4.0 EXPERIMENTAL AND TESTING PROTOCOL

4.1 Test Program

The test program included:

For Phase 1:

- Undertaking emission tests on a selection of vehicles fuelled from Council's works depot diesel bowsers using regular diesel fuel;
- Installation of in-line *Filter Technology* filters at the works depot diesel bowsers;
- Undertaking emission tests to determine the effect of filtering the diesel;
- Filling the Council's works depot diesel tanks with B20 fuel;
- Undertaking emission tests to determine the effect of the use of B20 fuel.

For Phase 2:

- Undertaking emission tests on a selection of vehicles using regular diesel fuel;
- Undertaking emission tests on the same vehicles using B20 biodiesel to determine the effect of the use of B20 fuel.

4.2 Test Method

The test method used for this project was the DT80 test as outlined in Appendix A.

4.3 Test Vehicles

Details of the twelve test vehicles are provided in Appendix B.

4.4 Test Fuels

The test fuels were:

- Regular automotive diesel with less than 500ppm sulphur. The diesel for this program was supplied to Newcastle City Council by a local fuel distributor under the NSW State Government's fuels contract which requires that fuel supplied under that contract be in accordance with the Fuel Standard (Automotive Diesel) Determination 2001 made under the Fuel Quality Standards Act 2000.
- B20 biodiesel: a blend of 20 percent biodiesel and 80 percent standard automotive diesel. A local fuel distributor also supplied the B20 biodiesel for this program to Newcastle City Council. It was supplied under contract, which required that the fuels used to blend the B20 biodiesel meet the respective Australian standards for diesel and biodiesel. There is no Australian standard for B20 biodiesel.

4.5 Tailpipe Emissions

Tailpipe emissions measured were:

- Smoke opacity (average)
- Particulate matter (PM)
- Oxides of Nitrogen (NOx)
- Carbon dioxide (CO2)

Fuel consumption was calculated from the carbon dioxide results using the carbon balance method.

4.6 Other Parameters

A number of parameters were also measured and recorded during testing for quality assurance and for use in determining emissions. They are not reported but included:

- Ambient temperature, relative humidity and barometric pressure

- Test duration
- Diluted exhaust sample temperature

The effect of fuel type on engine power at 80 kilometres per hour was measured by conducting power curve measurements for each vehicle and fuel type.

4.7 Testing Sequence

The testing sequence for Phase 1 is set out in Table 1 below. It assumes that the test vehicle has been installed on the dynamometer.

Table 1: Testing sequence

Test Cycle	Fuel	Comment
DT80	Diesel	Conditioning cycle and engine warm-up.
Idle	Diesel	Allows for data recording and resetting instruments
DT80	Diesel	Testing cycle.
Idle	Diesel	Allows for data recording and resetting instruments
DT80	Diesel	Testing cycle.
		Refuel with filtered diesel and operate for sufficient time to flush system. For most vehicles this was two to three days before the test was repeated.
DT80	Filtered Diesel	Conditioning cycle.
Idle	Filtered Diesel	Allows for data recording and resetting instruments
DT80	Filtered Diesel	Testing cycle.
Idle	Filtered Diesel	Allows for data recording and resetting instruments
DT80	Filtered Diesel	Testing cycle.
		Refuel with B20 and operate for sufficient time to flush system. For most vehicles this was about one week before the test was repeated.
DT80	Filtered B20	Conditioning cycle.
Idle	Filtered B20	Allows for data recording and resetting instruments
DT80	Filtered B20	Testing cycle.
Idle	Filtered B20	Allows for data recording and resetting instruments
DT80	Filtered B20	Testing cycle.

For Phase 2 the test sequence consisted of diesel and B20 biodiesel.

4.8 Data Analysis and Reporting

For each of the vehicles in the testing program two test cycles were run on each fuel as per Table 1 for both Phase 1 and Phase 2 testing. Comparisons between the fuels were made on the basis of the average result for the two tests on each vehicle.

The effect of fuel on power was determined in a similar fashion.

5.0 PROJECT OVERVIEW

Diesel Test Australia (DTA) were contracted to provide testing services to the Roads and Traffic Authority for this project. They in turn engaged the services of Intertek to undertake fuel analysis.

DTA commenced testing Newcastle City Council's fleet for Phase 1 on September 30, 2003 after setting up their equipment at Council's Work Depot in the Newcastle suburb of Waratah. By October 3, 2003 twelve trial vehicles from Newcastle City Council had been

tested on diesel. Between October 3, 2003 and October 8, 2003 ten of the twelve Newcastle City Council's trial vehicles were tested on filtered diesel.

DTA commenced the Phase 1 B20 biodiesel testing on November 12, 2003. By November 13, 2003 they had retested the twelve trial vehicles while operating on B20 biodiesel. The results for Phase 1 testing are contained in Appendix C1.

Phase 2 testing commenced on May 13, 2004 and was carried out by DTA at the premises of Mountain Industries on Kooragang Island in Newcastle harbour. The same twelve Newcastle City Council vehicles from Phase 1 were used during Phase 2 testing. The vehicles were tested on diesel fuel first and then tested on B20 biodiesel over the period May 13, 2004 to May 20, 2004. At the conclusion of the diesel tests each vehicle was refuelled with B20 biodiesel and operated on the road for several days before undergoing the B20 biodiesel test. The results for the tests on diesel and B20 biodiesel for these vehicles are contained in Appendix C2.

6.0 RESULTS

6.1 Diesel versus Filtered Diesel – Phase 1

Fuel samples were taken for analysis. The laboratory analysis report for the diesel sample and the filtered diesel sample indicates compliance with the Australian standard for automotive diesel set under the Fuel Quality Standards Act 2000.

During Phase 1 testing a problem developed with the measurement of oxides of nitrogen (NOx). Hence, no NOx results have been reported for Phase 1.

Ten vehicles were tested on both diesel and filtered diesel during Phase 1 with two tests carried out on each fuel. Figures 1 to 5 in Appendix D1 show the average results for the two tests while the Appendix also includes detailed discussion of the results.

Table 2 provides a summary of the overall mean results for the ten vehicles. An *analysis of variance* performed on the data indicates that there was no statistically significant difference in the mean value for diesel and filtered diesel at a 0.05 level of significance for the ten vehicles tested.

Table 2: Mean results for diesel and filtered diesel for all vehicles – Phase 1

	Average Opacity (%)	PM (mg/km/t)	CO2 (g/km)	FC (L/100km)	Power (kW) (at 80 kph)
Diesel	8.15	53.2	779.3	29.0	72.9
Filtered diesel	7.40	41.8	792.8	29.5	72.9
% Change	-9.1%	-21.5%	+1.7%	+1.7%	0.0%
Are means statistically different	No	No	No	No	No

6.2 Diesel versus B20 Biodiesel – Phase 1

As mentioned in Section 6.1 above, the diesel fuel complied with the Australian standard. There is no standard for B20 biodiesel.

Twelve vehicles were tested on both diesel and B20 biodiesel during Phase 1. Figure 6 to Figure 10 in Appendix D2 show the smoke opacity, particulate matter (PM), carbon dioxide (CO2), fuel consumption (FC) and maximum power at 80kph results for the average of the

tests. Appendix D2 includes detailed discussion of the results. As mentioned previously there are no NOx results for Phase 1.

Table 3 presents a summary of the overall mean results averaged across the twelve vehicles for B20 biodiesel compared to diesel for Phase 1. An *analysis of variance* performed on the data indicates that at a 0.05 level of significance there was a statistically significant difference in the mean values of average opacity and particulate emissions for the two fuels. The reduction in average opacity and particulate emissions was 28% and 39% respectively. An *analysis of variance* indicates that at a 0.05 level of significance there was no significant difference between diesel and B20 biodiesel fuels for carbon dioxide, fuel consumption and power at 80 kph.

Table 3: Mean results for diesel and B20 biodiesel for all vehicles – Phase 1

	Average Opacity (%)	PM (mg/km/t)	CO2 (g/km)	FC (L/100km)	Power (kW) (at 80 kph)
Diesel	7.17	46.2	914.1	34.0	76.5
B20 biodiesel	5.20	28.1	910.5	36.2	75.7
% Change	-27.5%	-39.2%	-0.4%	+6.5%	-1.0%
Are means statistically different	Yes	Yes	No	No	No

6.3 Diesel versus B20 Biodiesel – Phase 2

Analysis of the diesel fuel sample indicated the diesel fuel complied with the standard.

Twelve vehicles were tested on both diesel and B20 biodiesel during Phase 2. Figure 11 to Figure 16 in Appendix D3 show the average results for smoke opacity, particulate matter (PM), oxides of nitrogen (NOx), carbon dioxide (CO2), fuel consumption (FC) and maximum power at 80kph for each of the vehicles. Appendix D3 also includes detailed discussion of the results.

Table 4 presents a summary of the overall mean results for B20 biodiesel compared to diesel for Phase 2. An *analysis of variance* performed on the data indicates that at a 0.05 level of significance there was a statistically significant difference in the mean values of average opacity and particulate emissions for the two fuels. The reduction in average opacity and particulate emissions was 34% and 38% respectively. An *analysis of variance* indicates that at a 0.05 level of significance there was no significant difference between diesel and B20 biodiesel fuels for carbon dioxide, oxides of nitrogen, fuel consumption and power at 80 kph.

Table 4: Mean results for diesel and B20 biodiesel for all vehicles – Phase 2

	Average Opacity (%)	PM (mg/km/t)	NOx (g/km/t)	CO2 (g/km)	FC (L/100km)	Power (kW) (at 80 kph)
Diesel	5.78	41.4	0.49	942.1	35.1	76.4
B20 biodiesel	3.82	25.8	0.53	931.4	37.1	75.9
% Change	-34.0%	-37.7%	+7.2	-1.1%	+5.7%	-0.6%
Are means statistically different	Yes	Yes	No	No	No	No

6.4 Diesel versus B20 Biodiesel – Combined Phases 1 and 2

The results for Phase 1 and Phase 2 have been combined and averaged. The mean results are presented in Table 5.

Table 5: Mean results for diesel and B20 biodiesel for all vehicles – Phase 1 and Phase 2

	Average Opacity (%)	PM (mg/km/t)	NOx (g/km/t)	CO2 (g/km)	FC (L/100km)	Power (kW) (at 80 kph)
Diesel	6.48	43.8	0.49	928.1	34.5	76.4
B20 biodiesel	4.51	27.0	0.53	920.9	35.7	75.8
% Change	-30.4%	-38.5%	+7.2	-0.8%	+3.2%	-0.8%
Are means statistically different	Yes	Yes	No	No	No	No

The mean results for average opacity and PM for diesel and B20 biodiesel were statistically different at a 0.05 significance level. Particulate emissions were reduced by 39% across the test fleet while smoke opacity showed a similar trend with a reduction of 30%. The impact of these results for Newcastle City Council is a significant reduction in smoke and particulate emissions if B20 biodiesel were to be used across the whole diesel fleet. The reduction for PM is within the range given in the US EPA report cited earlier but is somewhat greater than the reported average of about 12% for a 20% biodiesel blend. The US EPA report did not provide any information on smoke opacity.

While it can be seen that there is a difference in the means for oxides of nitrogen, carbon dioxide, fuel consumption and power at 80 kph an *analysis of variance* indicates that at a 0.05 level of significance there was no significant difference between diesel and B20 biodiesel fuels for these parameters.

7.0 CONCLUSIONS

Testing for Newcastle City Council's biodiesel trial show that:

Filtering diesel fuel prior to dispensing into a vehicle's fuel tank had no significant affect on exhaust emissions, fuel consumption and power (at 80 kph).

For B20 biodiesel it was found that significant reductions were achieved for:

- Smoke (30%)
- PM emissions (39%)

The B20 biodiesel fuel had no significant affect on NOx emissions, CO2 emissions, fuel consumption and power at 80kph.

The benefits for B20 biodiesel fuel are consistent with other research reported by the United States Environment Protection Agency (US EPA). The US EPA reported that there are definite benefits for smoke and PM emissions with the use of B20 biodiesel.

APPENDIX A: DT80 Test

A1 Test Procedure

Before each test record vehicle details and conduct a pre-test safety inspection.

- Secure vehicle on dynamometer. Vehicles should be tested using the fuel present in the vehicle tank when it is submitted for testing.
- Set dynamometer to simulate the correct load and inertia for the vehicle under test.
- Start sampling
- Idle for 60 seconds
- Accelerate rapidly to 80 km/hr under simulated inertia using wide open throttle
- Decelerate by removing all pressure from the accelerator pedal and gently applying brakes to standstill
- Idle for 10 seconds
- Accelerate rapidly to 80 km/hr under simulated inertia using wide open throttle
- Decelerate by removing all pressure from the accelerator pedal and gently applying brakes to standstill
- Idle for 10 seconds
- Accelerate rapidly to 80 km/hr under simulated inertia using wide open throttle
- Maintain speed at 80 km/hr for 60 seconds – stop sampling. Bring vehicle to rest.

A2 Test Equipment

The test system has been designed to enable transportation to any site and to allow quick deployment. The system consists of the following:

- Chassis dynamometer
- Sample handling system
- Emissions instrumentation
- Data acquisition/reporting system

The dynamometer has:

- Twin rollers for easy wheel positioning and security
- Idler rollers for bogie axle vehicles
- 14 tonne axle load capacity
- Modular assembly and quick disconnect/tie down system
- A drivers aid with test instructions and dynamometer output display
- Inertia simulation on acceleration
- Real-time data acquisition and printout

With the exception of the sample used for opacity measurement the vehicle exhaust is diluted and the emissions analysers draw samples from the dilution tunnel.

- The particulate matter sample is kept below 125°F (51.7°C) in accordance with U.S. EPA CFR specifications and is measured using a laser light photometer calibrated for the particle size range found in diesel exhausts.

- NOx is calculated from the measurement of NO and corrected for atmospheric conditions at the test site and time of sampling in accordance with U.S. EPA light-duty in-service testing protocols. As NO is the actual pollutant measured on which NOx is calculated there is no deterioration of the sample due to the NO_2 dissolving in water condensation.

- Atmospheric conditions (air temperature, pressure and relative humidity) are measured and recorded during each test to enable the results to be corrected to standard temperature and pressures.

- Smoke is measured using a partial flow opacimeter sampling raw exhaust. Percentage opacity is measured continuously and average and maximum opacities are calculated from this data.

The data acquisition system is designed to enable results to be calculated on site at the completion of a test.

A3 Data Collected

A3.1 Pre-Test Data

Table A1 details the data to be collected on each vehicle before testing is commenced. Apart from any adjustments to enable safe operation of the vehicle during the test, the person undertaking the pre-test inspection shall not undertake any work to alter the "as delivered" condition of the vehicle, as this would defeat the objective of assessing real world emissions.

Table A1: Pre-Test Data – Item To Be Provided

Vehicle Details	
Registration Number	
Vehicle Make	
Vehicle Model	
Odometer reading	…….....km
Compliance Date	
Tare Mass & GVM	
Test Mass	
Fuel type	

A3.2 Test Data

Table A2 details the data to be collected from each vehicle undergoing the vehicle testing.

Table A2: Test Data To Be Provided

Time vehicle arrives	Hr:min
Time test commences	Hr:min
Test duration	Seconds
Distance travelled during test	Km
NOx emissions	g/km & g/km/tonne
Particulate mass emissions	g/km & g/km/tonne
Smoke emissions	Average & maximum (% opacity)
Time vehicle departs	Hr:min
Second by second data for the above pollutants matched to the respective speed trace	
Comments on any operational issues	

APPENDIX B: Test Vehicles

B1 Newcastle City Council

Fleet No:	Vehicle Description	Manufacturer Model	Engine	Transmission Auto. or Man.	Power (kW)	Year of Manufactured	Tare (kg)	GVM (kg)	Test Mass (kg)
Light Vehicles									
2307	Van	Volkswagen	Volkswagen (Audi) Turbo	Manual	75	2002	1650	2800	2225
2157	4WD Tray body	Nissan Patrol	Nissan	Manual	116	2002	1800	3400	2600
2404	Dual Cab Ute 2wd	Toyota	3.0 Lt Diesel	Manual	71	1998	1550	2730	2140
1769	2 tonne Ganger Truck	Mitsubishi	Mitsubishi	Manual	85	2000	3160	4495	3827.5
2472	2 tonne Ganger Truck	Daihatsu	Toyota	Manual	71	2002	3020	4450	3735
Trucks									
183	10 tonne tipper	International	Cummins	Manual	175	1993	9140	23500	16320
1760	10 tonne tipper	Isuzu FVZ	Isuzu	Auto	206	2000	9060	24000	16530
57	6 tonne tipper	Isuzu FSR 700S	Isuzu	Manual	150	1998	5500	11990	8745
1671	6 tonne tipper	Hino	Hino	Manual	150	1999	5760	11900	8830
687	3 tonne tipper	Isuzu NPR 400	Isuzu	Manual	98	1996	4020	7300	5660
1904	Side Loading Garbage Truck	International	Cummins	Auto	187	2001-2002	12280	24000	18140
824	Rear loading garbage truck	UD PK250	UD	Auto	186	1998	10040	16000	13020

APPENDIX C: Emission Test Data

C1 Phase 1 Results

Fleet No	Vehicle Make	Vehicle Model	Odometer (km)	Fuel Type	Council	Test Number	Test Date	Rego Number	Average Opacity (%)	PM (mg/km/t)	CO2 (g/km)	FC (L/100km)	Max Power (kW at 80kph)
2307	VW	Transporter	31702	Diesel	Newcastle	008100-1	07-10-03	ALM 32M	7.26	96.21	480.09	17.86	55.5
2307	VW	Transporter	31702	Diesel	Newcastle	008101-1	07-10-03	ALM 32M	6.93	87.50	445.04	16.56	55.5
2307	VW	Transporter	31739	Filtered Diesel	Newcastle	008123-1	08-10-03	ALM 32M	5.98	60.84	443.76	16.51	57.6
2307	VW	Transporter	31739	Filtered Diesel	Newcastle	008124-1	08-10-03	ALM 32M	6.00	62.24	452.85	16.85	57.6
2307	VW	Transporter	33302	B20 Biodiesel	Newcastle	008264-1	12-11-03	ALM 32M	6.90	50.44	474.31	18.87	56
2307	VW	Transporter	33302	B20 Biodiesel	Newcastle	008266-1	12-11-03	ALM 32M	7.01	60.48	476.07	18.94	56
183	International	Acco 2350E	233127	Diesel	Newcastle	008047-1	01-10-03	SPS 101	11.32	41.39	1174.91	43.72	115.9
183	International	Acco 2350E	233127	Diesel	Newcastle	008048-1	01-10-03	SPS 101	11.73	37.28	1161.10	43.20	115.9
183	International	Acco 2350E	233314	Filtered Diesel	Newcastle	008112-1	07-10-03	SPS 101	11.45	47.38	1231.18	45.81	116.1
183	International	Acco 2350E	233314	Filtered Diesel	Newcastle	008113-1	07-10-03	SPS 101	10.12	38.72	1212.66	45.12	116.1
183	International	Acco 2350E	235828	B20 Biodiesel	Newcastle	008310-1	13-11-03	SPS 101	9.16	37.35	1150.10	45.76	118.5
183	International	Acco 2350E	235828	B20 Biodiesel	Newcastle	008311-1	13-11-03	SPS 101	8.02	29.97	1152.08	45.84	118.5
687	Isuzu	NPR 66	139139	Diesel	Newcastle	008050-1	01-10-03	UGS 527	8.82	35.47	647.67	24.10	49.8

Fleet No	Vehicle Make	Vehicle Model	Odometer (km)	Fuel Type	Council	Test Number	Test Date	Rego Number	Average Opacity (%)	PM (mg/km/t)	CO2 (g/km)	FC (L/100km)	Max Power (kW at 80kph)
687	Isuzu	NPR 66	139139	Diesel	Newcastle	008051-1	01-10-03	UGS 527	9.27	29.90	659.60	24.54	49.8
687	Isuzu	NPR 66	139139	Filtered Diesel	Newcastle	008103-1	07-10-03	UGS 527	10.20	38.90	640.69	23.84	49.5
687	Isuzu	NPR 66	139139	Filtered Diesel	Newcastle	008104-1	07-10-03	UGS 527	9.46	37.40	647.23	24.08	49.5
687	Isuzu	NPR 66	140920	B20 Biodiesel	Newcastle	008293-1	13-11-03	UGS 527	7.06	31.70	642.38	25.56	50.5
687	Isuzu	NPR 66	140920	B20 Biodiesel	Newcastle	008294-1	13-11-03	UGS 527	6.58	25.49	663.26	26.39	50.5
824	Nissan	PKC 310	14255	Diesel	Newcastle	008041-1	01-10-03	VIH 583	3.14	16.59	1402.92	52.20	92.2
824	Nissan	PKC 310	14255	Diesel	Newcastle	008042-1	01-10-03	VIH 583	3.13	14.50	1379.99	51.35	92.2
824	Nissan	PKC 310	146742	B20 Biodiesel	Newcastle	008284-1	12-11-03	VIH 583	2.56	17.34	1378.94	54.86	80
824	Nissan	PKC 310	146742	B20 Biodiesel	Newcastle	008285-1	12-11-03	VIH 583	2.39	14.00	1349.26	53.68	80
1671	Hino	GD1J	50886	Diesel	Newcastle	008033-1	30-09-03	WJH 366	3.47	11.76	910.82	33.89	113
1671	Hino	GD1J	50886	Diesel	Newcastle	008034-1	30-09-03	WJH 366	3.61	11.47	894.37	33.28	113
1671	Hino	GD1J	50902	Filtered Diesel	Newcastle	008106-1	07-10-03	WJH 366	4.00	14.12	930.52	34.62	110.8
1671	Hino	GD1J	50902	Filtered Diesel	Newcastle	008107-1	07-10-03	WJH 366	3.98	13.64	925.34	34.43	110.8
1671	Hino	GD1J	51477	B20 Biodiesel	Newcastle	008269-1	12-11-03	WJH 366	2.34	9.96	989.77	39.38	110
1671	Hino	GD1J	51477	B20 Biodiesel	Newcastle	008270-1	12-11-03	WJH 366	2.47	10.79	1003.17	39.91	110
1760	Isuzu	FVZ 1400A	93231	Diesel	Newcastle	008030-1	30-09-03	WOL 553	5.61	27.77	1501.62	55.88	100.3

Fleet No	Vehicle Make	Vehicle Model	Odometer (km)	Fuel Type	Council	Test Number	Test Date	Rego Number	Average Opacity (%)	PM (mg/km/t)	CO2 (g/km)	FC (L/100km)	Max Power (kW at 80kph)
1760	Isuzu	FVZ 1400A	93231	Diesel	Newcastle	008031-1	30-09-03	WOL 553	5.28	21.96	1505.60	56.02	100.3
1760	Isuzu	FVZ 1400A	93635	Filtered Diesel	Newcastle	008116-1	07-10-03	WOL 553	5.72	24.20	1578.87	58.75	95.5
1760	Isuzu	FVZ 1400A	93635	Filtered Diesel	Newcastle	008117-1	07-10-03	WOL 553	5.21	19.02	1543.07	57.42	95.5
1760	Isuzu	FVZ 1400A	96062	B20 Biodiesel	Newcastle	008287-1	12-11-03	WOL 553	5.89	24.66	1511.10	60.12	97
1760	Isuzu	FVZ 1400A	96062	B20 Biodiesel	Newcastle	008288-1	12-11-03	WOL 553	5.61	20.14	1497.14	59.57	97
1769	Mitsubishi	Canter	76748	Diesel	Newcastle	008068-1	02-10-03	WOQ 336	11.27	61.85	576.52	21.45	49.2
1769	Mitsubishi	Canter	76748	Diesel	Newcastle	008069-1	02-10-03	WOQ 336	10.71	57.35	585.06	21.77	49.2
1769	Mitsubishi	Canter	76933	Filtered Diesel	Newcastle	008120-1	08-10-03	WOQ 336	11.01	59.58	617.43	22.97	49.1
1769	Mitsubishi	Canter	76933	Filtered Diesel	Newcastle	008121-1	08-10-03	WOQ 336	9.92	57.11	614.29	22.86	49.1
1769	Mitsubishi	Canter	78715	B20 Biodiesel	Newcastle	008296-1	13-11-03	WOQ 336	6.20	27.56	604.54	24.05	50.5
1769	Mitsubishi	Canter	78715	B20 Biodiesel	Newcastle	008297-1	13-11-03	WOQ 336	6.01	25.48	609.94	24.27	50.5
2157	Nissan	Patrol	28219	Diesel	Newcastle	008076-1	02-10-03	XOD 385	13.64	167.67	576.20	21.44	51.2
2157	Nissan	Patrol	28219	Diesel	Newcastle	008077-1	02-10-03	XOD 385	10.79	128.84	571.52	21.27	51.2
2157	Nissan	Patrol	28279	Filtered Diesel	Newcastle	008131-1	08-10-03	XOD 385	9.84	92.01	606.57	22.57	54.5
2157	Nissan	Patrol	28279	Filtered Diesel	Newcastle	008132-1	08-10-03	XOD 385	8.82	76.99	614.94	22.88	54.5
2157	Nissan	Patrol	29358	B20 Biodiesel	Newcastle	008273-1	12-11-03	XOD 385	7.13	64.75	574.41	22.85	54

Fleet No	Vehicle Make	Vehicle Model	Odometer (km)	Fuel Type	Council	Test Number	Test Date	Rego Number	Average Opacity (%)	PM (mg/km/t)	CO2 (g/km)	FC (L/100km)	Max Power (kW at 80kph)
2157	Nissan	Patrol	29358	B20 Biodiesel	Newcastle	008274-1	12-11-03	XOD 385	7.54	67.89	564.33	22.45	54
1904	International	Acco 2350G	33250	Diesel	Newcastle	008024-1	30-09-03	XZE 104	1.64	8.93	1807.05	67.24	96.7
1904	International	Acco 2350G	33250	Diesel	Newcastle	008025-1	30-09-03	XZE 104	1.28	5.66	1760.81	65.52	96.7
1904	International	Acco 2350G	36179	B20 Biodiesel	Newcastle	008280-1	12-11-03	XZE 104	1.27	9.31	1754.13	69.79	101
1904	International	Acco 2350G	36179	B20 Biodiesel	Newcastle	008281-1	12-11-03	XZE 104	0.98	4.82	1750.07	69.63	101
2404	Toyota	Hilux	15095	Diesel	Newcastle	008044-1	01-10-03	YCQ 856	4.17	29.12	500.47	18.62	48.4
2404	Toyota	Hilux	15095	Diesel	Newcastle	008045-1	01-10-03	YCQ 856	4.02	26.90	497.51	18.51	48.4
2404	Toyota	Hilux	15309	Filtered Diesel	Newcastle	008134-1	08-10-03	YCQ 856	3.25	20.89	490.14	18.24	47.9
2404	Toyota	Hilux	15309	Filtered Diesel	Newcastle	008135-1	08-10-03	YCQ 856	3.10	20.22	501.51	18.66	47.9
2404	Toyota	Hilux	16865	B20 Biodiesel	Newcastle	008299-1	13-11-03	YCQ 856	2.59	17.48	458.90	18.26	47.5
2404	Toyota	Hilux	16865	B20 Biodiesel	Newcastle	008300-1	13-11-03	YCQ 856	2.51	16.80	459.11	18.27	47.5
2472	Daihatsu	Delta	9050	Diesel	Newcastle	008065-1	02-10-03	YEZ 314	11.40	71.16	553.17	20.58	46
2472	Daihatsu	Delta	9050	Diesel	Newcastle	008066-1	02-10-03	YEZ 314	10.23	63.14	554.83	20.65	46
2472	Daihatsu	Delta	9150	Filtered Diesel	Newcastle	008127-1	08-10-03	YEZ 314	8.83	45.82	513.21	19.10	47.9
2472	Daihatsu	Delta	9150	Filtered Diesel	Newcastle	008128-1	08-10-03	YEZ 314	8.57	45.24	509.82	18.97	47.9
2472	Daihatsu	Delta	10009	B20 Biodiesel	Newcastle	008307-1	13-11-03	YEZ 314	7.95	36.44	527.85	21.00	43

Fleet No	Vehicle Make	Vehicle Model	Odometer (km)	Fuel Type	Council	Test Number	Test Date	Rego Number	Average Opacity (%)	PM (mg/km/t)	CO2 (g/km)	FC (L/100km)	Max Power (kW at 80kph)
2472	Daihatsu	Delta	10009	B20 Biodiesel	Newcastle	008308-1	13-11-03	YEZ 314	6.97	32.37	525.63	20.91	43
57	Isuzu	FSR 700A	122339	Diesel	Newcastle	008036-1	30-09-03	YQE 790	6.76	30.28	900.55	33.51	99.3
57	Isuzu	FSR 700A	122339	Diesel	Newcastle	008037-1	30-09-03	YQE 790	6.66	26.93	890.30	33.13	99.3
57	Isuzu	FSR 700A	122664	Filtered Diesel	Newcastle	008109-1	07-10-03	YQE 790	6.45	31.68	895.44	33.32	99.8
57	Isuzu	FSR 700A	122664	Filtered Diesel	Newcastle	008110-1	07-10-03	YQE 790	6.17	29.24	886.11	32.97	99.8
57	Isuzu	FSR 700A	125154	B20 Biodiesel	Newcastle	008290-1	12-11-03	YQE 790	4.70	19.44	866.56	34.48	100
57	Isuzu	FSR 700A	125154	B20 Biodiesel	Newcastle	008291-1	12-11-03	YQE 790	4.89	19.68	869.30	34.59	100

C2 Phase 2 Results

Fleet No	Vehicle Make	Vehicle Model	Odometer (km)	Fuel Type	Council	Test Number	Test Date	Rego Number	Average Opacity (%)	PM (mg/km.t)	NOx (g/km.t)	CO2 (g/km)	FC (l/100km)	Max Power (kW at 80kph)
2307	VW	Transporter	45,449	Diesel	Newcastle	009097-1	14-05-04	ALM 32M	4.95	69.00	0.77	489.89	18.23	61.2
2307	VW	Transporter	45,449	Diesel	Newcastle	009098-1	14-05-04	ALM 32M	4.55	59.95	0.75	487.70	18.15	61.2
2307	VW	Transporter	46,040	B20 Biodiesel	Newcastle	009174-1	19-05-04	ALM 32M	3.40	30.66	0.82	487.31	19.39	59.1
2307	VW	Transporter	46,040	B20 Biodiesel	Newcastle	009175-1	19-05-04	ALM 32M	3.59	36.67	0.82	485.62	19.32	59.1
183	International	Acco 2350E	243,760	Diesel	Newcastle	009111-1	17-05-04	SPS 101	6.06	29.14	0.36	1219.58	45.38	111
183	International	Acco 2350E	243,760	Diesel	Newcastle	009112-1	17-05-04	SPS 101	6.09	26.61	0.36	1205.36	44.85	111
183	International	Acco 2350E	243,971	B20 Biodiesel	Newcastle	009192-1	20-05-04	SPS 101	5.09	26.04	0.37	1235.94	49.17	109.5
183	International	Acco 2350E	243,971	B20 Biodiesel	Newcastle	009193-1	20-05-04	SPS 101	4.35	21.80	0.35	1167.52	46.45	109.5
687	Isuzu	NPR 400	146,630	Diesel	Newcastle	009119-1	17-05-04	UGS 527	8.09	36.86	0.39	631.24	23.49	51.2
687	Isuzu	NPR 400	146,630	Diesel	Newcastle	009120-1	17-05-04	UGS 527	7.40	33.41	0.39	628.04	23.37	51.2
687	Isuzu	NPR 400	146,850	B20 Biodiesel	Newcastle	009199-1	20-05-04	UGS 527	5.14	25.36	0.46	636.81	25.34	50.1
687	Isuzu	NPR 400	146,850	B20 Biodiesel	Newcastle	009200-1	20-05-04	UGS 527	5.15	24.86	0.46	643.74	25.61	50.1
824	Nissan	UD PK 250	165,704	Diesel	Newcastle	009077-1	13-05-04	VIH 583	2.81	21.33	0.44	1329.70	49.48	86.4

Fleet No	Vehicle Make	Vehicle Model	Odometer (km)	Fuel Type	Council	Test Number	Test Date	Rego Number	Average Opacity (%)	PM (mg/km.t)	NOx (g/km.t)	CO2 (g/km)	FC (l/100km)	Max Power (kW at 80kph)
824	Nissan	UD PK 250	165,704	Diesel	Newcastle	009078-1	13-05-04	VIH 583	2.91	15.59	0.44	1328.18	49.42	86.4
824	Nissan	UD PK 250	166,310	B20 Biodiesel	Newcastle	009154-1	18-05-04	VIH 583	2.02	14.06	0.48	1330.56	52.94	85.2
824	Nissan	UD PK 250	166,310	B20 Biodiesel	Newcastle	009155-1	18-05-04	VIH 583	2.15	13.53	0.47	1320.10	52.52	85.2
1671	Hino	GD1J	56,034	Diesel	Newcastle	009108-1	17-05-04	WJH 366	3.72	26.94	0.66	1155.15	42.98	113.3
1671	Hino	GD1J	56,034	Diesel	Newcastle	009109-1	17-05-04	WJH 366	3.40	25.39	0.69	1173.35	43.66	113.3
1671	Hino	GD1J	56,237	B20 Biodiesel	Newcastle	009195-1	20-05-04	WJH 366	1.74	9.74	0.57	955.42	38.01	114.6
1671	Hino	GD1J	56,237	B20 Biodiesel	Newcastle	009196-1	20-05-04	WJH 366	1.68	9.19	0.58	963.43	38.33	114.6
1760	Isuzu	FVZ 1400	106,925	Diesel	Newcastle	009115-1	17-05-04	WOL 553	6.90	38.09	0.54	1556.38	57.91	97.4
1760	Isuzu	FVZ 1400	106,925	Diesel	Newcastle	009116-1	17-05-04	WOL 553	5.67	30.72	0.52	1525.01	56.75	97.4
1760	Isuzu	FVZ 1400	107,194	B20 Biodiesel	Newcastle	009204-1	20-05-04	WOL 553	3.42	23.10	0.56	1509.60	60.06	95.6
1760	Isuzu	FVZ 1400	107,194	B20 Biodiesel	Newcastle	009205-1	20-05-04	WOL 553	3.22	21.59	0.56	1522.42	60.57	95.6
1769	Mitsubishi	Canter	88,730	Diesel	Newcastle	009069-1	13-05-04	WOQ 336	9.31	44.25	0.50	615.82	22.91	52.6
1769	Mitsubishi	Canter	88,730	Diesel	Newcastle	009070-1	13-05-04	WOQ 336	9.74	42.18	0.48	632.03	23.52	52.6
1769	Mitsubishi	Canter	89,130	B20 Biodiesel	Newcastle	009141-1	18-05-04	WOQ 336	4.99	29.96	0.53	614.81	24.46	52.2
1769	Mitsubishi	Canter	89,130	B20 Biodiesel	Newcastle	009142-1	18-05-04	WOQ 336	5.09	26.73	0.53	626.10	24.91	52.2
2157	Nissan	Patrol	34,646	Diesel	Newcastle	009093-1	14-05-04	XOD 385	9.24	127.85	0.34	638.53	23.76	50.6
2157	Nissan	Patrol	34,646	Diesel	Newcastle	009094-1	14-05-	XOD 385	8.51	100.51	0.34	646.53	24.06	50.6

Fleet No	Vehicle Make	Vehicle Model	Odometer (km)	Fuel Type	Council	Test Number	Test Date	Rego Number	Average Opacity (%)	PM (mg/km.t)	NOx (g/km.t)	CO2 (g/km)	FC (l/100km)	Max Power (kW at 80kph)
							04							
2157	Nissan	Patrol	34,736	B20 Biodiesel	Newcastle	009166-1	19-05-04	XOD 385	6.79	72.68	0.43	650.60	25.88	49.2
2157	Nissan	Patrol	34,736	B20 Biodiesel	Newcastle	009167-1	19-05-04	XOD 385	5.92	56.96	0.43	639.97	25.46	49.2
1904	Iveco	Acco	47,738	Diesel	Newcastle	009080-1	13-05-04	XZE 104	1.51	7.75	0.37	1587.04	59.05	102.5
1904	Iveco	Acco	47,738	Diesel	Newcastle	009081-1	13-05-04	XZE 104	1.38	6.04	0.36	1593.83	59.31	102.5
1904	Iveco	Acco	48,055	B20 Biodiesel	Newcastle	009149-1	18-05-04	XZE 104	1.03	3.71	0.41	1682.06	66.92	105.3
1904	Iveco	Acco	48,055	B20 Biodiesel	Newcastle	009152-1	18-05-04	XZE 104	1.05	3.78	0.36	1668.11	66.37	105.3
2404	Toyota	Hilux 3.0D	26,223	Diesel	Newcastle	009102-1	14-05-04	YCQ 856	4.03	44.55	0.31	547.55	20.37	44.2
2404	Toyota	Hilux 3.0D	26,223	Diesel	Newcastle	009103-1	14-05-04	YCQ 856	3.34	29.66	0.31	539.97	20.09	44.2
2404	Toyota	Hilux 3.0D	26,373	B20 Biodiesel	Newcastle	009182-1	19-05-04	YCQ 856	2.36	19.76	0.31	530.64	21.11	44.6
2404	Toyota	Hilux 3.0D	26,373	B20 Biodiesel	Newcastle	009183-1	19-05-04	YCQ 856	2.14	16.90	0.30	517.22	20.58	44.6
2472	Daihatsu	Delta	14,185	Diesel	Newcastle	009105-1	14-05-04	YEZ 314	8.51	56.80	0.58	556.78	20.72	46.6
2472	Daihatsu	Delta	14,185	Diesel	Newcastle	009106-1	14-05-04	YEZ 314	8.16	52.70	0.56	551.01	20.50	46.6
2472	Daihatsu	Delta	14,255	B20 Biodiesel	Newcastle	009179-1	19-05-04	YEZ 314	6.44	41.57	0.66	558.52	22.22	46.1
2472	Daihatsu	Delta	14,255	B20 Biodiesel	Newcastle	009180-1	19-05-04	YEZ 314	6.90	40.43	0.66	574.56	22.86	46.1
57	Isuzu	FSR700 Long	135,427	Diesel	Newcastle	009074-1	13-05-04	YQE 790	6.08	34.94	0.66	987.14	36.73	99.4
57	Isuzu	FSR700 Long	135,427	Diesel	Newcastle	009075-1	13-05-04	YQE 790	6.42	33.95	0.66	985.53	36.67	99.4

Fleet No	Vehicle Make	Vehicle Model	Odometer (km)	Fuel Type	Council	Test Number	Test Date	Rego Number	Average Opacity (%)	PM (mg/km.t)	NOx (g/km.t)	CO2 (g/km)	FC (l/100km)	Max Power (kW at 80kph)
57	Isuzu	FSR700 Long	135,591	B20 Biodiesel	Newcastle	009144-1	18-05-04	YQE 790	4.15	26.39	0.76	1021.82	40.65	99.3
57	Isuzu	FSR700 Long	135,591	B20 Biodiesel	Newcastle	009145-1	18-05-04	YQE 790	3.84	24.22	0.75	1009.62	40.17	99.3

APPENDIX D: Average Emission Results

D1 Diesel versus Filtered Diesel – Phase 1

Ten vehicles were tested on both diesel and filtered diesel during Phase 1 with two tests carried out on each fuel. Figures 1 to 5 show the average results for smoke opacity, particulate matter (PM), carbon dioxide (CO2), fuel consumption (FC) and maximum power at 80kph for each of the vehicles while Appendix D1 contains the data set.

The results demonstrate typical variation in sensitivity to fuel changes of different vehicles because of the variations in engine design and the emission standards they complied with. For example, for average smoke opacity the mean results for each of the vehicles range from about 3% to slightly over 12%. On some vehicles the average opacity is higher for filtered diesel when compared to diesel. While on other vehicles the reverse occurred. Averaged across the ten vehicles, the average opacity is slightly lower for filtered diesel than diesel.

Similar trends are evident for particulate emissions while the mean results for each of the vehicles range from about 10 mg/km/t to about 150 mg/km/t. Particulate emissions averaged across the ten vehicles are lower for filtered diesel than diesel.

Carbon dioxide, fuel consumption and maximum power at 80kph, like average opacity and PM, are higher for some vehicles on filtered diesel than diesel and visa versa for other vehicles. For CO2 the mean results for each of the ten vehicles range from about 450 g/km to about 1550 g/km, while for FC the mean results range from about 17 L/100km to about 58 L/100km and for power at 80 kph the mean results for each vehicle range from about 46 kW to about 115 kW.

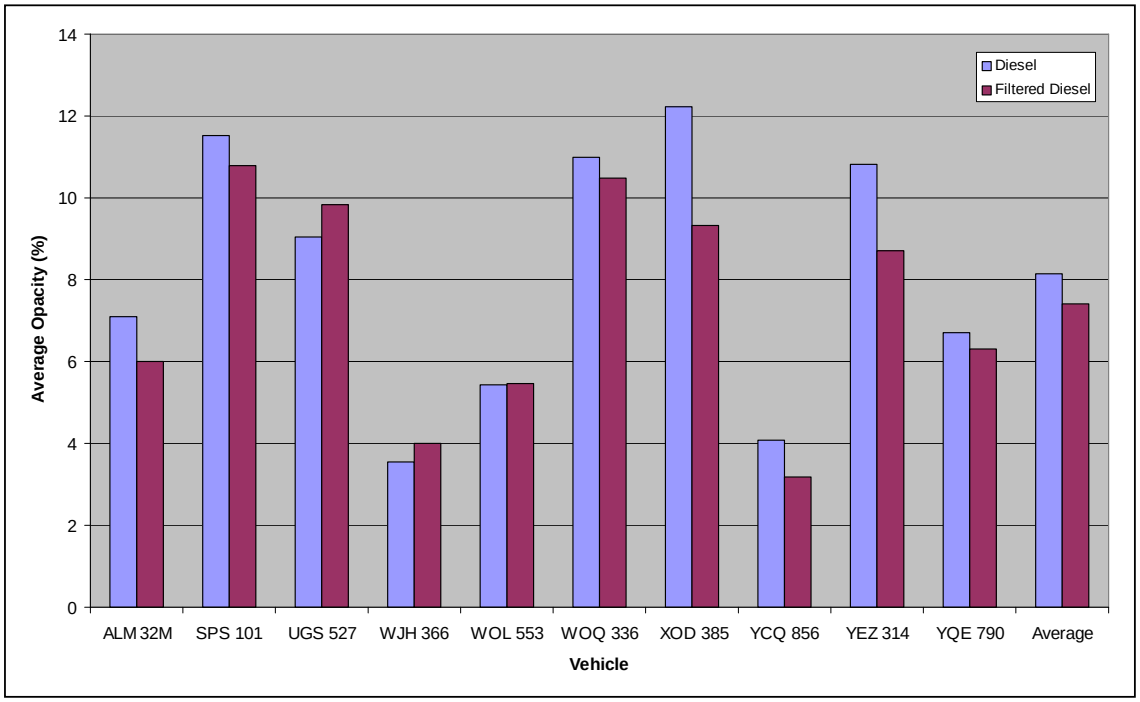

Figure 1: Average opacity results for diesel and filtered diesel for individual vehicles – Phase 1

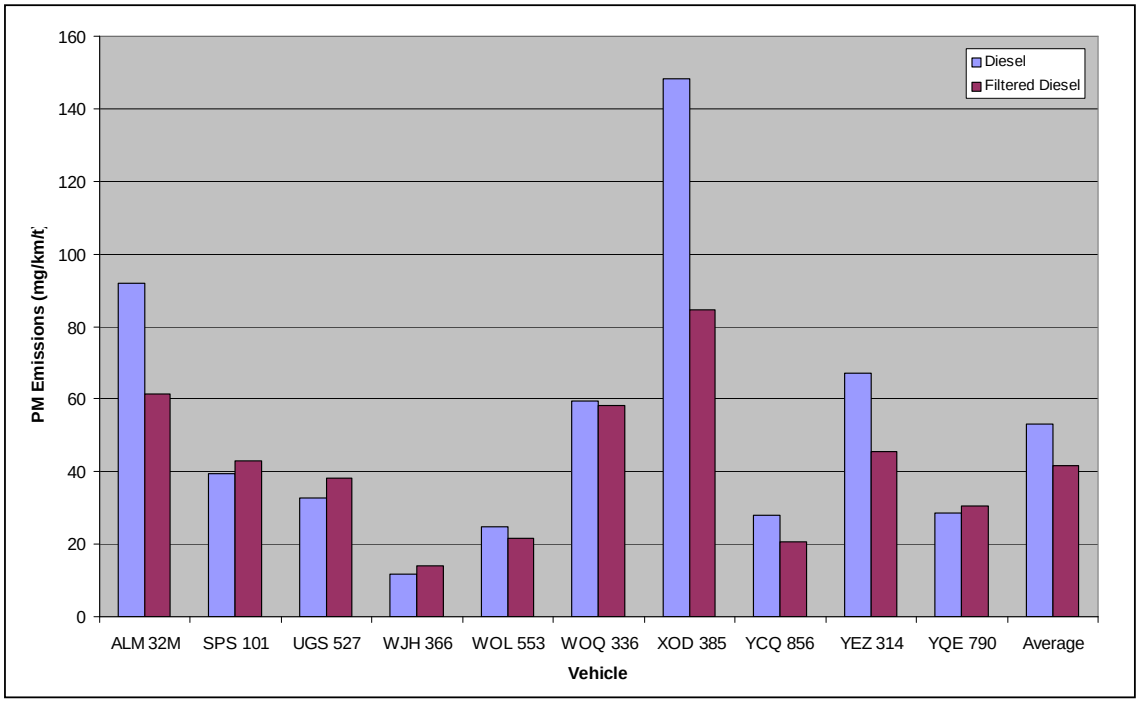

Figure 2: Particulate results for diesel and filtered diesel for individual vehicles – Phase 1

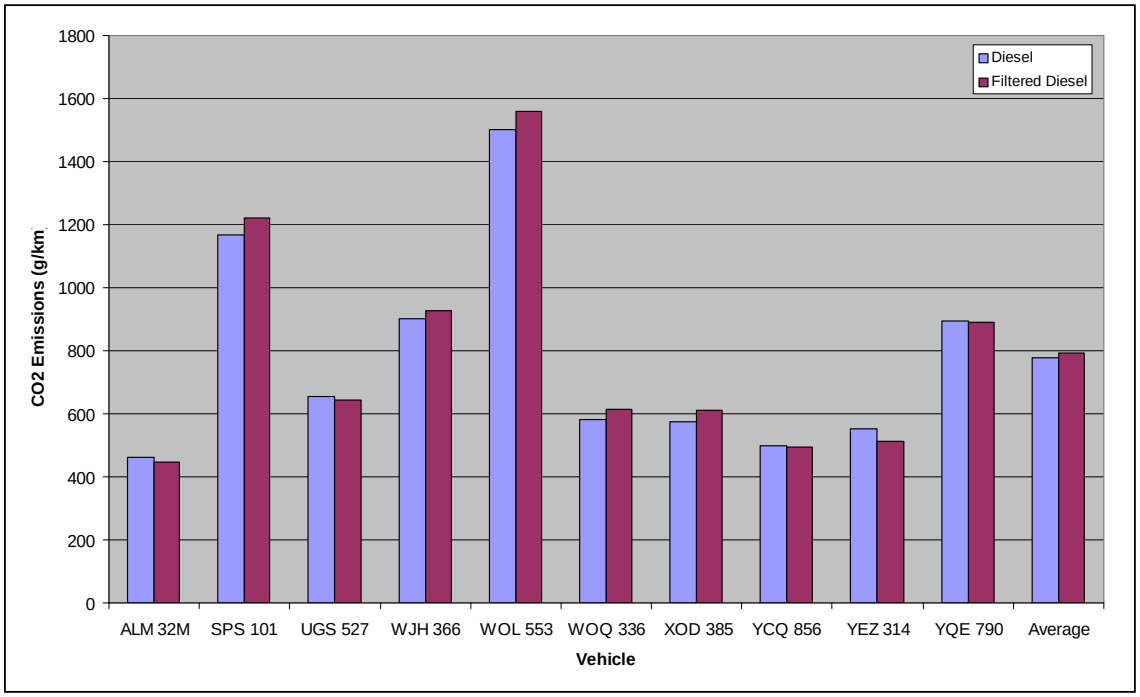

Figure 3: Carbon dioxide results for diesel and filtered diesel for individual vehicles – Phase 1

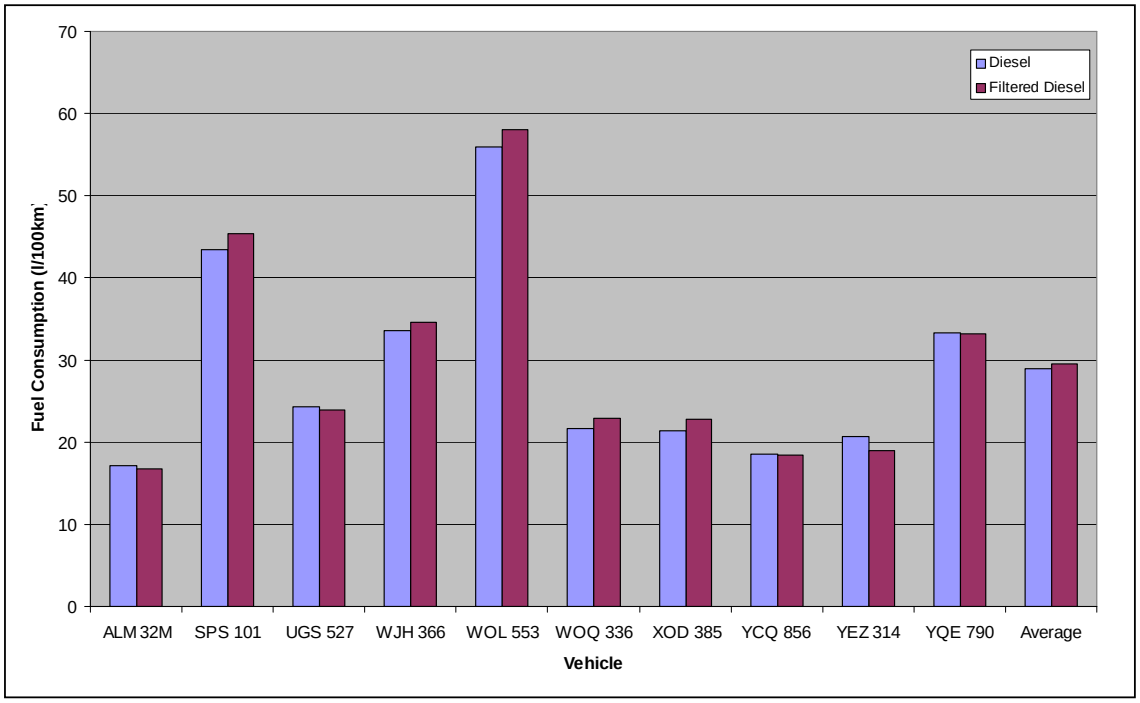

Figure 4: Fuel consumption results for diesel and filtered diesel for individual vehicles – Phase 1

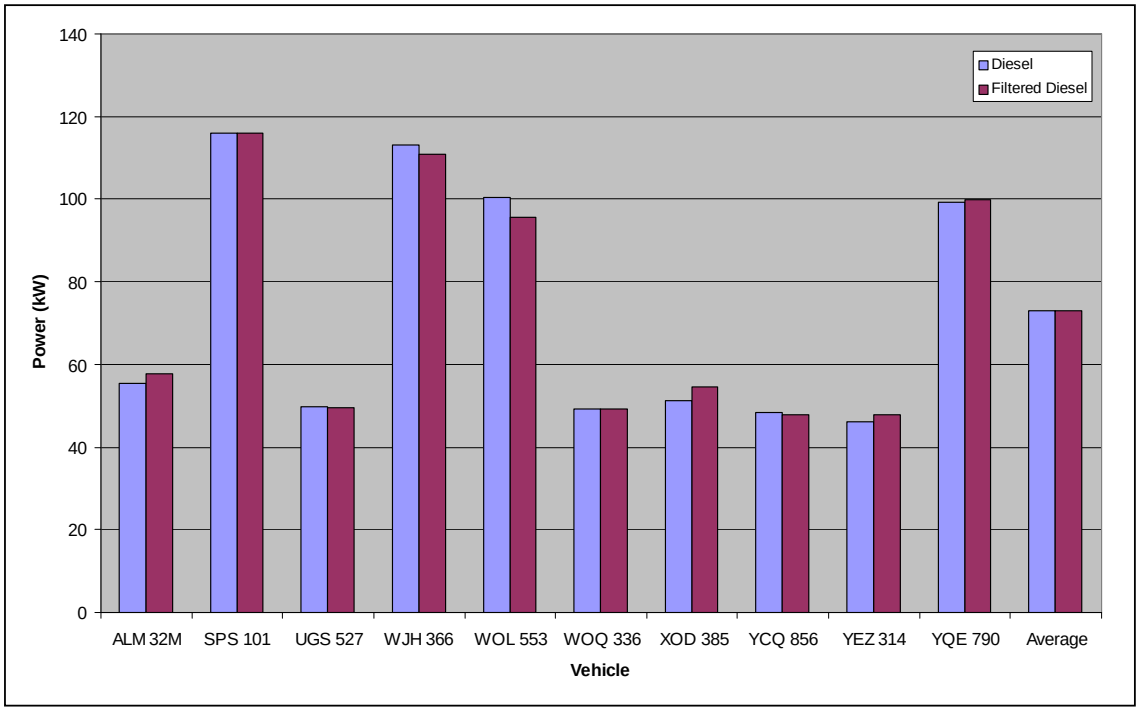

Figure 5: Power results for diesel and filtered diesel for individual vehicles – Phase 1

D2 Diesel versus B20 Biodiesel – Phase 1

Twelve vehicles were tests on both diesel and B20 biodiesel during Phase 1 with two tests carried out on each fuel. Figure 6 to Figure 10 show the smoke opacity, particulate matter (PM), carbon dioxide (CO2), fuel consumption (FC) and maximum power at 80kph results for the average of the two tests on each vehicle while Appendix D1 contains the full set of data.

The results demonstrate typical variation in sensitivity to fuel changes of different vehicles because of the variations in engine design and the emission standards they complied with. For example, average smoke opacity from each of the twelve vehicles range from about 1.5% to slightly over 12%. On all vehicles, except one, the average opacity is lower for B20 biodiesel when compared to diesel. Averaged across the twelve vehicles, the overall average opacity is lower for B20 biodiesel than diesel.

Similar trends to those observed with smoke opacity are evident for PM emissions. Mean PM results for each of the vehicles range from about 5 mg/km/t to slightly over 145 mg/km/t with all but one vehicle under 95 mg/km/t for both fuels. PM emissions are lower for B20 biodiesel on all but one vehicle. The overall average for the twelve vehicles show that B20 biodiesel is lower than diesel.

Carbon dioxide, fuel consumption and maximum power at 80kph are higher for some vehicles on B20 biodiesel when compared to diesel and visa versa for other vehicles. For CO2 the mean results for each of the vehicles range from about 460 g/km to about 1800 g/km, while for FC the mean results range from about 17 L/100km to about 70 L/100km and for power at 80 kph the mean results range from about 43 kW to about 119 kW. However, averaged across the twelve vehicles the overall mean result for CO2 and maximum power from B20 biodiesel is slightly lower while FC is slightly higher when compared to diesel fuel.

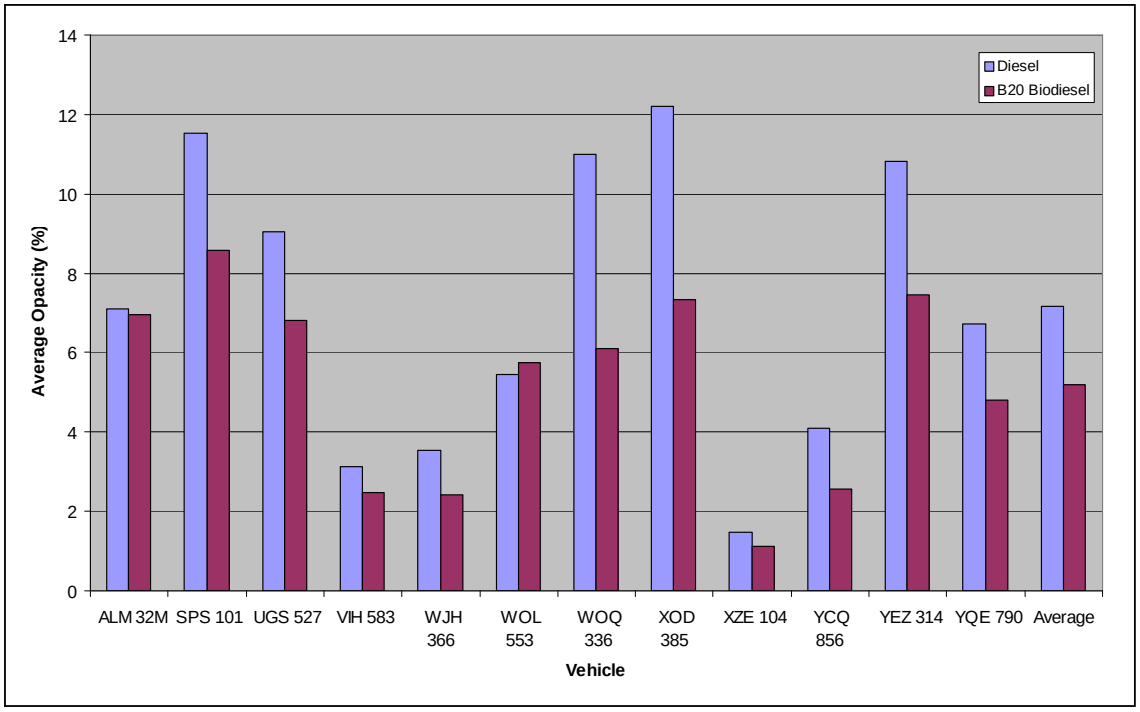

Figure 6: Average opacity results for diesel and B20 Biodiesel for individual vehicles – Phase 1

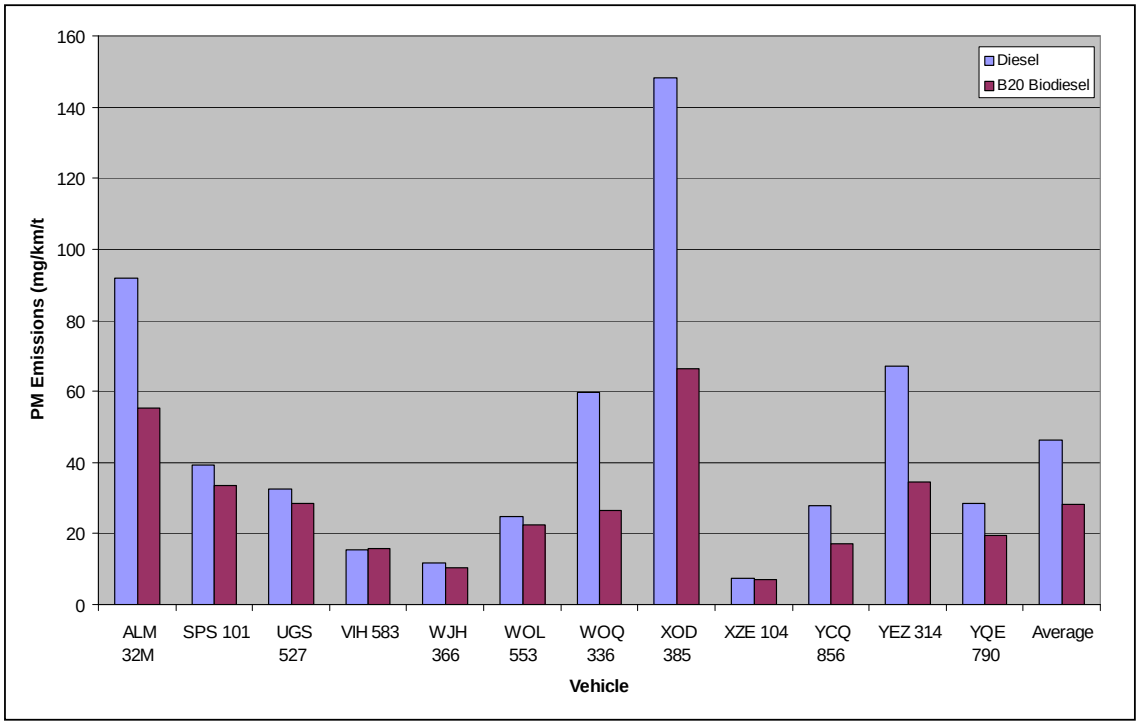

Figure 7: Particulate results for diesel and B20 biodiesel for individual vehicles – Phase 1

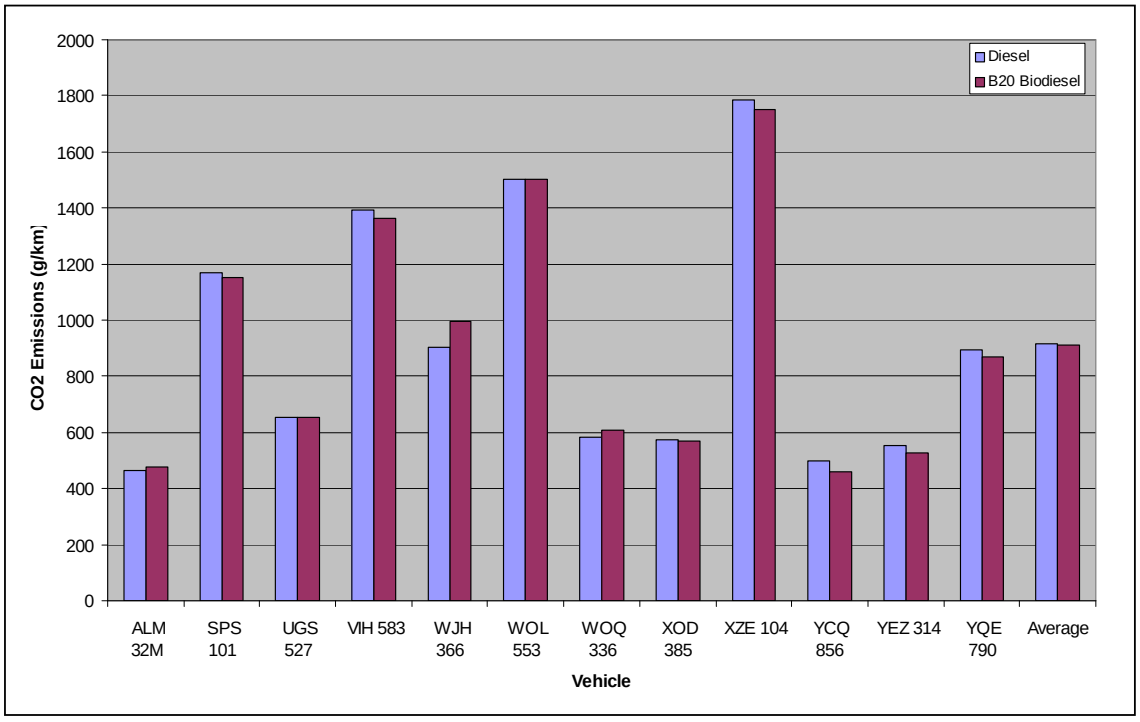

Figure 8: Carbon dioxide results for diesel and B20 biodiesel for individual vehicles – Phase 1

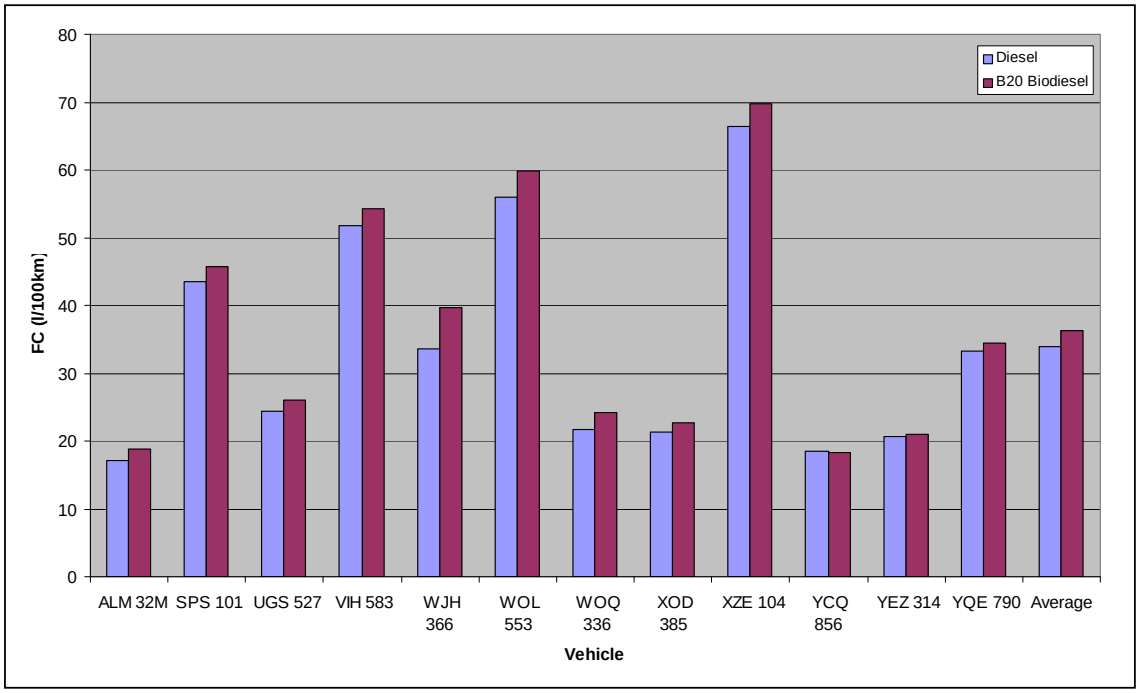

Figure 9: Fuel consumption results for diesel and B20 biodiesel for individual vehicles – Phase 1

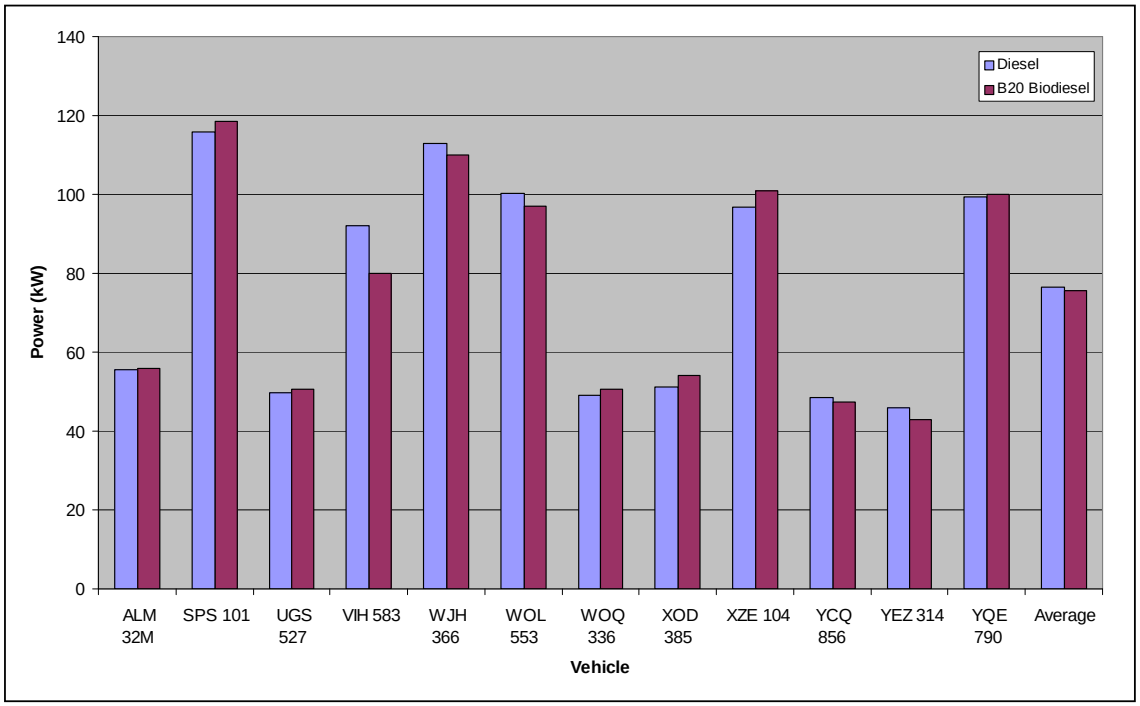

Figure 10: Power results for diesel and B20 biodiesel for individual vehicles – Phase 1

D3 Diesel versus B20 Biodiesel – Phase 2

Twelve vehicles were tested on both diesel and B20 biodiesel during Phase 2 with two tests carried out on each fuel. These were the same vehicles as tested in Phase 1. Figure 11 to Figure 16 in Appendix E3 show the average results for smoke opacity, particulate matter (PM), oxides of nitrogen (NOx), carbon dioxide (CO2), fuel consumption (FC) and maximum power at 80kph for each of the vehicles while Appendix D2 contains the full set of data.

The results demonstrate typical variation in sensitivity to fuel changes of different vehicles because of the variations in engine design and the emission standards they complied with. For example, average smoke opacity results for each of the twelve vehicles range from about 1.0% to slightly over 9.5%, which are slightly lower than for Phase 1. For each of the vehicles the average opacity is lower for B20 biodiesel when compared to diesel whereas in Phase 1 average opacity was lower on some vehicles and higher on others. Averaged across the twelve vehicles, the average opacity is lower for B20 biodiesel than diesel.

Similar trends to those observed with smoke opacity are evident for PM emissions. Mean results for each of the twelve vehicles range from about 4 mg/km/t to slightly over 110 mg/km/t with all but one vehicles under 70 mg/km/t. On all twelve vehicles the B20 biodiesel results for PM are all lower than the diesel results as is the overall mean result.

Mean NOx results for each of the twelve vehicles range from about 0.3 g/km/t to about 0.83 g/km/t. Some vehicles have higher NOx emissions from B20 biodiesel than diesel while other vehicles exhibit the reverse. The NOx emissions for B20 biodiesel, when averaged over the twelve vehicles, are higher than for diesel.

The mean CO2, FC and power at 80kph results are higher for some vehicles on B20 biodiesel when compared to diesel and visa versa for other vehicles. The mean result for each vehicle for CO2 ranges from about 480 g/km to about 1700 g/km, while for FC the range is from about 18 L/100km to about 65 L/100km and for power at 80 kph the range is from about 44 kW to about 114 kW. However, the overall mean result for CO2 and maximum power from B20 biodiesel is slightly lower while FC is slightly higher when compared to the average for diesel fuel.

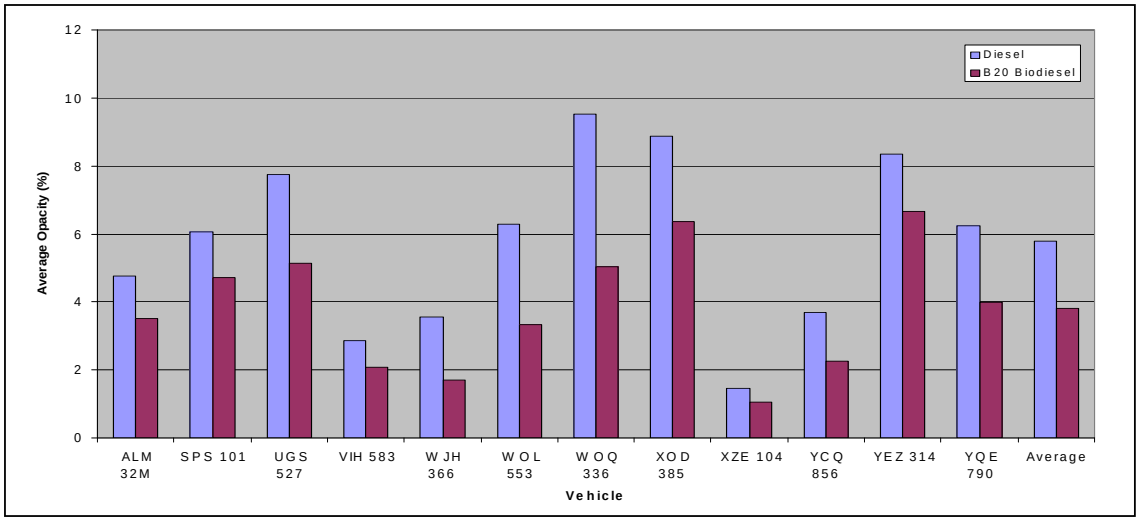

Figure 11: Average opacity results for diesel and B20 Biodiesel for individual vehicles – Phase 2

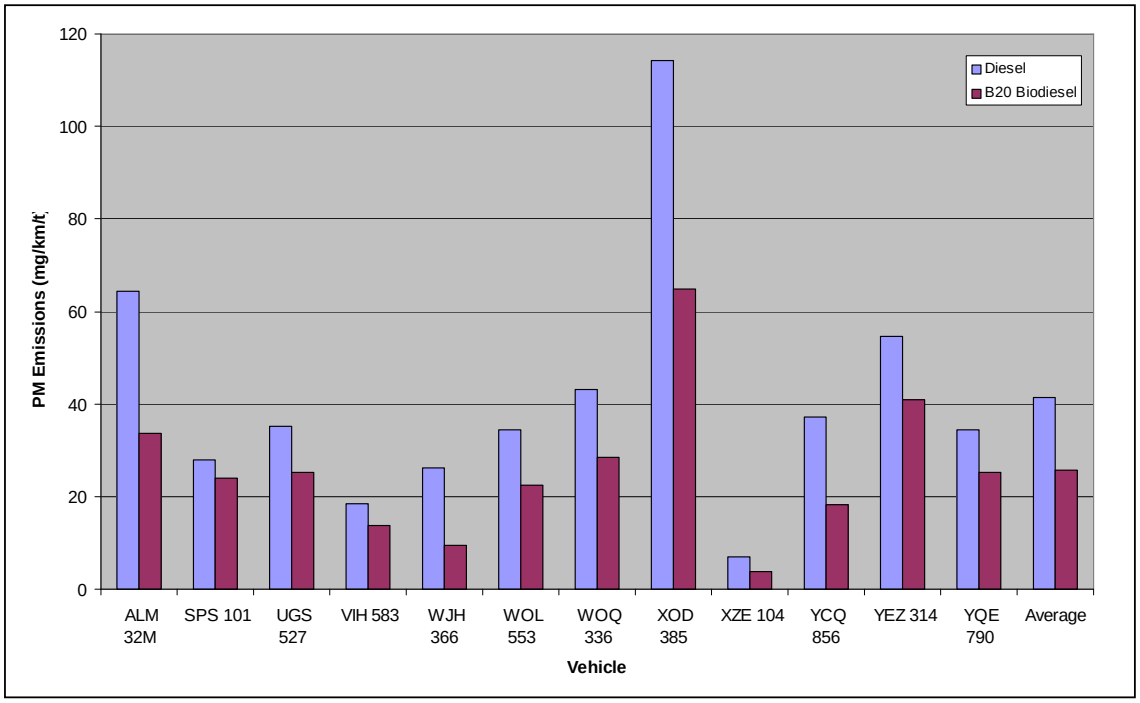

Figure 12: Particulate results for diesel and B20 biodiesel for individual vehicles – Phase 2

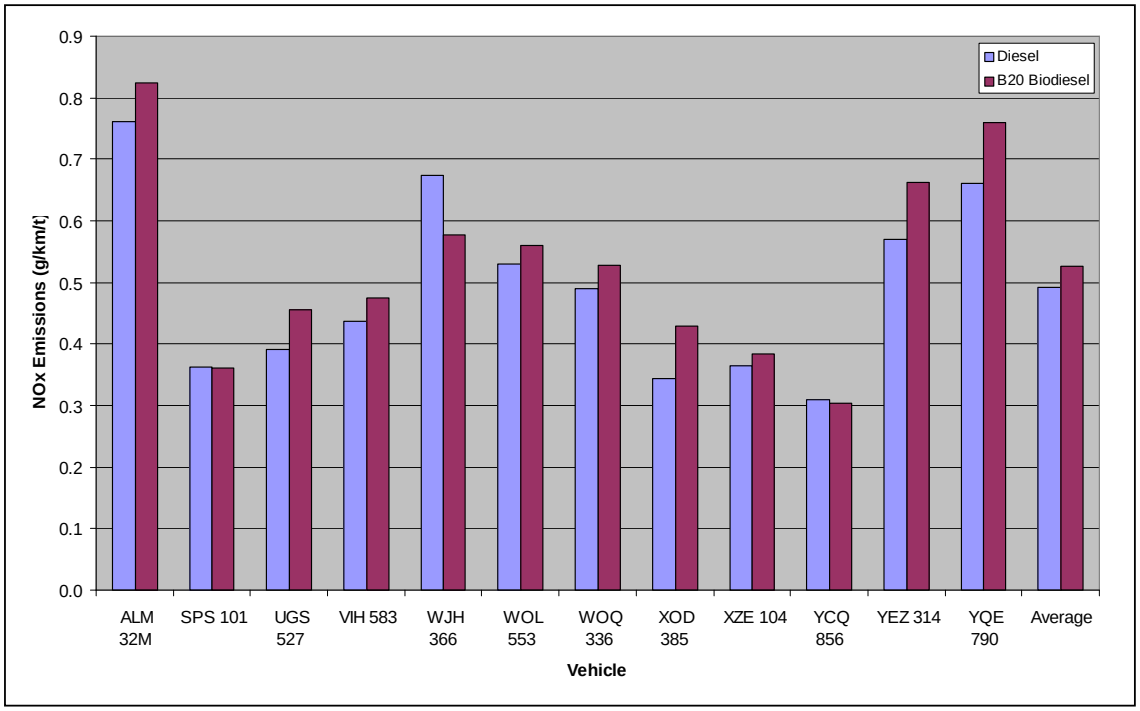

Figure 13: Oxides of Nitrogen results for diesel and B20 biodiesel for individual vehicles – Phase 2

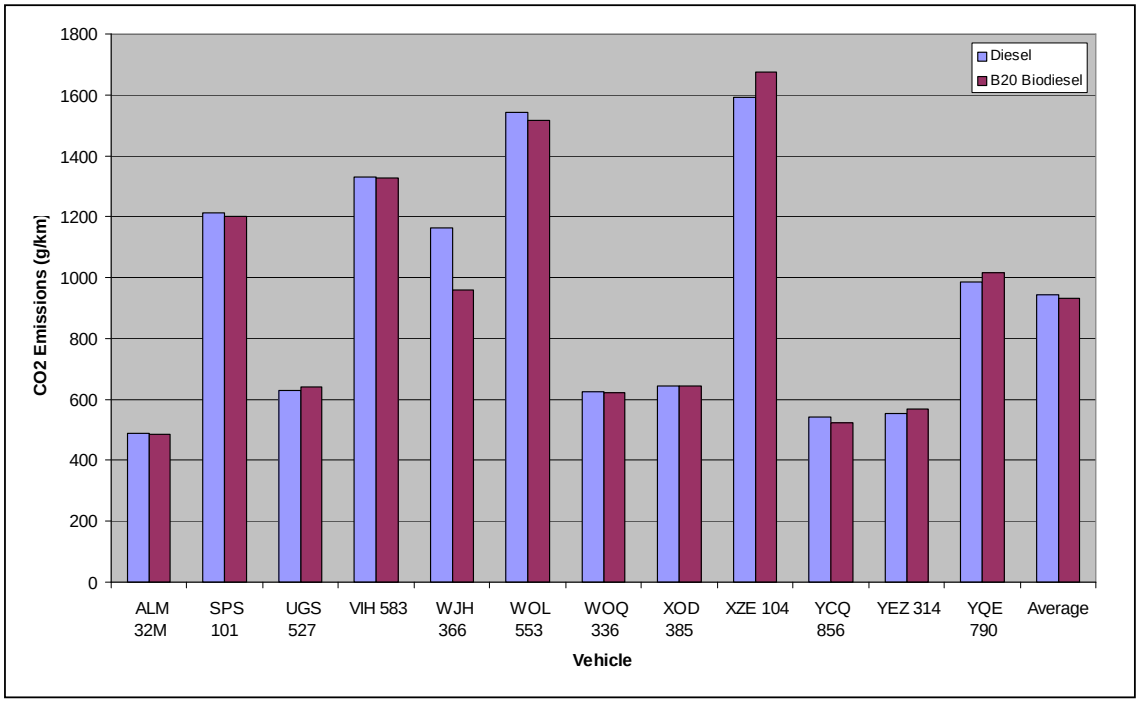

Figure 14: Carbon dioxide results for diesel and B20 biodiesel for individual vehicles – Phase 2

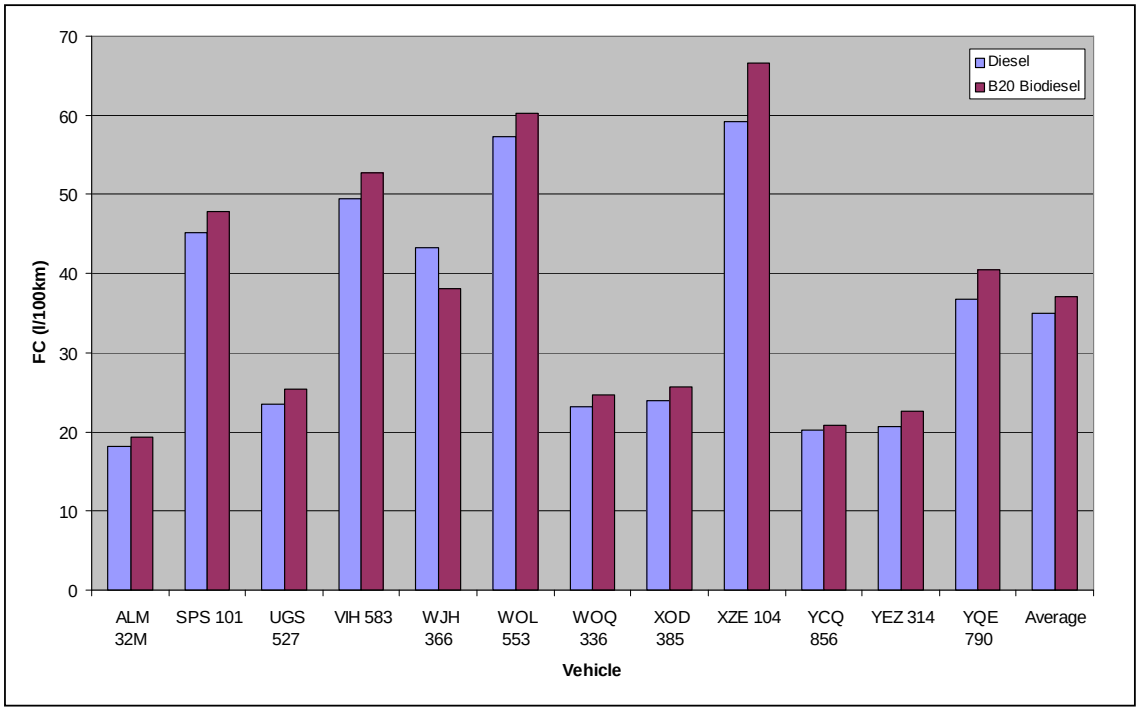

Figure 15: Fuel consumption results for diesel and B20 biodiesel for individual vehicles – Phase 2

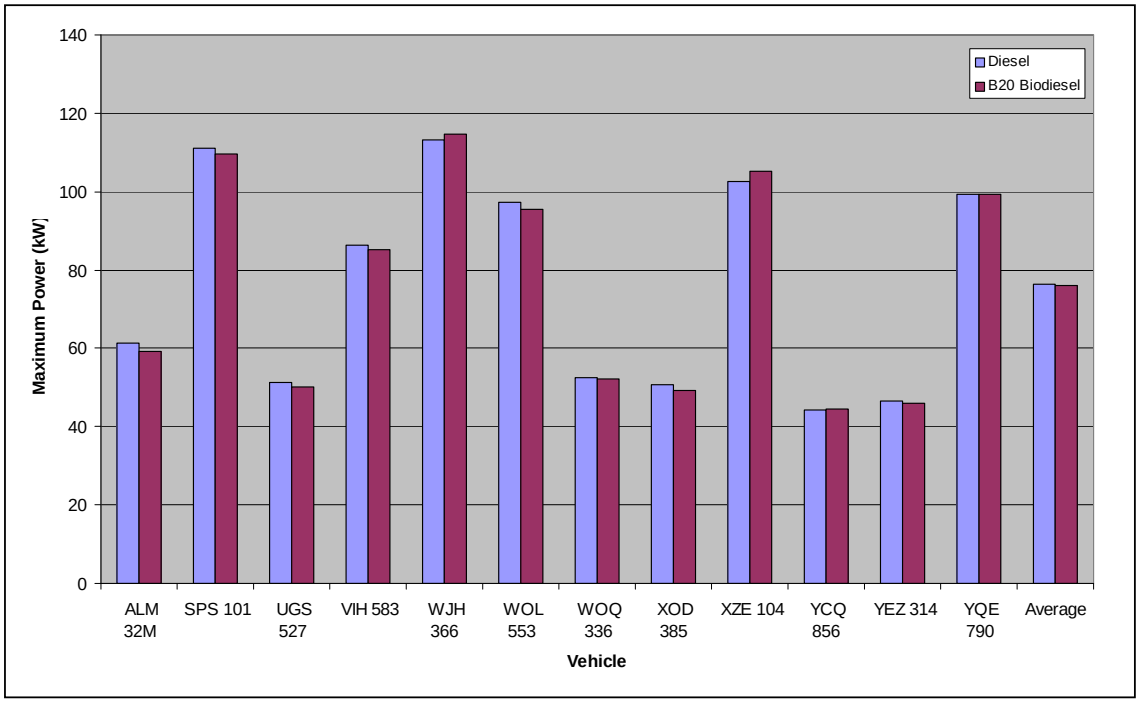

Figure 16: Power results for diesel and B20 biodiesel for individual vehicles – Phase 2