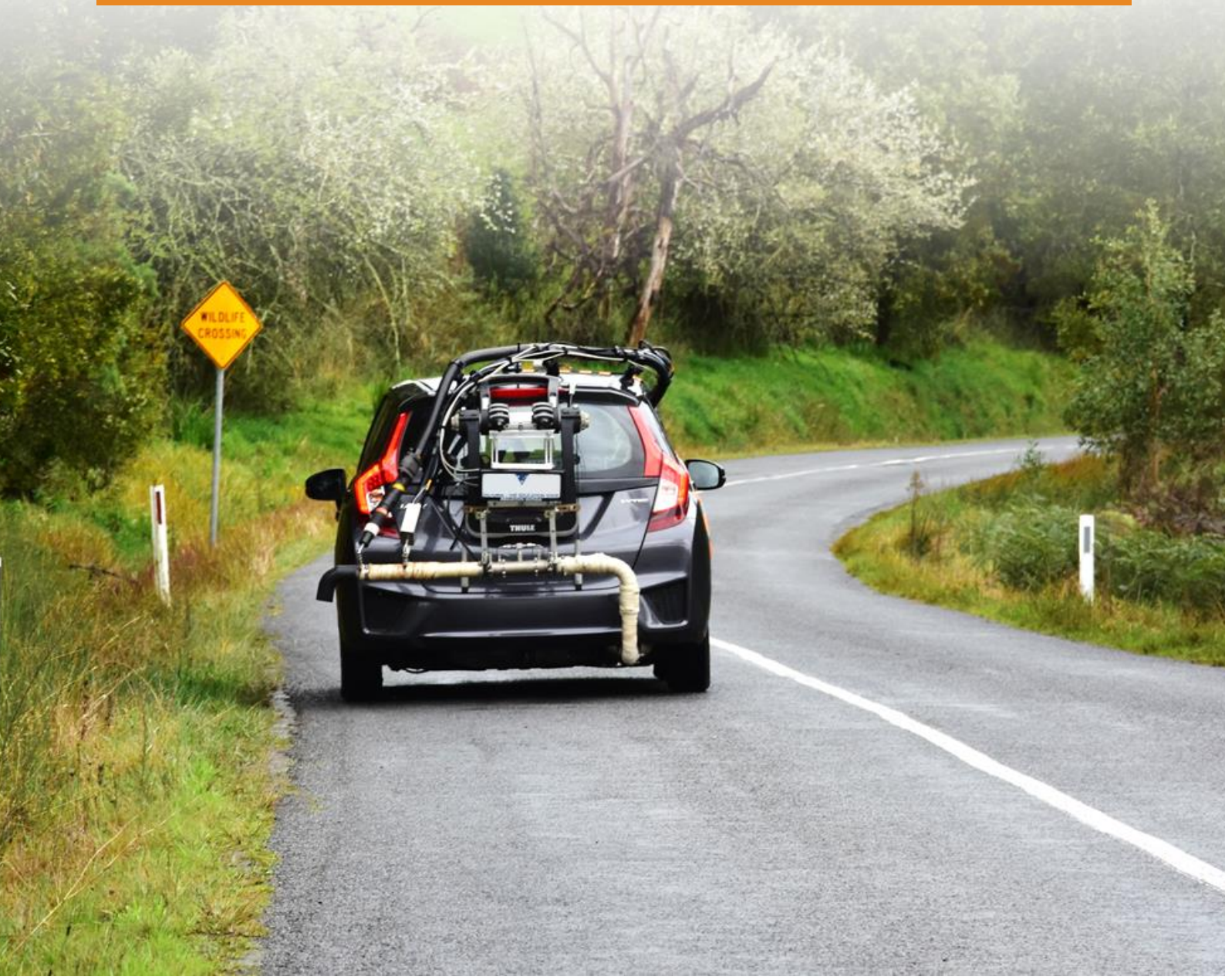
REAL-WORLD DRIVING

Fuel Efficiency & Emissions Testing

Prepared for the Australian Automobile Association – Mar 2017
17 Vehicles Tested to Date



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Real-world Driving

Fuel Efficiency & Emissions Testing

Interim Report March 2017

For the Australian Automobile Association

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PRELIMINARY FINDINGS

OVERVIEW:

This report presents the emissions and fuel consumption summary test results from seventeen different passenger and light commercial vehicle configurations ("light duty vehicles"), measured with a Portable Emissions Measurement System on Australian Roads. Testing was conducted by ABMARC for the Australian Automobile Association, generally in accordance with EC No 2016_427 and the draft Real Driving Emissions (RDE) procedure, adapted to suit Australia's unique roads and conditions. Each vehicle was tested twice, with one cold start and one warm start per test sequence. The testing was conducted on Melbourne roads between May 2016 and March 2017.

The current new vehicle emissions standard in Australia for both petrol and diesel is Euro 5.

PROJECT BACKGROUND:

Real-world vehicle emissions testing by various agencies overseas has confirmed that the emissions from certain light duty vehicles are substantially higher when measured on the road than when measured in a controlled laboratory environment. Pollutants, such as NO_X (oxides of nitrogen) from diesel cars, have regularly been found to exceed the permitted test-cycle emissions limits by four to eight times. The disconnect between road and laboratory emissions was first identified as an air quality issue in Europe; reductions in permissible NO_x emissions from road transport vehicles were not as effective at improving air quality as the regulations had anticipated. Similarly, official fuel consumption figures were often not reflective of what motorists were able to achieve in the real world. The discrepancy between official figures and the real-world fuel consumption figures has been increasing over time, most likely as a result of manufacturers optimising technologies to ensure compliance with their CO_2 obligations. To improve compliance with emissions requirements, the European Commission's Joint Research Centre (JRC) has developed a test procedure with Portable Emissions Measurement Systems (PEMS) for mandatory Real Driving Emissions (RDE) testing at type approval of new vehicles. The RDE testing is applicable from Euro 6c. The JRC was consulted in adapting this test procedure for Australian conditions.

Real-world measurement of emissions and fuel consumption enables a vehicle to be tested in the same road and environmental conditions it will be subjected to during normal operation. This testing reduces the ability of manufacturers to implement "defeat devices", and limits the use of emissions reduction technologies that are more effective on the test drive cycle than in real-world use.

The Australian Government is currently considering adopting Euro 6 emissions and CO_2 standards, in addition to reviewing Australian fuel quality standards. Presently, European regulation requires testing with PEMS on European roads only. The Australian market has a number of vehicles with engine configurations not sold in Europe, as well as vehicles that are not sold in Europe at all. This may result in a situation where vehicles are sold in Australia that have not been subjected to the regulatory requirements of RDE testing. Introduction of a CO_2 policy may result in consumers paying more for advanced technology in their vehicles, and it is considered important to ensure that any additional costs incurred by consumers provides benefit via real CO_2 emissions reductions. The figure below provides an illustration of the factors taken into account when determining real driving emissions.

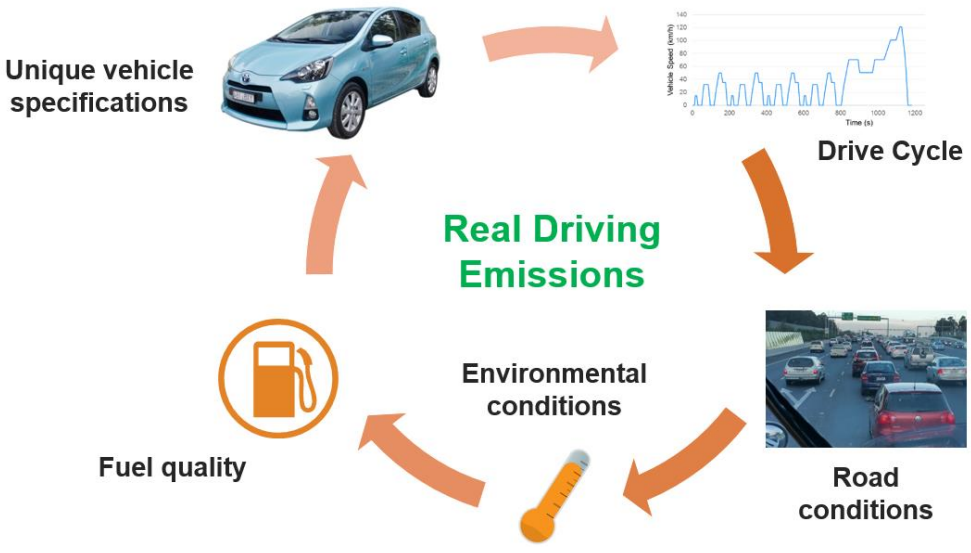

Figure 1 – Real Driving Emissions Overview

The objective of the AAA program of real-world emissions and fuel consumption measurement is to compare the actual on-road vehicle performance of a range of cars to the regulated laboratory emissions limits and fuel consumption results in order to understand how Australian vehicles perform in Australian real-world conditions. In total, 30 vehicles will be tested.

TEST VEHICLES:

Thirty vehicles were selected to represent Australia's new vehicle fleet. At the time of publication, the first 16 test vehicles have been fully tested. One vehicle was tested in two configurations (petrol and LPG), meaning 17 test sequences have been conducted.

The 30 vehicles have been selected to:

- Maximise the representation of Australia's new vehicle fleet
- Cover a representative range of:
  - Manufacturers
  - Vehicle segments
  - Fuel types
- Include vehicles of interest by:
  - Technology
  - Fuel type
- Low volume, new market entries and models not sold into Europe or the USA

All vehicles tested were chosen based on the following criteria:

- The current model is available in Australia
- The vehicle tested has driven at least 2,000 km but no more than 85,000 km
- The actual test vehicle is a 2014 year model or newer

Vehicles tested were taken from the general service fleet.

MEASUREMENTS:

Emissions
Emissions were measured with a Portable Emissions Measurement System (PEMS), providing repeatability of 1% or better and complying with EC 2016_427 and European RDE draft regulations.

- **Particulate Matter (PM):** Collected on gravimetric filter with real time photo acoustic sensor for second by second data.
- **Gaseous:** Total Hydrocarbons, Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitric Oxide (NO) and Nitrogen Dioxide (NO_2).

The exhaust gas sample was taken from probes in the exhaust extension and transferred via heated sample lines to the gaseous analysers and gravimetric filter.

Fuel Consumption
Fuel consumption was derived using the carbon balance method by utilising an exhaust flow meter as specified in EC 2016/427 Appendix 2 Paragraph 7. Fuel properties were determined as per ASTM 4052 (density) and ASTM D240 (gross calorific value) to correct emissions and fuel consumption to standard fuel data.

Vehicle Information
An OBD data logger was used to record engine parameters via CAN-Bus (SAE J1979) according to EC 2016/427 Appendix 1 Paragraph 3.4.5.

Ambient Conditions
Ambient conditions, humidity, pressure & temperature were recorded according to EC 2016/427 Appendix 2 Paragraph 8.

Location & Vehicle Speed
Vehicle speed and vehicle location was recorded via GPS, according to EC 2016/427 Appendix 1 Paragraph 4.7.

OUTPUT:

For each test the following were measured and/or calculated from measured values and have been reported:

- Grams (g) of emissions per kilometre travelled (km)
- Litres of fuel per 100 kilometres travelled (100 km)

The emissions data processing and calculations were performed in accordance with prescribed methodologies conforming to EC2016_427 Annex IIIA Appendix 4, for the analysis of RDE measurement data.

The allowable emissions on the RDE test under Euro 6c are determined by using a Conformity Factor (CF). The CF is a multiplier, which is applied to the laboratory limits. Presently, there is only a CF specified for NOx (at 2.1), with a CF for Particulate Number currently under consideration. There is no regulated CF available for pre-Euro 6c vehicles. The purpose of this study is to compare the real-world pollutant emission measurement of vehicles to their respective laboratory limits.

EMISSIONS TEST PROCEDURE:

The tests were conducted by driving each vehicle around a compliant route based in Melbourne, Victoria. The route consisted of urban, extra-urban and freeway driving, with approximately one third of the test being driven in each segment. Each real-world test is driven in normal traffic conditions and accumulates more than seven times the equivalent distance of that when driving the NEDC for the laboratory test.

The test route was devised to satisfy the current draft Real Driving Emissions test procedure developed by the Joint Research Council (JRC), and meets requirements specified by the draft RDE procedure and EC No 2016_427 Annex IIIA Part 6. In order to be a viable test route using public roads in Australian conditions, some minor modifications must be made, namely:

- Maximum speed is limited to 100 km/h which inhibits the ability to achieve at least 5 minutes' driving in excess of 100 km/h for RDE.
- Urban average vehicle speed in Australia is around 25 – 50 km/h compared to 15 – 30 km/h in Europe due to different city speed limits.

KEY OUTCOMES OF REAL-WORLD DRIVING EMISSIONS TESTING:

An evidence based approach to policy development.

Real-world fuel economy over the designated route incorporating urban, rural and freeway driving conditions, and comparison to the official fuel economy.

Evaluation of vehicle emissions in real-world driving conditions compared to their certified laboratory limits.

Evaluation of the emissions performance and fuel consumption across a range of fuel types and technologies available in the Australian market.

RESULTS:

The following results are based on 17 tests.

Chart 1 shows that on average, the real-world fuel consumption across all vehicles tested was 25% higher than the official fuel results based on the cold start tests. The vertical lines on all charts denote the minimum and maximum values recorded across all vehicles tested. The average fuel consumption of vehicles improved when tested with a warm engine, the real-world average fuel consumption was 22.9% higher than the official results.

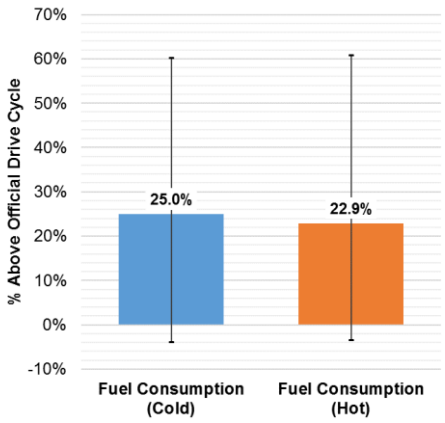

Chart 1 – Average Fuel Consumption of All Vehicles Tested Compared to Official Results

Resolving into the individual fuel types,

Chart 2 shows the average fuel consumption for petrol, diesel and LPG vehicles compared to their respective official results for the laboratory test.

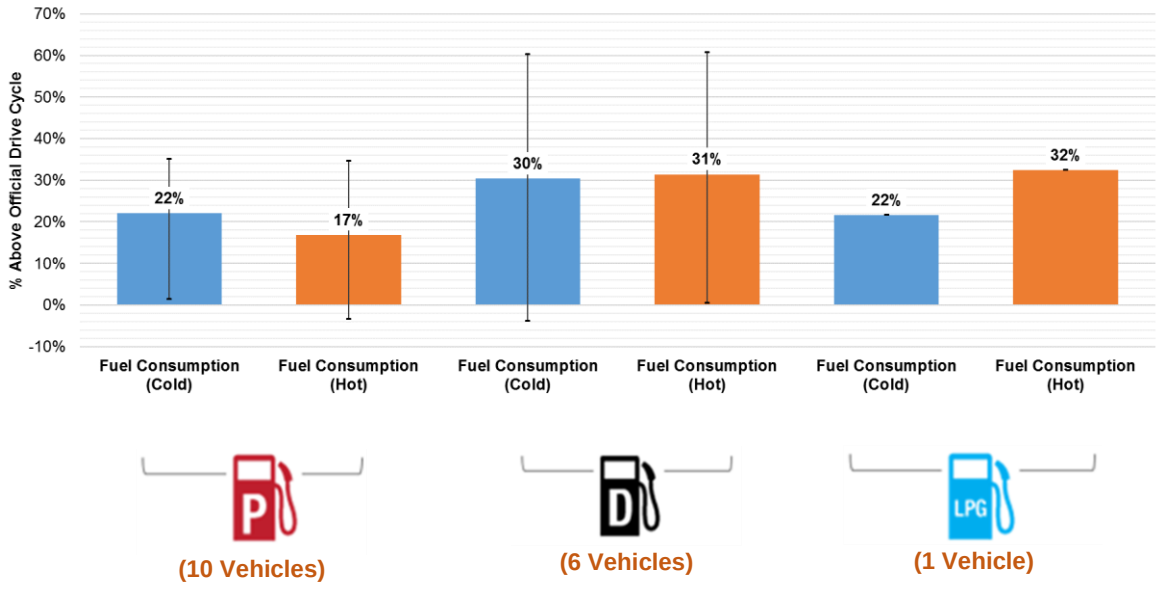

Chart 2 – Average Fuel Consumption of Petrol, Diesel and LPG Vehicles Compared to Official Results

On average, diesel vehicles have the highest variation between real-world fuel consumption and the laboratory results, with 30.4% higher consumption during the cold test. The petrol and LPG vehicles also have significant discrepancies, with both consuming 22% more fuel on average during the cold test than the laboratory drive cycle. It should be noted that only one LPG vehicle has been tested. The height of the vertical bars denotes the variation from minimum to maximum fuel consumption across the vehicles. As a greater number of petrol vehicles were tested than diesel, it could be expected that there is greater variation in petrol fuel consumption. However, the results show the opposite; the variation in real-world fuel consumption of diesel vehicles from the official results is the largest of the fuel types tested. This suggests that the real-world fuel consumption of diesel vehicles is harder to predict based on the laboratory results.

Chart 3 shows the average, minimum and maximum noxious emissions measured, regardless of the relevant emissions standard. This chart shows the amount the variation in real-world emissions across the 17 tests.

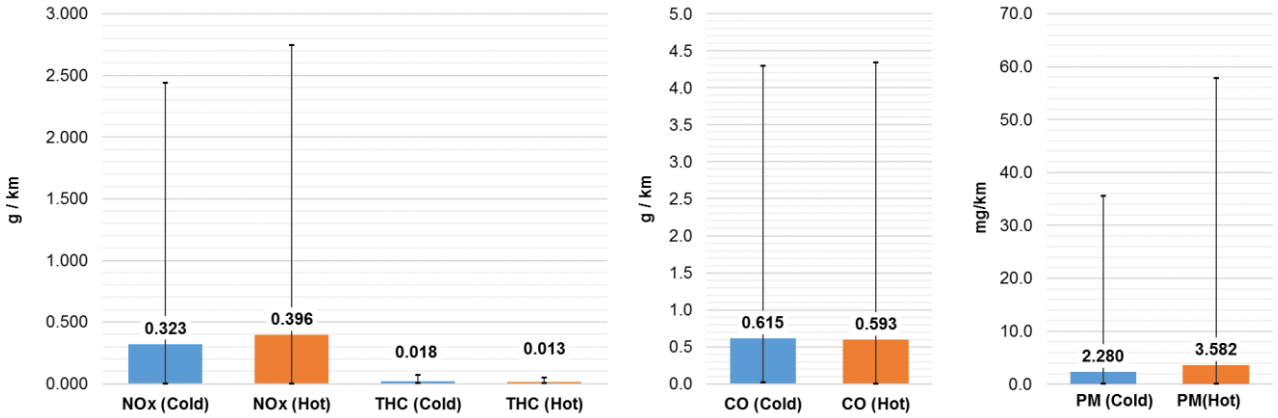

Chart 3 – Variation of Real-world Emissions across all 18 vehicles

POLLUTANT LIMIT EXCEEDANCE:

Charts Chart 6, 4 and 5 below show specific pollutant limit exceedances, where the real-world emissions of individual vehicles exceeded the laboratory limit. Each vehicle tested has been anonymised by use of a unique alphabetical character, A to Q.

Chart 6 shows that all of the NOx limit exceedances to date were by diesel vehicles. Only one of the 6 diesel vehicles (Vehicle 'O', Euro 6 emissions standard), satisfied the relevant limit when tested on the road. A conformity factor applies to Euro 6 vehicles, which permits higher real-world NO_X emissions. The most significant exceedances of NO_X limits are from the Euro 4 and Euro 5 cars, with the light commercial Euro 4 category (N1 Class 3) vehicles exceeding the NOx limit by a smaller margin.

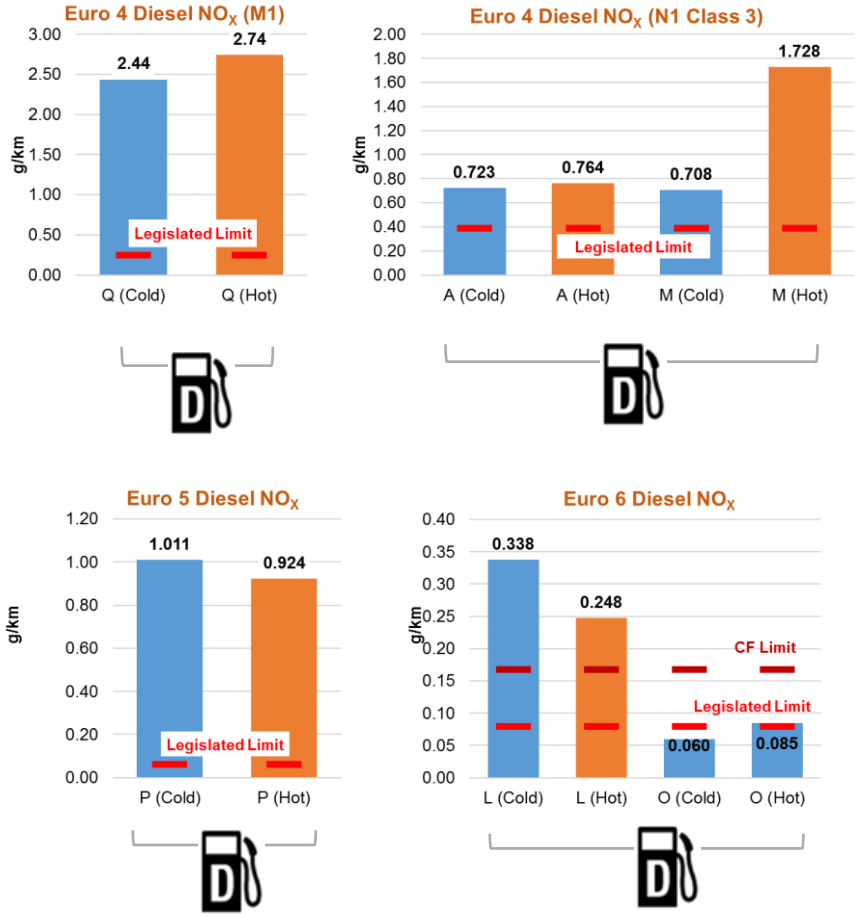

Chart 6 – Real-world Exceedances of Laboratory NO_X Emission Limits

Chart 7 shows that the only vehicle to exceed the laboratory PM limit is vehicle 'M', a Euro 4 diesel light commercial vehicle (N1 Class 3). This vehicle exceeded the Euro 4 laboratory limit of 0.06 g/km by almost 40% for the cold test, however, the hot test PM emissions were almost 10% under the PM limit. Chart 7 includes the PM results for the other Euro 4, N1 Class 3 vehicle tested to date, which comfortably meets the PM limit for the cold test, but was just 4% under the limit during the hot test.

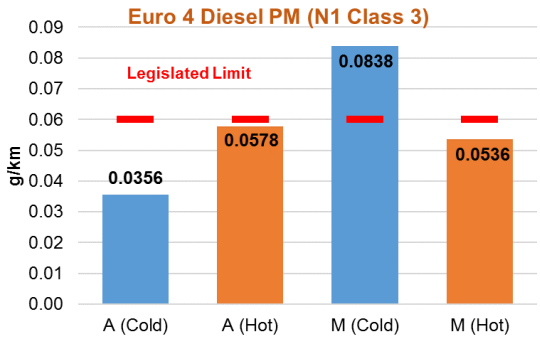

Chart 7 – Real-world Exceedances of Laboratory PM Emission Limits

Chart 8 shows that vehicles 'F' and 'K' exceeded the 1 g/km CO limit for Euro 5 petrol engines by a significant margin. Vehicle 'F' exceeded this limit by 234% and vehicle 'K' exceed the limit by 330%, based on the cold test results. In both these cases, no diagnostic codes were detected before or after test, and the test driver did not perceive any issues in engine or vehicle operation.

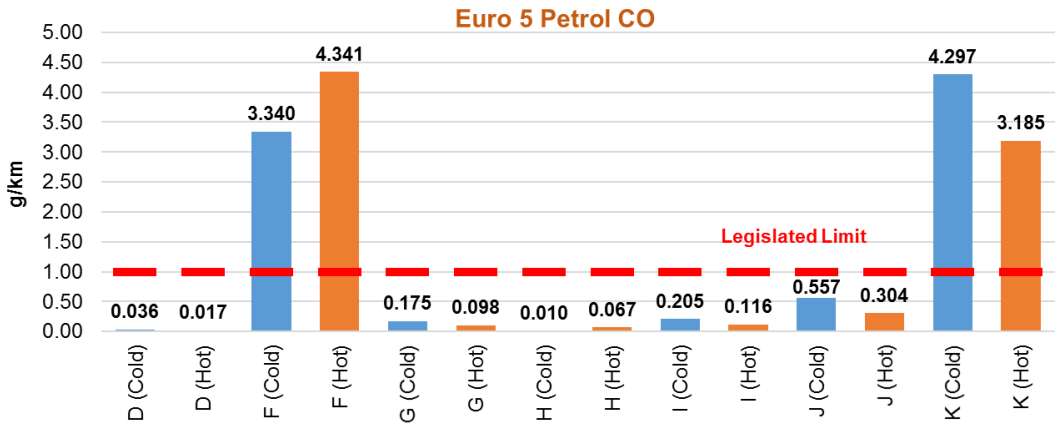

Chart 8 – Real-world Exceedances of Laboratory CO Emission Limits

Table 1 shows the real-world noxious emissions and fuel consumption for of all 17 vehicles tested to date ('A' to 'Q') compared to each vehicle's official results. The official results are based on the cold test in the laboratory. Green shading indicates that the real-world emissions or fuel consumption are within the laboratory based limit (with negative values indicating they are "under the limit"), and red shading indicates that the emission or fuel consumption exceeds the limit. A blank cell indicates that there is no limit relevant to that particular vehicle for that pollutant.

		Vehicle	NO_X	CO	PM	HC +NO_X	THC	NMHC	Fuel
Euro 4	Diesel	A	86%	-96%	-41%	61%			-4%
	Diesel	M	82%	-90%	40%	56%			60%
	Diesel	Q	875%	-97%	-28%	718%			26%
	Petrol	B	-53%	-68%				-86%	19%
	Petrol	C	-91%	-76%				-75%	17%
Euro 5	Diesel	P	462%	-83%	-98%	343%			4%
	LPG	E	-80%	-92%			-92%	-83%	22%
	Petrol	D	-99%	-96%			-93%	-90%	27%
	Petrol	F	-37%	234%			-54%	-33%	30%
	Petrol	G	-90%	-82%			-88%	-82%	34%
	Petrol	I	-83%	-65%			-84%	-77%	10%
	Petrol	J	-85%	-80%	-95%		-84%	-77%	35%
	Petrol	K	-44%	-44%	-93%		-79%	-70%	17%
	Petrol	N	-23%	330%	-36%		-29%	2%	1%
Euro 6	Diesel	L	322%	-94%	-47%	101%			52%
	Diesel	O	-25%	-8%	-99%	-62%			44%
	Petrol	H	-90%	-84%	-88%		-83%	-75%	30%
Total Exceedances			5	2	1	5	0	1	16

Table 1 – Percentage Exceedance of the Emissions Limits, and Official Fuel Consumption Results (Cold Test)

Grouping each vehicle by emissions standard and fuel type allows comparisons to be made between the categories and a specific vehicle's ability to meet the laboratory limits in the real-world.

The five vehicles which exceed the NOx limits are all diesel vehicles. One vehicle exceeded the NOx limit by 875%. Exceedances occurred regardless of the emissions standard to which the vehicle was designed. These five vehicles also exceeded the respective limit for HC + NO_X, which is attributed to the high NO_X emissions. Only one diesel vehicle met the NO_X limit. All petrol and LPG vehicles tested emitted less NO_X than the relevant laboratory limits.

Two vehicles did not meet the CO limits. Both vehicles are petrol fuelled, Euro 5 vehicles. It cannot be determined whether this is a trend specific to Euro 5 vehicles.

Only one vehicle failed to meet the relevant PM limit, a diesel fuelled Euro 4 light commercial vehicle (N1 Class 3).

The only vehicle that exceeded an NMHC limit was vehicle 'N' with a small (2%) exceedance. All other vehicles emitted significantly lower NMHC than the relevant limits. It must be noted however, that for this vehicle the NMHC uses the default estimate of 98% of the total hydrocarbons measured.

Sixteen of the seventeen vehicles exceeded the laboratory fuel consumption results. This demonstrates that independent of fuel type or emissions standard, the majority of vehicles tested in the real-world consume more fuel than their official values, which are determined using the current NEDC laboratory test. One of these vehicles was only 1% higher than its official value, and two were more than 50% higher (52% and 60% exceedance). The discrepancy between the real-world and laboratory test values is not due to any single vehicle attribute, and cannot be determined or inferred by a simple equation; discrepancies occur across a range of fuel types, technology levels, and vehicle emissions standards. The high variation in exceedance from the laboratory fuel consumption results further confirm that real-world vehicle testing is the best way to help consumers make informed decisions when purchasing their next vehicle.

CONCLUSION:

To date, this program has determined that:

- It may not be possible to rely on tests conducted in overseas jurisdictions to ensure the compliance of Australia's light duty fleet, as many vehicles (or vehicle configurations) sold in Australia are not available in Europe.
- Although it is not possible to meet all the requirements of the European Real Driving Emissions (RDE) test schedule on Australian roads due to the Australian climate, and different traffic and speed conditions, adaptations made to the RDE test route specifications were made following consultation with the JRC.
- The real-world fuel consumption of vehicles tested was, on average, 25% higher than the NEDC results, with the highest exceedance being 60% over the official value.
- When compared to the laboratory limits, vehicle pollutant emissions were exceeded for the following:
    - CO was exceeded by 20% of petrol vehicles tested (two out of ten vehicles). These vehicles emitted more than three times the laboratory limit for CO.
    - NOx was exceeded by 83% of diesel vehicles tested (five out of six vehicles). The highest of these emitted almost nine times the laboratory limit for NO_X.
    - PM was exceeded by 17% of diesel vehicles tested (one out of six vehicles). This vehicle emitted 40% more CO than the laboratory limit.

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