

Highways England  
**Work Package Ref 1-185**  
**Paraffinic Fuels Emission Testing**  
Report Final

Final | 9 March 2018

Report to



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## Executive Summary

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ES1. The work reported here was undertaken by the Arup AECOM Consortium, working with Emissions Analytics as sub-contractors, on Work Package Reference 1-185, Paraffinic Fuels Emission Testing (WP1-185). It was commissioned by Highways England under the Specialist Professional and Technical Services (SPaTS) Framework Lot 1 (Technical Consultancy, Engineering Advice, Research and Innovation for roads, vehicles, highway infrastructure and operations), as Work Package reference 1-185.

ES2. A programme of testing and analysis has been undertaken to provide real world driving emissions data to compare pollutant emissions from vehicles using conventional diesel fuel (European Standard EN 590<sup>1</sup>) compared with the same vehicles using Gas-To-Liquid (GTL) fuel (European Standard EN-15940)<sup>2,3</sup>. The GTL fuel was supplied by Shell, whose testing has suggested that use of GTL fuels can simultaneously reduce carbon monoxide, hydrocarbon, soot, oxides of nitrogen and fine particulate matter emissions at a variety of engine operating conditions compared to conventional diesel. If these results were reproduced under real world driving conditions, GTL fuels could play a role in helping the UK achieve the EU limit values for nitrogen dioxide across the country.

ES3. 22 vehicles were tested: 12 vans and 10 cars, covering a range from Euro 4 to Euro 6, of eight different makes. The numbers in each category were:

- Cars, Euro 5: 8
- Cars, Euro 6: 2
- Vans, Euro 4: 4
- Vans, Euro 5: 5
- Vans, Euro 6: 3

ES4. The split of vehicles and the makes were agreed with Highways England, with the intention of covering popular models and makes of vehicles that would be representative of the vehicle parc in England. The 22 vehicles were selected to give a cross-section of different makes, powertrain technologies and Euro certification stages, covering both passenger cars and light duty commercial vehicles. Furthermore, there was a focus on relatively high-selling models in order to achieve representation of a large proportion of sales in the UK market. The original planned fleet mix included five Euro 4 vans, but due to the difficulty of sourcing sufficient Euro 4 vans without very high mileage and maintenance issues, Highways England agreed to change one of the Euro 4 vans for a Euro 6 van.

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<sup>1</sup> European Union Directive 2009/30/EC

<sup>2</sup> Certas Energy. Available at: <https://www.certasenergy.co.uk/commercial/products-and-services/shell-gtl/benefits-of-shell-gtl-fuel> (accessed October 2017)

<sup>3</sup> European Committee for Standardization, <https://www.cen.eu/news/brief-news/Pages/NEWS-2016-010.aspx>, (accessed 30 January 2018)

- ES5. The drive cycle was agreed with Highways England and comprised elements of urban, rural and motorway driving as well as different dynamic modes of driving including gentle and hard acceleration and deceleration, and “Smart Motorway” driving practices. The cars and vans were tested with a consistent payload throughout.
- ES6. The pollutants measured were: oxides of nitrogen (NO<sub>x</sub>), nitrogen dioxide (NO<sub>2</sub>), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), and for a subset of vehicles (three vans and two cars), particle number concentration (PN) was measured. PN was measured on a subset of the vehicles (five vehicles: two cars and three vans). The emissions data was gathered using Portable Emissions Measurement Equipment (PEMS) which allows for measurement during on-road and on-track driving. PEMS was chosen for this project due to its combination of accuracy and ability to measure emissions under real world driving conditions. The equipment was installed on board the test vehicles that were tested in real world driving conditions on the public highway and at a vehicle proving ground.

## Fuel consumption and CO<sub>2</sub>

- ES7. The main statistically significant results were that for the combined cycle the average decrease in fuel consumption was 0.31 l/100km and **the average percentage decrease in fuel consumption was 3.9%**. Similarly, for the combined cycle **the average decrease in CO<sub>2</sub> emissions was 8.1g/km and the average percentage decrease was 3.9%**.
- ES8. The results of testing for PN on four vehicles showed large percentage increases in PN for the two cars tested (86% to 91%), and smaller percentage decreases (13% to 54%) when using GTL fuel for two vans tested. The results were statistically significant. A fifth vehicle tested showed very high results that were thought to be due to the DPF having just been replaced, and occurred despite degreasing the DPF with about 150 miles of driving before the first test.

## Other pollutants

- ES9. There were no clear trends in CO emissions nor NO<sub>x</sub>, NO<sub>2</sub> and NO emissions.
- ES10. It was found that the change in the primary NO<sub>2</sub> fraction (fNO<sub>2</sub>) was less than 20% for all but one vehicle and that increases or decreases were equally likely.

## Comparison against limit values

- ES11. Testing found that almost all the Euro 6 vehicles tested exceeded the CO<sub>2</sub> emission limits for new vehicles manufactured in 2016/2017 (130g/km for cars and 175g/km for light duty vehicles), with fuel A and fuel B.

ES12. All except one vehicle complied with the limit for CO under almost all conditions and drive cycle elements, whereas the NO<sub>x</sub> limit was exceeded in almost all cases, by up to 13 times.

# 1 Introduction

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1. The work reported here was undertaken by the Arup AECOM Consortium, working with Emissions Analytics as sub-contractors commissioned by Highways England under the Specialist Professional and Technical Services (SPaTS) Framework Lot 1 (Technical Consultancy, Engineering Advice, Research and Innovation for roads, vehicles, highway infrastructure and operations), as Work Package reference 1-185.
2. Defra's 2017 Air Quality Plan for the UK<sup>4</sup> reported that the EU limit value for NO<sub>2</sub> was exceeded in 37 out of the 43 defined zones in the country in 2015 (the latest year reported). NO<sub>2</sub> is, therefore, the most pressing air quality issue for the UK. Despite progressively tighter EU emissions certification standards for road vehicles that are being met under laboratory testing conditions, ambient NO<sub>x</sub> and NO<sub>2</sub> concentrations have not fallen as quickly as anticipated. This is attributed to the emissions of NO<sub>x</sub> in real world driving of diesel vehicles (European Standard EN 590<sup>5</sup>) being greater than expected on the basis of laboratory testing, and the increase in the proportion of diesel vehicles in the UK fleet.
3. The market penetration of diesel passenger cars grew significantly in the UK from the 1980s until recent years, from less than 7.4% of the car fleet before 1994 to 39% in 2016.<sup>6</sup> This was encouraged in part by the approximately 16% fuel economy advantage of the diesel car over an equivalent petrol, and government policy that prioritised reduction in CO<sub>2</sub> emissions. The challenge for the UK government is how to improve urban air quality without leading to increasing CO<sub>2</sub> emissions by, for example, a switch back from diesel to petrol cars. Gas-to-Liquid (GTL) fuel (European Standard EN-15940)<sup>7,8</sup> is a potential solution to the dilemma. It has the attraction of being a ready substitute for diesel, in the sense that engines would not require conversion. Understanding the effects of using GTL fuel on NO<sub>x</sub> and CO<sub>2</sub> emissions under real world driving conditions is the objective of this test programme.

## 1.1 Scope and objectives

4. The scope of WP1-185 was to provide real world driving emissions data to compare pollutant emissions from vehicles using conventional diesel fuel compared with the same vehicles using GTL fuel.

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<sup>4</sup> Air quality plan for nitrogen dioxide (NO<sub>2</sub>) in UK (2017), Department for Environment, Food & Rural Affairs and Department for Transport, 26 July 2017

<sup>5</sup> European Union Directive 2009/30/EC

<sup>6</sup> Department for Transport (2017) Transport Statistics Great Britain 2017, 2017 Edition

<sup>7</sup> Certas Energy. Available at: <https://www.certasenergy.co.uk/commercial/products-and-services/shell-gtl/benefits-of-shell-gtl-fuel> (accessed October 2017)

<sup>8</sup> European Committee for Standardization, <https://www.cen.eu/news/brief-news/Pages/NEWS-2016-010.aspx>, (accessed 30 January 2018)

5. Table 1 and Table 2 show the number and type of cars and light goods vehicles (LGVs, or vans) that were originally specified to be tested in the Highways England tender document.<sup>9</sup>
6. The available funding constrained the number of vehicles which could be tested. 22 vehicles were tested, as defined in Table 3. The numbers in each category were:
  - Cars, Euro 5: 8
  - Cars, Euro 6: 2
  - Vans, Euro 4: 4
  - Vans, Euro 5: 5
  - Vans, Euro 6: 3
7. The split of vehicles and the makes were agreed with Highways England, with the intention of covering popular models and makes of vehicles that would be representative of the vehicle parc in England. The 22 vehicles were selected to give a cross-section of different makes, powertrain technologies and Euro certification stages, covering both passenger cars and light duty commercial vehicles. Furthermore, there was a focus on relatively high-selling models in order to achieve representation of more common vehicle types in the UK market. The original planned fleet mix included five Euro 4 vans, but due to the difficulty of sourcing sufficient Euro 4 vans without very high mileage and maintenance issues, Highways England agreed to change one of the Euro 4 vans for a Euro 6 van.
8. The drive cycle was agreed with Highways England and comprised elements of urban, rural and motorway driving as well as different dynamic modes of driving including gentle and hard acceleration and deceleration, and “Smart Motorway” driving practices. The cars and vans were tested with a consistent payload throughout.
9. During each test fuel consumption was measured. The pollutants measured were: oxides of nitrogen (NO<sub>x</sub>), nitrogen dioxide (NO<sub>2</sub>), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), and for a subset of vehicles (three vans and two cars), particle number concentration (PN) was measured. PN was measured on a subset of the vehicles (five vehicles: two cars and three vans). The emissions data was gathered using Portable Emissions Measurement Equipment (PEMS).

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<sup>9</sup> Highways England (2016) Work Package Scope for vehicle emission testing and analysis to evaluate real world performance of paraffinic fuels (GTL Fuel) comparative to conventional diesel fuels.

Table 1: The split of cars defined in Table 2 of the Highways England tender

Vehicle type	Euro standard	No. of vehicles	Fuel	Pollutants		
				NO <sub>x</sub>	CO <sub>2</sub>	PM
Mini	4	5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Small		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Medium		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Large		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
MPV		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Mini	5	5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Small		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Medium		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Large		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
MPV		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Mini	6	2	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Small		2	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Medium		2	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Large		2	Diesel GTL fuel	✓✓✓	✓✓✓	✓
MPV		2	Diesel GTL fuel	✓✓✓	✓✓✓	✓

✓✓✓ Emissions monitoring for these pollutants is essential

✓ Emissions monitoring for this pollutants is desirable

Table 2: The split of LGVs defined in Table 3 of the Highways England tender

Vehicle type	Euro standard	No. of vehicles	Fuel	Pollutants		
				NO <sub>x</sub>	CO <sub>2</sub>	PM
Vans (N1, N2)	4	5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Vans (N3)		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Vans (N1, N2)	5	5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Vans (N3)		5	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Vans (N1, N2)	6	2	Diesel GTL fuel	✓✓✓	✓✓✓	✓
Vans (N3)		2	Diesel GTL fuel	✓✓✓	✓✓✓	✓

✓✓✓ Emissions monitoring for these pollutants is essential

✓ Emissions monitoring for this pollutants is desirable

Table 3: Vehicles tested

Make	Car or Van	Model	Engine	Year of registration	Euro class	Miles on clock	Leased/purchased?
Ford	Car	Focus Zetec	1.6 TDCI	2009	5	98,440	Purchased
Mini	Car	Cooper S	2.0 D	2011	5	43,783	Purchased
Vauxhall	Car	Astra Design	1.7 CDTI Ecoflex	2013	5	60,601	Purchased
Volkswagen	Car	Polo*	1.2 TDI Bluemotion	2013	5	31,380	Purchased
Nissan	Car	Qashqai Acenta Premium	1.6 dCi	2014	5	11,251	Leased
Ford	Car	Mondeo Titanium X Sport	2.0 TDCI (163ps)	2014	5	49,673	Leased
Peugeot	Car	308 Active	1.6 HDI	2014	5	26,152	Leased
Volkswagen	Car	Passat GT Tech Estate	2.0 TDI Bluemotion	2015	5	45,280	Leased
Ford	Car	Focus ST-Line	1.5 TDCI	2017	6	4,776	Leased
Nissan	Car	Qashqai N-Connect*	1.5 dCi	2017	6	10,416	Leased
Vauxhall	Van	Vivaro 2900 SWB	2.0 CDI	2007	4	45,158	Leased
Citroen	Van	Berlingo Enterprise*	1.6 HDI	2008	4	98,795	Leased
Volkswagen	Van	Crafter CR35 MWB High Roof*	2.5 TDI 88ps	2008	4	147,961	Purchased
Ford	Van	Transit 350EF LWB Chassis cab	2.4 TDCI 115ps	2011	4	118,254	Leased
Mercedes-Benz	Van	Sprinter 3.5 MWB 313	2.1 CDI	2011	5	128,612	Leased
Ford	Van	Transit Connect Trend	1.8 TDCI 90	2011	5	78,333	Leased
Ford	Van	Transit 280	2.2 TDCI 100ps	2012	5	53,251	Leased
Renault	Van	Trafic SL27 Business +	1.6 DCI	2015	5	21,519	Leased
Peugeot	Van	Partner 850 Professional*	1.6 HDI	2015	5	32,676	Leased
Peugeot	Van	Partner Professional 850	1.6 HDI 850	2016	6	23,687	Leased
Ford	Van	Transit 350 Luton L4	2.0 TDCI 130	2017	6	3,908	Leased
Volkswagen	Van	Crafter CR35 Startline	2.0 TDI	2017	6	2,379	Leased

**NB: The VW Crafter CR35 MWB High Roof 2008 had a new PDF filter fitted before testing, and when new, the filters are less efficient.**  
**\*Vehicles on which measurements of PN were carried out.**

## 2 GTL Fuel

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10. GTL fuel is a subset of the “paraffinic fuels” group,<sup>8</sup> which are fuels produced from feedstock such as biomass, natural gas or waste vegetable oils (BTL, GTL, HVO respectively). These fuels are synthetically manufactured and can be substituted as a ‘drop-in’ fuel for conventional diesel without modification of the engine (in heavy- and light-duty engines). Broadly speaking GTL has similar physical characteristics to conventional diesel however has a much higher cetane number<sup>10</sup>, higher calorific values and a lower density. A vehicle running on GTL fuel would therefore be expected to start more easily, have better fuel consumption due to the higher calorific value and due to the lighter fuel load, than a vehicle running on conventional diesel.
11. The GTL process<sup>11</sup> converts natural gas to a variety of synthetic hydrocarbons such as diesel, kerosene and lubricant oil. The most common synthesis technique for producing GTL is Fischer-Tropsch (F-T). F-T synthesis is a three-step process:
- Partial oxidation of natural gas to produce synthesis gas (a hydrogen and carbon monoxide mixture);
  - A catalyst is used to convert the synthesis gas into liquid hydrocarbons, with a consistency of wax at room temperature; and
  - Cracking and isomerisation to cut the molecule chains into shorter lengths.
12. There are six main GTL products:
- a. GTL naphtha – used as a feedstock for chemical plants (produces the building blocks for the plastics industry);
  - b. GTL kerosene – can be blended with aircraft fuel or used for heating/lighting;
  - c. GTL normal paraffin – premium feedstock for detergent production;
  - d. GTL gasoil – an alternative to diesel fuel;
  - e. GTL base oil – high quality base material for lubricants in engines; and
  - f. GTL wax – high quality products with various uses (e.g. printer inks, adhesives, candles, construction and food packaging).
13. It was the GTL gasoil product that has been used in this project.
14. The Certas Energy report<sup>7</sup> on Shell GTL fuel describes the fuel and its benefits. In this report, paraffinic fuels are said to be a clean, high quality fuel, which mixes readily and can be used in blends with petroleum-derived diesel or biodiesel. There is therefore no need to clean out tanks first.

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<sup>10</sup> The higher the cetane number is, the easier it is to start (ignite) a direct-injection diesel engine

<sup>11</sup> [www.shell.com/energy-and-innovation/natural-gas/gas-to-liquids.html](http://www.shell.com/energy-and-innovation/natural-gas/gas-to-liquids.html)

15. The synthetic processing produces a fuel with more uniform molecules compared to its crude oil counterpart. It is this consistency from the F-T process that improves the combustion properties of the fuel and may potentially lower emissions of pollutants<sup>7</sup>.
16. Wu et al<sup>12</sup> report that GTL fuels are colourless and almost odourless, virtually sulphur free, and the aromatic (polyaromatics, aromatics, poly-cyclic aromatics), nitrogen and metals contents are low. Wu reports that GTL fuels can simultaneously reduce CO, hydrocarbon, soot, NO<sub>x</sub> and fine particulate matter (PM) emissions at a variety of engine operating conditions compared to conventional diesel. In addition to the reduction in emissions, GTL fuels are reported to have shown improvements in thermal efficiency and fuel economy.
17. Hassaneen et al<sup>13</sup> reports that GTL produces 5% lower CO<sub>2</sub> emissions than conventional fuel or Rapeseed Methyl Ester (RME) alternative fuel.
18. Shell currently uses GTL in a diesel blend. Table 4 shows the reductions in NO<sub>x</sub> and PM measured by Shell with the use of GTL fuel. The reduction in emissions depends on engine size, age and use of vehicle.

Table 4: Reductions in emissions of NO<sub>x</sub> and PM with the use of GTL fuels

Area of use	NO <sub>x</sub>	PM
<b>On-road heavy-duty transport</b>	5-37%	10-38%
<b>Off-road vehicles</b>	6-25%*	10-90%
<b>Marine</b>	6-13%	15-60%

The data in this table has been taken from: [www.certasenergy.co.uk/docs/default-source/default-document-library/shellgtlbenefits.pdf](http://www.certasenergy.co.uk/docs/default-source/default-document-library/shellgtlbenefits.pdf) (footnote 6)

\*Lower reduction in off-road vehicles is due to less sophisticated vehicles and less stringent fuel specifications.

The ranges represent the maximum variation of results observed in scientific experiments.

<sup>12</sup> Wu et al., 2007. Physical and Chemical Properties of GTL-Diesel Fuel Blends and Their Effects on Performance and Emissions of a Multicylinder DI Compression Ignition Engine. Energy Fuels, 21 (4), pp. 1908-1914.

<sup>13</sup> Hassaneen et al., 2012. Fuel economy and emission characteristic of Gas-to-Liquid (GTL) and Rapeseed Methyl Ester (RME) as alternative fuels for diesel engines. Fuel. Volume 97, pp. 125-130.

## 3 Test Methodology

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### 3.1 Rationale for approach

19. PEMS was chosen for this project due to its combination of accuracy and ability to measure emissions under real world driving conditions. The equipment was installed on board the test vehicles that were tested in real world driving conditions on the public highway and at a vehicle proving ground. The equipment is capable of measuring CO<sub>2</sub> and NO<sub>x</sub>, among other pollutants, on a second-by-second basis to a level of accuracy such that it is increasingly being adopted by official certification bodies internationally. PEMS has been part of the type approval for Euro VI heavy duty vehicles since 2014,<sup>14</sup> is required as part of the EU's improved type approval regulations for Euro 6 light duty vehicles.<sup>15</sup> This has been applied to all new models of light duty vehicles from 1<sup>st</sup> September 2017, and will apply to all new cars from 2021, and all new vans from 2022

### 3.2 Robustness of testing

20. The approach to testing used to ensure robustness of results was as follows:

- The test route was designed so it can be driven repeatedly and as consistently as possible;
- Attention was paid to vehicle conditioning to ensure consistency between tests;
- The same driver was used for each pair of tests, i.e. for each fuel in a given vehicle;
- The timing of the second test was flexible to match the ambient temperature and other climatic conditions as closely as possible to the first test in a pair;
- No testing was conducted if the carriageway was wet or in poor weather, such as rain, snow, ice and high winds, as these would affect the rolling resistance of the vehicle, the load on the engine and consequently the fuel burnt and emissions. Extreme ambient temperatures were also avoided, mirroring the requirements of the Real Driving Emissions regulatory framework; and
- Any events not in the planned drive cycle, such as regeneration of the diesel particulate filter during the test, were removed. This is because the purpose of the testing was to compare the performance of the fuels under “like-for-like” conditions. An unplanned events would mean the comparison was not like-for-like.

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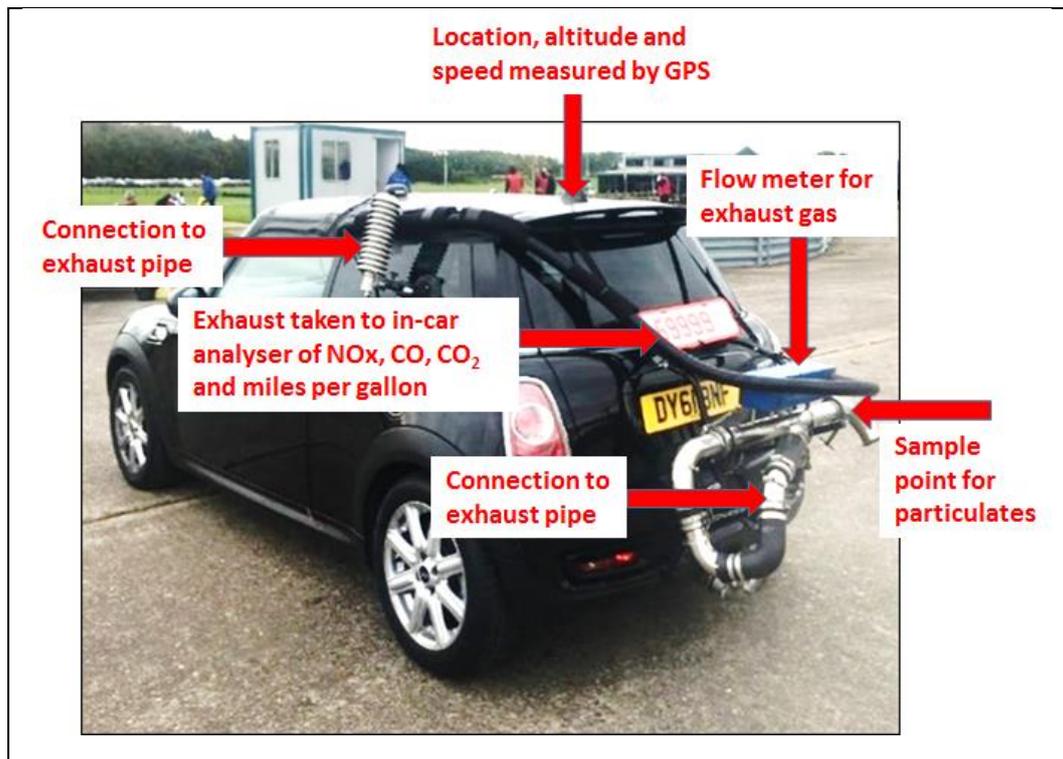
<sup>14</sup> Regulation (EC) 595/2009

<sup>15</sup> Regulation (EC) 2016/427 of 20 April 2016

### 3.3 Testing equipment

21. The emissions tests were conducted with a Sensors SEMTECH-LDV for gaseous emissions from LDVs and the Pegasor Mi2 for particulate matter. The equipment used is described in brief in Appendix A and the calibration certificates are shown in Appendix B.
22. To measure the total mass flow of gas a Sensors flow tube was used, mounted on the exterior of the vehicle, as shown in Figure 1. No permanent modification to the vehicles were required to install the equipment.

Figure 1: Testing equipment used



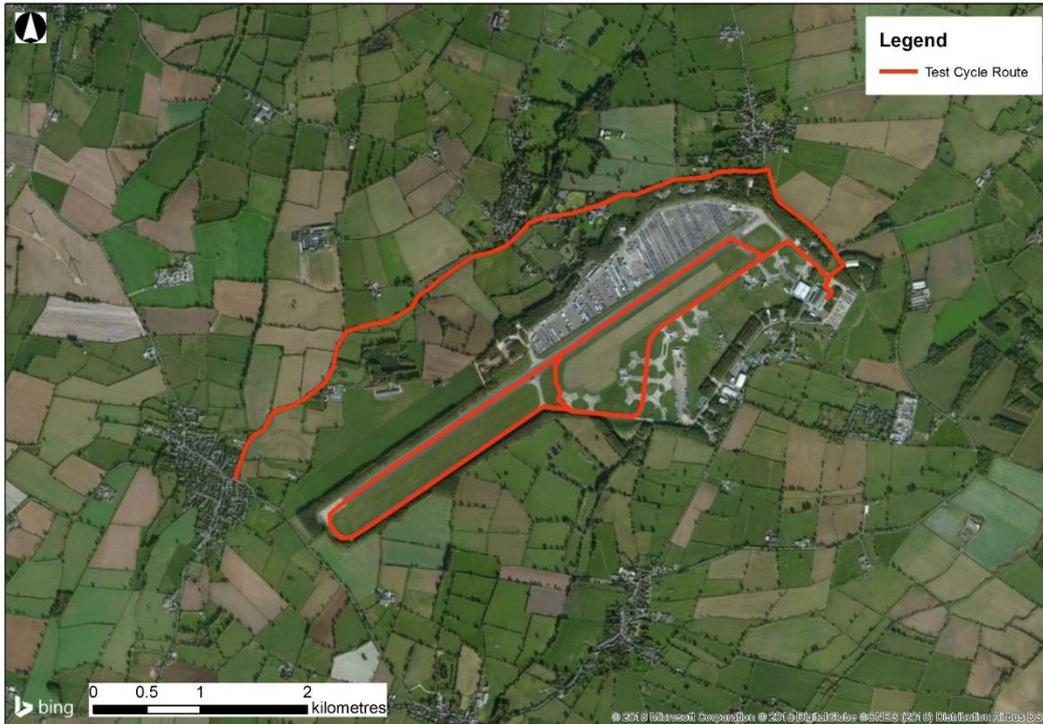
### 3.4 Vehicles

23. The three main sources of vehicles were: short-term rental fleets; fleets with which Emissions Analytics has a relationship; and purchasing from the second-hand market and disposing at the end of the project. Table 3 shows which of the vehicles tested were leased and which were purchased. It also shows the engine size, year of registration, Euro class and miles on clock.

### 3.5 Duty cycle

24. The venue for emissions testing and mileage accumulation was Bruntingthorpe Proving Ground in Lutterworth, Leicestershire<sup>16</sup>, and the public roads around the proving ground. A test cycle included a section similar to the Real Driving Emissions regulations for light duty vehicles<sup>15</sup>, which took place on the public highway. The test cycle route is shown in Figure 2.

Figure 2: Map of test cycle



25. The test protocol had the following elements and is defined in Box 1:

- Urban dynamic cycle test on-track up to a maximum of 30 mph: six repeats, 60 minutes;
  - Motorway-style driving featuring multiple dynamic elements for example gentle / harsh acceleration and deceleration: six repeats, 30 minutes; and
  - Rural driving on the public highway: 60 minutes in total.
- a. The cycle included all the elements stated in section 3.2 (1) of the tender<sup>9</sup> (i to iv below), with the exception of cold start. All testing was conducted from warm start.
- i) Motorway / Urban Driving / Junctions / Slip roads
  - ii) Free-flow / Speed Control / Congested conditions

<sup>16</sup> [www.bruntingthorpeprovingground.com](http://www.bruntingthorpeprovingground.com)

- iii) All tests to be “warm-start”<sup>17</sup> for motorway driving
  - iv) Consider a mixture of cold and warm starts for urban driving
- b. Each test was conducted with a consistent use of on-board systems, in particular air conditioning systems. They were conducted with a single, fixed payload that is at a consistent level depending on the vehicle type, this was 50% of maximum load for passenger cars and 67% of maximum load for light goods vehicles.
- c. Before the each test, each vehicle was conditioned on the new fuel through mileage accumulation equivalent to 25miles. To minimise the chance of a regeneration of the diesel particulate filter, a forced regeneration was conducted before each test. The equipment does not successfully force regeneration on every vehicle type and on some vehicles regeneration happens frequently. Therefore, if despite the forced regeneration being attempted a regeneration did occur during a test, the affected part of the test was re-run such that all the end results excluded any such events.
- d. The multiple repeats of the track tests were to show the repeatability of the results without traffic flow as a confounding factor. These results were the basis of tests of statistical significance of the differences between the fuels. The on-road test was to evidence performance in real world driving conditions on a route similar to that specific in the new NO<sub>x</sub> regulations.
- e. For each car, the driver and test equipment was the same for the tests on both fuels.

#### Box 1: Test cycle definition

- a. Vehicle checklist to be carried out ensuring the vehicle is in good health; tyre pressures and tread depths must be taken.
- b. Flush out original fuel from vehicle.
- c. Fill tank with 15 litres of Fuel A, enough to cover short mileage accumulation and whole of test block.
- d. Mileage accumulation: 25 miles
- e. Conduct first half of Test A
  - a. 6x laps at 70mph (must be consistent track throughout test, start laps at first corner)
  - b. 6x laps of rural element (gatehouse to Gilmorton to gatehouse)
  - c. 6x Urban element
- f. Drain and flush tank, then refuel with 15 litres of Fuel B
- g. Mileage accumulation: 25 miles

<sup>17</sup> Based on the definition in the draft Real Driving Test procedure (March 2015), warm start refers to 5 minutes after the initial start of the combustion engine, or when coolant temperature has reached 70°C.

- h. Conduct first half of Test B
  - a. 6x laps at 70mph (must be consistent track throughout test, start laps at first corner)
  - b. 6x laps of rural element (gatehouse to Gilmorton to gatehouse)
  - c. 6x Urban element
- i. Refuel vehicle for next test
- j. Conduct second half of Test B
  - a. 6x laps at 70mph (must be consistent track throughout test, start laps at first corner)
  - b. 6x laps of rural (gatehouse to Gilmorton to gatehouse)
  - c. 6x Urban element
- k. Drain and flush tank, then refuel with 15 litres of Fuel A.
- l. Mileage accumulation: 25 miles
- m. Conduct second half of Test A
  - a. 6x laps at 70mph (must be consistent track throughout test, start laps at first corner)
  - b. 6x laps of rural (gatehouse to Gilmorton to gatehouse)
  - c. 6x Urban element

### 3.6 Test plan

26. The test structure was ABBA, where “A” is a complete duty cycle on standard diesel and “B” is on GTL. The second, third and fourth emissions tests were scheduled to match the ambient temperature, pressure and humidity as closely as possible to the first test. Temperature, pressure and humidity can affect engine performance and after-treatment performance.

## 4 Method of Analysis

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27. The data quality management process is set out in Appendix C.
28. The first stage of analysis is to derive fuel consumption from the measured tailpipe emissions. This is achieved by using the carbon balance method. If the chemical composition in the tank is known, the amount of fuel burnt can be mathematically derived from the carbon-based gases emitted, as the tailpipe is a closed system from the engine to exhaust. The process used in this case matches the process used during official certification testing.
29. The validated data was then analysed in the following way, to compare between the fuels within each vehicle:
- Each complete test was split into the individual repeats of urban, rural and motorway driving, and the emissions and fuel economy values calculated for each repeat.
  - For each fuel and within each of the route types (urban, rural and motorway), the mean and standard deviation of results across the multiple repeats were calculated.
  - The differences (absolute and percentage) between the mean values for diesel and GTL for each route type were calculated.
  - A statistical test was then applied to those difference to see if the change was considered statistically significant.
30. As the 22 vehicles tested (five vehicles for PN) underwent six repetitions of the different drive cycle elements, the effective sample size was 132 for the gaseous pollutants, and 30 for the PN measurements.
31. The test of statistical significance assesses how likely it is that the observed results were due to genuine differences between the fuel rather than random measurement error. The approach used was a two-tailed Student's-t-test with a 90% confidence threshold. Two-tailed means that both improvements and reduction in performance were being tested for, and the confidence threshold means that the probability of the results not being random needs to be 90% or more to be considered a significant result.
32. The above approach was used on the following measured values:
- Fuel consumption;
  - CO<sub>2</sub>;
  - CO;
  - NO<sub>x</sub>, the combination of nitric oxide (NO) and NO<sub>2</sub>; and
  - PN (with 23nm lower size cut-off; applied to a subset of vehicles).
33. The test method of "ABBA" involved testing diesel in the morning of day 1, GTL in the afternoon of day 1, GTL again in the morning of day 2 and finally diesel in the afternoon of day 2. The main results described above combined

the two groups of A as the diesel result, and the two groups of B as the GTL result, compared the two and applied the test for statistical significance.

34. A final stage of analysis and validation involved testing to see whether the results were a function of the time of day and/or order of testing. The hypothesis here is that there is no difference between the test results to be compared and therefore the Student's-t test would be expected to produce a statistical significance less than 90%. These results are reported in section 5.2 and the data is given in Appendix E.
35. Highways England requested that the results from the testing be compared with results from the hundreds of previous tests carried out by Emissions Analytics on passenger cars and vans, to help put the results into a wider context. The results are reported in section 5.3 and the data is given in Appendix F.
36. There are several reasons why the comparison against the Emissions Analytics database would show significant differences:
  - The vehicles tested were not all in the database and therefore the comparison was with the vehicle judged to be the nearest equivalent;
  - The drive cycle for this test was different from the Emissions Analytics standard cycle; and
  - The database includes mainly vehicles tested when new, whereas the vehicles tested under this work package were used vehicles.

## 5 Summary of Results

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37. This section contains the results of the testing for each vehicle and each testing element – urban (U), rural (R), motorway (M), and by the combined elements. Table 5, 7, 9, 11, 13, 15 and 17 show the fuel consumption (Table 5) and pollutant emission rate for CO<sub>2</sub>, CO, NO<sub>x</sub>, NO<sub>2</sub>, NO and PN respectively. For each of the parameters, the tables show the absolute values for fuel A and fuel B and the statistical significance of the results. Significance values greater than or equal to 90% are highlighted in yellow.
38. A confidence threshold of 90% or greater has been used as the test for whether the changes measured were statistically significant.
39. The comparison of absolute values and limit value (where relevant are shown in Figures 3 to 6 for fuel consumption, Figures 7 to 10 for CO<sub>2</sub>, Figures 11 to 14 for CO, Figures 15 to 18 for NO<sub>x</sub>, Figures 19 to 22 for NO<sub>2</sub>, Figures 23 to 26 for NO and Figures 27 to 30 for PN).
40. Tables 6, 8, 10, 12, 14, 16 and 18 show the absolute change in each parameter and the percentage change due to use of GTL fuel compared with conventional diesel. The change is calculated as:
- Fuel B [GTL fuel] minus Fuel A [conventional diesel]
- And the percentage change is calculated as
- (Fuel B [GTL fuel] minus Fuel A [conventional diesel]) x 100% / Fuel A.
41. A negative percentage for pollutant emissions shows that the GTL fuel has a lower emission rate than the conventional diesel; a positive value shows that the GTL fuel has a higher emission rate than the conventional diesel value.

### 5.1 Comparison of conventional diesel and GTL fuels

#### 5.1.1 Fuel consumption

42. Considering the combined cycles, all vehicles tested had lower fuel consumption using GTL fuels than conventional diesel. The change in fuel consumption varied from a decrease of 0.71 l/100km for the Mercedes-Benz Sprinter 3.5 MWB 313 Euro 5 van, to a decrease of 0.07 l/100km for the Ford Focus ST-Line Euro 6 car and the Renault Trafic SL27 Business+ Euro 5 van. These were also the largest (-6.4%) and smallest (-0.9% for the Renault Euro 5 van) percentage changes.
43. Fuel consumption was less with GTL fuel than conventional diesel for almost all vehicles and all elements of the drive cycle. Most of the vehicle-drive cycle elements had a statistically significant measured difference.

44. For the combined cycle, fuel consumption was less with GTL fuel than conventional diesel for all vehicles. The average decrease was 0.31 l/100km and the average percentage decrease was 3.9%.

### 5.1.2 Carbon dioxide and carbon monoxide

45. Trends in CO<sub>2</sub> emissions followed the same trend as the fuel consumption.
46. Most of the vehicle-drive cycle element tests had a statistically significant measured difference.
47. Considering the combined cycles, all vehicles tested had CO<sub>2</sub> emissions using GTL fuels than conventional diesel. The change in CO<sub>2</sub> emissions varied from a decrease of 19.1g/km for the Mercedes Benz Sprinter 3.5 MWB 313 Euro 5 van, to a decrease of 0.4g/km for the Peugeot Traffic SL27 Business+ Euro 5 van. These were also the largest (-10.4%) and smallest (-0.2%) percentage changes.
48. For the combined cycle the average decrease in CO<sub>2</sub> emissions was 8.1g/km and the average percentage decrease was 3.9%.
49. There were no clear trends in CO emissions with large percentage increases and decreases measured. The change in CO emissions for the combined cycle varied from a decrease of 0.14g/km for the Volkswagen Crafter CR35 MWB High Roof Euro 4 van, to an increase of 0.07g/km for the Volkswagen Crafter CR35 Startline Euro 6 van. The largest percentage decrease (-65%) was for the Vauxhall Astra Design Euro 5 car, and the largest percentage increase (203%) percentage change was for the Volkswagen Crafter CR35 Startline Euro 6 van.
50. Most of the vehicle-drive cycle element tests did not have a statistically significant measured difference.

### 5.1.3 Nitrogen oxides (including NO<sub>2</sub>-fraction)

51. There were no clear trends in NO<sub>x</sub>, NO<sub>2</sub> and NO emissions and most of the vehicle-drive cycle element tests did not have a statistical significant measured difference.
52. For NO<sub>x</sub> emissions fairly large percentage increases and decreases were measured, from a 47% decrease for the Volkswagen Crafter CR35 Startline Euro 6 van to a 22% increase for the Renault Traffic SL27 Business+ Euro 5 van for the combined cycle.
53. For NO<sub>2</sub> emissions fairly large percentage increases and decreases were measured. The maximum percentage changes in NO<sub>2</sub> were a 76% decrease for the Volkswagen Crafter CR35 Startline Euro 6 van and a 39% increase for the Renault Traffic SL27 Business+ Euro 5 van for the combined cycle.
54. Figure 31 shows the change in NO<sub>2</sub> as a function of the change in NO<sub>x</sub>. It shows that for some vehicles, while NO<sub>x</sub> emissions decrease, NO<sub>2</sub> emission increase (the top left quarter of the plot). The points in the bottom left quarter

show decreases in both NO<sub>x</sub> and NO<sub>2</sub>; the top right quarter shows when NO<sub>x</sub> emissions increase, the increase in NO<sub>2</sub> is generally smaller.

55. Table 19 shows the primary NO<sub>2</sub> fraction (fNO<sub>2</sub>) and the change in fNO<sub>2</sub>. The change in the primary NO<sub>2</sub> fraction (fNO<sub>2</sub>) was less than 20% (except for the Volkswagen Crafter CR35 Startline Euro 6 Van, for which there was a decrease of 55% using GTL fuel) and increases or decreases in fNO<sub>2</sub> were equally likely.

### 5.1.4 Particulates

56. With the exception of the results for the Volkswagen Crafter CR35 MWB Euro 4 van, the results shows showed large percentage increases in PN for the two cars tested (86% to 91%), and smaller percentage decreases (13% to 54%) when using GTL fuel for the two other vans tested.
57. Most of the vehicle-drive cycle element tests had a statistically significant measured difference.
58. For the Volkswagen Crafter CR35 MWB Euro 4 van, the recorded PN using conventional diesel was very high compared to the other vehicles, and using GTL fuel was much reduced but still very large compared to PN for the other vehicles. The reason for the high reading is thought to be that the diesel particulate filter (DPF) had just been replaced, and for a period (until they are sooted up) they do not work as well in capturing the PN. To counteract this effect the DPF was degreed with about 150 miles of driving before the first test. However, it is possible that it was still not up to full filtration efficiency.

## 5.2 Comparison of A v A and B v B

59. Combined cycle CO<sub>2</sub> emissions have been used to compare the results from each test to determine whether the results were affected by the time of day and/or the order of the test. The tables of results and figures are given in Appendix E.
60. The difference in CO<sub>2</sub> emissions is:
- A on day 1 to A on day 2: -1.7%; and
  - B on day 1 to B on day 2: 0.6%;
- Compared with the average difference between A and B (-3.9%), it can be concluded that the time of day of the test, or the order of the test, was not a confounding factor.
61. Comparing A and B tests the difference in CO<sub>2</sub> emissions is:
- A on day 1 to B on day 1: -5.0%;
  - A on day 2 to B on day 1: -3.1%;
  - A on day 1 to B on day 2: -5.0%; and
  - A on day 2 to B on day 2: -2.6%.
- All of these results cluster close to the overall average and therefore the day of the test is not a confounding factor.

62. The tests of statistical significance within the A results are applied separately for urban, rural and motorway. There are some individual instances where statistical significance is, but for no vehicle is this seen across all the cycle types. The same applies for the tests within the B results.

### 5.3 Comparison of emissions against limit values

63. EU Regulation No 443/2009<sup>18</sup> sets targets for CO<sub>2</sub> emissions from light duty vehicles. The target for new passenger cars is 130g/km from 2016, and 95g/km from 2021. For light commercial vehicles the emissions target is 175g/km from 2017, and 147 g/km from 2020. The 2016/2017 targets of 130g/km for cars and 175g/km for light duty vehicles, which apply to Euro 6 vehicles, are plotted in Figures 7 to 10. Almost all the Euro 6 vehicles tested exceeded the 2016/2017 CO<sub>2</sub> emission with fuel A and with fuel B.

64. Figures 11 to 14 show that almost all the vehicles complied with the limit of CO under almost all conditions and drive cycle elements, whereas Figures 15 to 18 shows that the NO<sub>x</sub> limit was exceeded in almost all cases, by up to 13 times (Nissan Qashqai N-Connect Euro 6 car).

### 5.4 Comparison of emissions against the Emissions Analytics database

65. The nearest equivalent models from the Emissions Analytics database showed fuel consumption 4.6% lower than standard diesel from this test, and 0.7% less than on GTL. For CO<sub>2</sub>, the difference was -8.5% compared to standard diesel and -5.0% compared to GTL. Fuel consumption and CO<sub>2</sub> emissions for the tested vehicles were therefore higher than for the nearest equivalent vehicles in the Emissions Analytics database.

66. For pollutant emissions, the comparisons are made in terms of the “exceedance factor” to the official regulatory limits. For CO, the vehicles were 0.31 times the limit on both standard diesel and GTL, compared to 0.33 from the Emissions Analytics database. For NO<sub>x</sub> emissions, the vehicles were 5.6 times the limit on standard diesel, 5.7 times on GTL and 4.4 times from the database. Emissions of CO and NO<sub>x</sub> for the tested vehicles were therefore similar to the nearest equivalent vehicles in the Emissions Analytics database.

67. The potential reasons for the differences between the vehicles tested in this work package and those in the database are given in paragraph 36.

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<sup>18</sup> REGULATION (EC) No 443/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009, setting emission performance standards for new passenger cars as part of the Community’s integrated approach to reduce CO<sub>2</sub> emissions from light-duty vehicles

Table 5: Fuel consumption for fuels A and B (l/100km) and statistical significance (%)

Model	A (diesel)				B (GTL)				Statistical significance (A vs B) (%)				Limit values
	U	R	M	C	U	R	M	C	U	R	M	C	
<b>Focus Zetec/ Euro 5</b>	8.63	5.57	6.58	6.92	8.50	5.21	6.40	6.70	59.8	99.7	100.0	-	-
<b>Cooper S/ Euro 5</b>	8.08	4.93	5.66	6.22	7.29	4.72	5.48	5.83	100.0	99.0	99.2	-	-
<b>Astra Design/ Euro 5</b>	8.70	5.83	6.43	6.99	8.07	5.58	6.29	6.65	97.0	97.5	87.2	-	-
<b>Polo/ Euro 5</b>	6.04	4.82	5.55	5.47	5.74	4.50	5.27	5.17	100.0	100.0	100.0	-	-
<b>Qashqai Acenta Premium/Euro 5</b>	6.80	5.16	6.12	6.03	6.51	4.99	5.73	5.74	98.5	88.2	100.0	-	-
<b>308 Active/ Euro 5</b>	5.45	4.42	5.24	5.04	5.41	4.35	5.13	4.96	63.0	61.8	86.6	-	-
<b>Mondeo Titanium X Sport/ Euro 5</b>	7.31	5.80	6.88	6.66	7.03	5.34	6.46	6.27	100.0	100.0	99.6	-	-
<b>Passat GT Tech Estate/ Euro 5</b>	8.43	6.62	7.22	7.42	8.49	6.26	6.86	7.20	40.5	98.8	100.0	-	-
<b>Qashqai N-Connect/ Euro 6</b>	6.53	5.44	6.11	6.03	6.34	5.12	5.93	5.80	97.6	99.8	89.7	-	-
<b>Focus ST-Line/ Euro 6</b>	6.96	5.52	5.78	6.09	6.83	5.58	5.66	6.02	98.0	38.0	90.6	-	-
<b>Vivaro 2900 SWB/ Euro 4</b>	10.36	7.56	8.59	8.84	9.71	7.17	8.22	8.37	100.0	99.8	99.9	-	-
<b>Crafter CR35 MWB High Roof/ Euro 4</b>	14.41	9.52	11.60	11.84	14.19	8.83	11.01	11.35	97.9	100.0	99.9	-	-
<b>Berlingo Enterprise/ Euro 4</b>	7.73	5.62	7.03	6.79	7.26	5.30	6.94	6.50	100.0	95.2	59.4	-	-
<b>Transit 350EF LWB Chassis cab/ Euro 4</b>	9.85	10.83	13.46	11.38	9.56	9.80	12.85	10.74	66.5	99.9	99.9	-	-
<b>Transit Connect Trend/ Euro 5</b>	9.84	6.61	7.11	7.85	9.45	6.49	6.80	7.58	100.0	52.7	99.7	-	-
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	11.94	9.39	12.05	11.13	11.76	8.53	10.97	10.42	91.8	100.0	100.0	-	-
<b>Transit 280/ Euro 5</b>	9.47	7.64	8.43	8.51	9.26	7.25	7.73	8.08	84.9	99.2	100.0	-	-
<b>Partner 850 Professional/ Euro 5</b>	6.77	5.17	6.55	6.16	6.23	4.82	6.50	5.85	100.0	100.0	67.1	-	-
<b>Traffic SL27 Business + / Euro 5</b>	9.02	6.61	7.41	7.68	8.92	6.71	7.20	7.61	50.5	65.4	99.9	-	-
<b>Partner Professional 850/ Euro 6</b>	7.93	5.50	6.44	6.62	7.83	5.31	6.31	6.49	85.6	97.4	98.2	-	-
<b>Crafter CR35 Startline/ Euro 6</b>	10.32	9.37	9.96	9.88	9.88	9.37	9.73	9.66	99.9	0.8	76.4	-	-
<b>Transit 350 Luton L4/ Euro 6</b>	10.89	10.02	12.38	11.10	10.57	9.65	12.28	10.84	96.3	74.9	37.5	-	-

Note: Cars above the thick green line, vans are below the line

Table 6: Change in fuel consumption (absolute and percentage)

Model	Urban		Rural		Motorway		Combined	
	B-A l/100km	(B-A)/A (%)	B-A l/100km	(B-A)/A (%)	B-A l/100km	(B-A)/A (%)	B-A l/100km	(B-A)/A (%)
<b>Focus Zetec/ Euro 5</b>	-0.13	-1.5	-0.36	-6.5	-0.18	-2.7	-0.22	-3.2
<b>Cooper S/ Euro 5</b>	-0.79	-9.8	-0.21	-4.3	-0.18	-3.2	-0.39	-6.3
<b>Astra Design/ Euro 5</b>	-0.63	-7.2	-0.25	-4.3	-0.14	-2.2	-0.34	-4.9
<b>Polo/ Euro 5</b>	-0.30	-5.0	-0.32	-6.6	-0.28	-5.0	-0.30	-5.5
<b>Qashqai Acenta Premium/Euro 5</b>	-0.29	-4.3	-0.17	-3.3	-0.39	-6.4	-0.29	-4.8
<b>308 Active/ Euro 5</b>	-0.04	-0.7	-0.07	-1.6	-0.11	-2.1	-0.08	-1.6
<b>Mondeo Titanium X Sport/ Euro 5</b>	-0.28	-3.8	-0.46	-7.9	-0.42	-6.1	-0.39	-5.9
<b>Passat GT Tech Estate/ Euro 5</b>	0.06	0.7	-0.36	-5.4	-0.36	-5.0	-0.22	-3.0
<b>Qashqai N-Connect/ Euro 6</b>	-0.19	-2.9	-0.32	-5.9	-0.18	-2.9	-0.23	-3.8
<b>Focus ST-Line/ Euro 6</b>	-0.13	-1.9	0.06	1.1	-0.12	-2.1	-0.07	-1.1
<b>Vivaro 2900 SWB/ Euro 4</b>	-0.65	-6.3	-0.39	-5.2	-0.37	-4.3	-0.47	-5.3
<b>Crafter CR35 MWB High Roof/ Euro 4</b>	-0.22	-1.5	-0.69	-7.2	-0.59	-5.1	-0.49	-4.1
<b>Berlingo Enterprise/ Euro 4</b>	-0.47	-6.1	-0.32	-5.7	-0.09	-1.3	-0.29	-4.3
<b>Transit 350EF LWB Chassis cab/ Euro 4</b>	-0.29	-2.9	-1.03	-9.5	-0.61	-4.5	-0.64	-5.6
<b>Transit Connect Trend/ Euro 5</b>	-0.39	-4.0	-0.12	-1.8	-0.31	-4.4	-0.27	-3.4
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	-0.18	-1.5	-0.86	-9.2	-1.08	-9.0	-0.71	-6.4
<b>Transit 280/ Euro 5</b>	-0.21	-2.2	-0.39	-5.1	-0.70	-8.3	-0.43	-5.1
<b>Partner 850 Professional/ Euro 5</b>	-0.54	-8.0	-0.35	-6.8	-0.05	-0.8	-0.31	-5.0
<b>Traffic SL27 Business + / Euro 5</b>	-0.10	-1.1	0.10	1.5	-0.21	-2.8	-0.07	-0.9
<b>Partner Professional 850/ Euro 6</b>	-0.10	-1.3	-0.19	-3.5	-0.13	-2.0	-0.13	-2.0
<b>Crafter CR35 Startline/ Euro 6</b>	-0.44	-4.3	0.00	0.0	-0.23	-2.3	-0.22	-2.2
<b>Transit 350 Luton L4/ Euro 6</b>	-0.32	-2.9	-0.37	-3.7	-0.10	-0.8	-0.26	-2.3

Note: Cars above the thick green line, vans are below the line

Table 7: CO<sub>2</sub> emissions for fuels A and B (g/km) and statistical significance (%)

Model	A (diesel)				B (GTL)				Statistical significance (A vs B) (%)				Limit values
	U	R	M	C	U	R	M	C	U	R	M	C	
<b>Focus Zetec/ Euro 5</b>	231.3	149.1	175.9	185.5	227.9	139.7	171.3	179.7	58.7	99.7	100.0	-	130
<b>Cooper S/ Euro 5</b>	212.2	129.6	148.3	163.4	192.0	124.4	144.1	153.5	100.0	98.4	98.2	-	130
<b>Astra Design/ Euro 5</b>	228.1	153.2	168.1	183.1	211.9	146.5	164.5	174.3	96.8	97.7	87.5	-	130
<b>Polo/ Euro 5</b>	159.1	126.7	145.5	143.7	151.8	118.9	139.0	136.6	100.0	100.0	100.0	-	130
<b>Qashqai Acenta Premium/Euro 5</b>	178.4	135.7	161.1	158.4	170.8	130.9	150.8	150.8	98.7	90.8	100.0	-	130
<b>308 Active/ Euro 5</b>	143.1	116.1	137.2	132.1	142.0	114.1	134.2	130.1	70.4	64.1	88.2	-	130
<b>Mondeo Titanium X Sport/ Euro 5</b>	192.4	152.0	180.3	174.9	185.0	139.8	169.3	164.7	100.0	100.0	99.6	-	130
<b>Passat GT Tech Estate/ Euro 5</b>	222.1	174.3	189.8	195.4	223.8	164.8	180.7	189.8	43.9	99.0	100.0	-	130
<b>Qashqai N-Connect/ Euro 6</b>	175.2	146.2	164.2	161.9	170.2	137.6	159.7	155.8	96.3	99.8	87.4	-	130
<b>Focus ST-Line/ Euro 6</b>	186.3	147.6	153.6	162.5	182.6	149.3	150.3	160.7	98.1	36.5	92.6	-	130
<b>Vivaro 2900 SWB/ Euro 4</b>	272.2	198.4	225.4	232.0	255.7	188.4	215.5	219.9	100.0	99.8	99.8	-	175
<b>Crafter CR35 MWBHigh Roof/E4</b>	379.1	249.8	304.4	311.1	373.1	231.8	288.3	297.7	98.5	100.0	99.9	-	175
<b>Berlingo Enterprise/ Euro 4</b>	203.1	147.4	184.2	178.2	191.4	139.6	182.7	171.2	100.0	94.3	42.4	-	175
<b>Transit 350EFLWBChassisCab/ E4</b>	265.4	292.0	363.4	307.0	257.6	264.1	346.5	289.4	66.4	99.9	99.9	-	175
<b>Transit Connect Trend/ Euro 5</b>	262.3	176.8	189.9	209.6	251.7	173.9	181.8	202.4	100.0	48.7	99.6	-	175
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	319.0	251.1	321.9	297.3	314.0	227.9	292.8	278.2	94.0	100.0	100.0	-	175
<b>Transit 280/ Euro 5</b>	253.5	204.5	225.1	227.7	247.5	193.9	206.4	215.9	86.9	99.3	100.0	-	175
<b>Partner 850 Professional/ Euro 5</b>	178.4	136.1	172.1	162.2	164.0	126.8	170.8	153.9	100.0	100.0	69.1	-	175
<b>Traffic SL27 Business + / Euro 5</b>	238.7	175.5	196.8	203.7	237.4	179.7	192.7	203.3	25.9	84.9	98.8	-	175
<b>Partner Professional 850/ Euro 6</b>	213.1	147.8	173.0	178.0	210.1	142.5	169.3	174.0	87.8	98.0	99.4	-	175
<b>Crafter CR35 Startline/ Euro 6</b>	272.2	247.5	262.6	260.8	260.7	247.1	256.3	254.7	99.9	5.0	78.1	-	175
<b>Transit 350 Luton L4/ Euro 6</b>	291.3	268.4	331.1	296.9	282.7	258.3	328.3	289.7	95.9	75.8	39.7	-	175

Note: Cars above the thick green line, vans are below the line

Table 8: Change in CO<sub>2</sub> emissions (absolute and percentage)

Model	Urban		Rural		Motorway		Combined	
	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)
<b>Focus Zetec/ Euro 5</b>	-3.40	-1.5	-9.40	-6.3	-4.60	-2.6	-5.80	-3.1
<b>Cooper S/ Euro 5</b>	-20.20	-9.5	-5.20	-4.0	-4.20	-2.8	-9.90	-6.1
<b>Astra Design/ Euro 5</b>	-16.20	-7.1	-6.70	-4.4	-3.60	-2.1	-8.80	-4.8
<b>Polo/ Euro 5</b>	-7.30	-4.6	-7.80	-6.2	-6.50	-4.5	-7.10	-4.9
<b>Qashqai Acenta Premium/Euro 5</b>	-7.60	-4.3	-4.80	-3.5	-10.30	-6.4	-7.60	-4.8
<b>308 Active/ Euro 5</b>	-1.10	-0.8	-2.00	-1.7	-3.00	-2.2	-2.00	-1.5
<b>Mondeo Titanium X Sport/ Euro 5</b>	-7.40	-3.8	-12.20	-8.0	-11.00	-6.1	-10.20	-5.8
<b>Passat GT Tech Estate/ Euro 5</b>	1.70	0.8	-9.50	-5.	-9.10	-4.8	-5.60	-2.9
<b>Qashqai N-Connect/ Euro 6</b>	-5.00	-2.9	-8.60	-5.9	-4.50	-2.7	-6.10	-3.8
<b>Focus ST-Line/ Euro 6</b>	-3.70	-2.0	1.70	1.2	-3.30	-2.1	-1.80	-1.1
<b>Vivaro 2900 SWB/ Euro 4</b>	-16.50	-6.1	-10.00	-5.0	-9.90	-4.4	-12.10	-5.2
<b>Crafter CR35 MWB High Roof/ Euro 4</b>	-6.00	-1.6	-18.00	-7.2	-16.10	-5.3	-13.40	-4.3
<b>Berlingo Enterprise/ Euro 4</b>	-11.70	-5.8	-7.80	-5.3	-1.50	-0.8	-7.00	-3.9
<b>Transit 350EF LWB Chassis cab/ Euro 4</b>	-7.80	-2.9	-27.90	-9.6	-16.90	-4.7	-17.60	-5.7
<b>Transit Connect Trend/ Euro 5</b>	-10.60	-4.0	-2.90	-1.6	-8.10	-4.3	-7.20	-3.4
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	-5.00	-1.6	-23.20	-9.2	-29.10	-9.0	-19.10	-6.4
<b>Transit 280/ Euro 5</b>	-6.00	-2.4	-10.60	-5.2	-18.70	-8.3	-11.80	-5.2
<b>Partner 850 Professional/ Euro 5</b>	-14.40	-8.1	-9.30	-6.8	-1.30	-0.8	-8.30	-5.1
<b>Traffic SL27 Business + / Euro 5</b>	-1.30	-0.5	4.20	2.4	-4.10	-2.1	-0.40	-0.2
<b>Partner Professional 850/ Euro 6</b>	-3.00	-1.4	-5.30	-3.6	-3.70	-2.1	-4.00	-2.2
<b>Crafter CR35 Startline/ Euro 6</b>	-11.50	-4.2	-0.40	-0.2	-6.30	-2.4	-6.10	-2.3
<b>Transit 350 Luton L4/ Euro 6</b>	-8.60	-3.0	-10.10	-3.8	-2.80	-0.8	-7.20	-2.4

Note: Cars above the thick green line, vans are below the line

Table 9: CO emissions for fuels A and B (g/km) and statistical significance (%)

Model	A (diesel)				B (GTL)				Statistical Significance (A vs B) (%)				Limit g/km
	U	R	M	C	U	R	M	C	U	R	M	C	
<b>Focus Zetec/ Euro 5</b>	0.073	0.242	0.076	0.131	0.038	0.079	0.024	0.047	71.2	99.9	99.5	-	0.50
<b>Cooper S/ Euro 5</b>	0.035	0.012	0.010	0.019	0.082	0.031	0.025	0.046	100.0	100.0	100.0	-	0.50
<b>Astra Design/ Euro 5</b>	0.357	0.042	0.069	0.156	0.122	0.015	0.025	0.054	100.0	100.0	99.3	-	0.50
<b>Polo/ Euro 5</b>	0.037	0.022	0.016	0.025	0.028	0.018	0.011	0.019	87.5	84.4	98.4	-	0.50
<b>Qashqai Acenta Premium/Euro 5</b>	0.696	0.409	0.257	0.454	0.692	0.521	0.213	0.475	2.3	67.8	63.5	-	0.50
<b>308 Active/ Euro 5</b>	0.081	0.034	0.020	0.045	0.087	0.033	0.026	0.049	43.3	13.2	96.9	-	0.50
<b>Mondeo Titanium X Sport/ Euro 5</b>	0.080	0.064	0.009	0.051	0.076	0.073	0.014	0.054	25.3	35.6	90.4	-	0.50
<b>Passat GT Tech Estate/ Euro 5</b>	0.075	0.074	0.058	0.069	0.080	0.056	0.047	0.061	29.4	91.0	65.1	-	0.50
<b>Qashqai N-Connect/ Euro 6</b>	0.334	0.211	0.173	0.239	0.310	0.213	0.178	0.234	93.8	25.7	71.7	-	0.50
<b>Focus ST-Line/ Euro 6</b>	0.111	0.133	0.050	0.098	0.060	0.094	0.041	0.065	98.6	74.0	27.1	-	0.50
<b>Vivaro 2900 SWB/ Euro 4</b>	0.116	0.037	0.017	0.057	0.119	0.056	0.050	0.075	4.5	80.6	97.4	-	0.63
<b>Crafter CR35 MWBHigh Roof/E4</b>	1.228	0.613	0.922	0.921	0.780	0.532	1.022	0.778	100.0	65.9	72.9	-	0.74
<b>Berlingo Enterprise/ Euro 4</b>	0.082	0.066	0.032	0.060	0.041	0.031	0.021	0.031	100.0	97.2	94.7	-	0.63
<b>Transit 350EFLWBChassisCab/ E4</b>	0.360	0.280	0.294	0.311	0.297	0.214	0.251	0.254	97.9	99.9	99.2	-	0.74
<b>Transit Connect Trend/ Euro 5</b>	0.858	0.047	0.022	0.309	1.009	0.051	0.024	0.361	58.4	34.2	41.1	-	0.63
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	0.106	0.013	0.011	0.043	0.047	0.020	0.009	0.025	99.9	67.0	95.7	-	0.74
<b>Transit 280/ Euro 5</b>	0.102	0.022	0.013	0.045	0.171	0.037	0.015	0.074	93.8	86.4	41.4	-	0.63
<b>Partner 850 Professional/ Euro 5</b>	0.152	0.125	0.043	0.107	0.202	0.133	0.062	0.132	100.0	39.7	100.0	-	0.63
<b>Traffic SL27 Business + / Euro 5</b>	0.572	0.045	0.021	0.213	0.709	0.093	0.018	0.274	88.5	76.8	35.8	-	0.63
<b>Partner Professional 850/ Euro 6</b>	0.268	0.155	0.162	0.195	0.253	0.144	0.157	0.185	85.7	98.0	69.7	-	0.63
<b>Crafter CR35 Startline/ Euro 6</b>	0.054	0.020	0.033	0.036	0.179	0.085	0.062	0.109	100.0	99.8	90.7	-	0.74
<b>Transit 350 Luton L4/ Euro 6</b>	0.098	0.075	0.048	0.074	0.092	0.069	0.045	0.069	16.3	25.6	19.4	-	0.74

Note: Cars above the thick green line, vans are below the line

Table 10: Change in CO emissions (absolute and percentage)

Model	Urban		Rural		Motorway		Combined	
	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)
<b>Focus Zetec/ Euro 5</b>	-0.04	-47.9	-0.16	-67.4	-0.0520	-68.4	-0.08	-64.1
<b>Cooper S/ Euro 5</b>	0.05	134.3	0.02	158.3	0.0150	150.0	0.03	142.1
<b>Astra Design/ Euro 5</b>	-0.24	-65.8	-0.03	-64.3	-0.0440	-63.8	-0.10	-65.4
<b>Polo/ Euro 5</b>	-0.01	-24.3	0.00	-18.2	-0.0050	-31.3	-0.01	-24.0
<b>Qashqai Acenta Premium/Euro 5</b>	-0.004	-0.6	0.11	27.4	-0.0440	-17.1	0.02	4.6
<b>308 Active/ Euro 5</b>	0.01	7.4	0.00	-2.9	0.0060	30.0	0.00	8.9
<b>Mondeo Titanium X Sport/ Euro 5</b>	0.00	-5.0	0.01	14.1	0.0050	55.6	0.00	5.9
<b>Passat GT Tech Estate/ Euro 5</b>	0.01	6.7	-0.02	-24.3	-0.0110	-19.0	-0.01	-11.6
<b>Qashqai N-Connect/ Euro 6</b>	-0.02	-7.2	0.00	0.9	0.0050	2.9	0.00	-2.1
<b>Focus ST-Line/ Euro 6</b>	-0.05	-45.9	-0.04	-29.3	-0.0090	-18.0	-0.03	-33.7
<b>Vivaro 2900 SWB/ Euro 4</b>	0.00	2.6	0.02	51.4	0.0330	194.1	0.02	31.6
<b>Crafter CR35 MWB High Roof/ Euro 4</b>	-0.45	-36.5	-0.08	-13.2	0.1000	10.8	-0.14	-15.5
<b>Berlingo Enterprise/ Euro 4</b>	-0.04	-50.0	-0.04	-53.0	-0.0110	-34.4	-0.03	-48.3
<b>Transit 350EF LWB Chassis cab/ Euro 4</b>	-0.06	-17.5	-0.07	-23.6	-0.0430	-14.6	-0.06	-18.3
<b>Transit Connect Trend/ Euro 5</b>	0.15	17.6	0.00	8.5	0.0020	9.1	0.05	16.8
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	-0.06	-55.7	0.01	53.8	-0.0020	-18.2	-0.02	-41.9
<b>Transit 280/ Euro 5</b>	0.07	67.6	0.02	68.2	0.0020	15.4	0.03	64.4
<b>Partner 850 Professional/ Euro 5</b>	0.05	32.9	0.01	6.4	0.0190	44.2	0.03	23.4
<b>Traffic SL27 Business + / Euro 5</b>	0.14	24.0	0.05	106.7	-0.0030	-14.3	0.06	28.6
<b>Partner Professional 850/ Euro 6</b>	-0.02	-5.6	-0.01	-7.1	-0.0050	-3.1	-0.01	-5.1
<b>Crafter CR35 Startline/ Euro 6</b>	0.13	231.5	0.07	325.0	0.0290	87.9	0.07	202.8
<b>Transit 350 Luton L4/ Euro 6</b>	-0.01	-6.1	-0.01	-8.0	-0.0030	-6.3	0.00	-6.8

Note: Cars above the thick green line, vans are below the line

Table 11: NO<sub>x</sub> emissions for fuels A and B (g/km) and statistical significance (%)

Model	A (diesel)				B (GTL)				Statistical Significance (A vs B) (%)				Limit g/km
	U	R	M	C	U	R	M	C	U	R	M	C	
<b>Focus Zetec/ Euro 5</b>	0.554	0.909	0.964	0.809	0.576	0.869	0.947	0.797	41.6	55.2	60.1	-	0.180
<b>Cooper S/ Euro 5</b>	0.935	0.743	0.680	0.786	0.927	0.754	0.676	0.786	69.2	34.3	25.0	-	0.180
<b>Astra Design/ Euro 5</b>	1.778	1.270	1.267	1.438	1.688	1.296	1.206	1.397	97.7	64.2	100.0	-	0.180
<b>Polo/ Euro 5</b>	0.635	0.615	0.850	0.700	0.839	0.672	0.851	0.787	100.0	98.6	5.5	-	0.180
<b>Qashqai Acenta Premium/Euro 5</b>	0.947	0.824	1.166	0.979	0.943	0.760	0.964	0.889	3.5	87.4	95.9	-	0.180
<b>308 Active/ Euro 5</b>	0.342	0.592	0.668	0.534	0.368	0.604	0.634	0.535	87.5	43.2	97.4	-	0.180
<b>Mondeo Titanium X Sport/ Euro 5</b>	0.510	0.767	0.838	0.705	0.525	0.686	0.779	0.664	94.3	99.8	99.8	-	0.180
<b>Passat GT Tech Estate/ Euro 5</b>	0.322	0.428	0.536	0.429	0.307	0.406	0.496	0.403	41.8	48.1	87.8	-	0.180
<b>Qashqai N-Connect/ Euro 6</b>	0.776	1.177	1.160	1.038	0.828	1.093	1.172	1.031	78.0	73.0	24.9	-	0.080
<b>Focus ST-Line/ Euro 6</b>	0.234	0.531	0.766	0.510	0.262	0.639	0.725	0.542	52.7	93.1	59.2	-	0.080
<b>Vivaro 2900 SWB/ Euro 4</b>	1.131	1.420	1.834	1.462	1.060	1.377	1.877	1.438	64.2	51.0	52.1	-	0.330
<b>Crafter CR35 MWBHigh Roof/E4</b>	1.727	1.291	1.330	1.449	1.566	1.169	1.221	1.319	100.0	100.0	100.0	-	0.390
<b>Berlingo Enterprise/ Euro 4</b>	0.462	0.740	1.144	0.782	0.462	0.698	1.184	0.781	1.5	56.1	84.0	-	0.330
<b>Transit 350EFLWBChassisCab/ E4</b>	0.616	1.182	1.450	1.083	0.673	1.142	1.486	1.100	97.0	27.2	54.8	-	0.390
<b>Transit Connect Trend/ Euro 5</b>	0.742	1.225	1.019	0.995	0.753	1.280	0.971	1.001	67.2	53.8	88.4	-	0.235
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	1.484	1.651	0.935	1.357	1.506	1.661	0.869	1.345	58.4	15.6	79.9	-	0.280
<b>Transit 280/ Euro 5</b>	0.738	1.388	1.127	1.084	0.802	1.464	1.239	1.168	97.2	71.0	100.0	-	0.235
<b>Partner 850 Professional/ Euro 5</b>	0.585	0.743	0.854	0.727	0.553	0.655	0.857	0.688	99.9	99.8	21.4	-	0.235
<b>Traffic SL27 Business + / Euro 5</b>	1.184	1.137	1.058	1.126	1.350	1.381	1.403	1.378	89.8	99.5	98.5	-	0.235
<b>Partner Professional 850/ Euro 6</b>	0.765	1.090	1.016	0.957	0.755	1.040	0.957	0.917	41.4	78.5	100.0	-	0.105
<b>Crafter CR35 Startline/ Euro 6</b>	0.063	0.112	0.149	0.108	0.028	0.077	0.066	0.057	100.0	97.1	100.0	-	0.125
<b>Transit 350 Luton L4/ Euro 6</b>	0.109	0.733	0.859	0.567	0.103	0.687	0.815	0.535	26.6	47.5	87.4	-	0.125

Note: Cars above the thick green line, vans are below the line

Table 12: Change in NO<sub>x</sub> emissions (absolute and percentage)

Model	Urban		Rural		Motorway		Combined	
	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)
<b>Focus Zetec/ Euro 5</b>	0.02	4.0	-0.04	-4.4	-0.02	-1.8	-0.01	-1.5
<b>Cooper S/ Euro 5</b>	-0.01	-0.9	0.01	1.5	0.00	-0.6	0.00	0.0
<b>Astra Design/ Euro 5</b>	-0.09	-5.1	0.03	2.0	-0.06	-4.8	-0.04	-2.9
<b>Polo/ Euro 5</b>	0.20	32.1	0.06	9.3	0.00	0.1	0.09	12.4
<b>Qashqai Acenta Premium/Euro 5</b>	0.00	-0.4	-0.06	-7.8	-0.20	-17.3	-0.09	-9.2
<b>308 Active/ Euro 5</b>	0.03	7.6	0.01	2.0	-0.03	-5.1	0.00	0.2
<b>Mondeo Titanium X Sport/ Euro 5</b>	0.02	2.9	-0.08	-10.6	-0.06	-7.0	-0.04	-5.8
<b>Passat GT Tech Estate/ Euro 5</b>	-0.02	-4.7	-0.02	-5.1	-0.04	-7.5	-0.03	-6.1
<b>Qashqai N-Connect/ Euro 6</b>	0.05	6.7	-0.08	-7.1	0.01	1.0	-0.01	-0.7
<b>Focus ST-Line/ Euro 6</b>	0.03	12.0	0.11	20.3	-0.04	-5.4	0.03	6.3
<b>Vivaro 2900 SWB/ Euro 4</b>	-0.07	-6.3	-0.04	-3.0	0.04	2.3	-0.02	-1.6
<b>Crafter CR35 MWB High Roof/ Euro 4</b>	-0.16	-9.3	-0.12	-9.5	-0.11	-8.2	-0.13	-9.0
<b>Berlingo Enterprise/ Euro 4</b>	0.00	0.0	-0.04	-5.7	0.04	3.5	0.00	-0.1
<b>Transit 350EF LWB Chassis cab/ Euro 4</b>	0.06	9.3	-0.04	-3.4	0.04	2.5	0.02	1.6
<b>Transit Connect Trend/ Euro 5</b>	0.01	1.5	0.05	4.5	-0.05	-4.7	0.01	0.6
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	0.02	1.5	0.01	0.6	-0.07	-7.1	-0.01	-0.9
<b>Transit 280/ Euro 5</b>	0.06	8.7	0.08	5.5	0.11	9.9	0.08	7.7
<b>Partner 850 Professional/ Euro 5</b>	-0.03	-5.5	-0.09	-11.8	0.00	0.4	-0.04	-5.4
<b>Traffic SL27 Business + / Euro 5</b>	0.17	14.0	0.24	21.5	0.35	32.6	0.25	22.4
<b>Partner Professional 850/ Euro 6</b>	-0.01	-1.3	-0.05	-4.6	-0.06	-5.8	-0.04	-4.2
<b>Crafter CR35 Startline/ Euro 6</b>	-0.04	-55.6	-0.04	-31.3	-0.08	-55.7	-0.05	-47.2
<b>Transit 350 Luton L4/ Euro 6</b>	-0.01	-5.5	-0.05	-6.3	-0.04	-5.1	-0.03	-5.6

Note: Cars above the thick green line, vans are below the line

Table 13: NO<sub>2</sub> emissions for fuels A and B (g/km) and statistical significance (%)

Model	A (diesel)				B (GTL)				Statistical Significance (A vs B) (%)				Limit g/km
	U	R	M	C	U	R	M	C	U	R	M	C	
<b>Focus Zetec/ Euro 5</b>	0.147	0.200	0.159	0.169	0.171	0.230	0.164	0.188	92.7	96.9	36.4	-	-
<b>Cooper S/ Euro 5</b>	0.186	0.233	0.214	0.211	0.177	0.246	0.236	0.220	32.5	95.9	99.9	-	-
<b>Astra Design/ Euro 5</b>	0.290	0.392	0.417	0.366	0.268	0.392	0.396	0.352	38.5	0.5	84.3	-	-
<b>Polo/ Euro 5</b>	0.338	0.230	0.272	0.280	0.463	0.267	0.321	0.350	100.0	99.9	100.0	-	-
<b>Qashqai Acenta Premium/Euro 5</b>	0.238	0.206	0.315	0.253	0.265	0.162	0.206	0.211	45.0	92.5	96.5	-	-
<b>308 Active/ Euro 5</b>	0.098	0.114	0.067	0.093	0.114	0.102	0.050	0.089	65.8	69.7	90.6	-	-
<b>Mondeo Titanium X Sport/ Euro 5</b>	0.072	0.226	0.197	0.165	0.140	0.217	0.184	0.180	100.0	58.2	86.0	-	-
<b>Passat GT Tech Estate/ Euro 5</b>	0.052	0.104	0.130	0.095	0.049	0.082	0.102	0.078	22.6	96.4	100.0	-	-
<b>Qashqai N-Connect/ Euro 6</b>	0.264	0.333	0.249	0.282	0.257	0.303	0.219	0.260	32.4	77.9	98.7	-	-
<b>Focus ST-Line/ Euro 6</b>	0.041	0.092	0.140	0.091	0.063	0.115	0.129	0.102	89.7	80.5	49.7	-	-
<b>Vivaro 2900 SWB/ Euro 4</b>	0.352	0.584	0.681	0.539	0.388	0.574	0.707	0.556	97.7	35.2	68.3	-	-
<b>Crafter CR35 MWBHigh Roof/E4</b>	0.158	0.262	0.375	0.265	0.099	0.212	0.318	0.210	99.0	96.9	99.9	-	-
<b>Berlingo Enterprise/ Euro 4</b>	0.292	0.352	0.437	0.360	0.288	0.335	0.476	0.366	24.0	58.5	100.0	-	-
<b>Transit 350EFLWBChassisCab/ E4</b>	0.204	0.294	0.222	0.240	0.224	0.274	0.247	0.248	84.7	60.4	90.1	-	-
<b>Transit Connect Trend/ Euro 5</b>	0.325	0.342	0.296	0.321	0.350	0.390	0.284	0.341	98.4	95.3	78.6	-	-
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	0.076	0.258	0.114	0.149	0.130	0.284	0.091	0.168	99.8	92.0	98.5	-	-
<b>Transit 280/ Euro 5</b>	0.073	0.190	0.126	0.129	0.100	0.197	0.152	0.150	100.0	45.9	100.0	-	-
<b>Partner 850 Professional/ Euro 5</b>	0.210	0.165	0.105	0.160	0.207	0.155	0.097	0.153	28.8	84.3	73.5	-	-
<b>Traffic SL27 Business + / Euro 5</b>	0.268	0.284	0.236	0.263	0.295	0.409	0.389	0.365	65.4	99.1	98.6	-	-
<b>Partner Professional 850/ Euro 6</b>	0.286	0.234	0.117	0.212	0.276	0.255	0.125	0.219	74.4	97.8	67.6	-	-
<b>Crafter CR35 Startline/ Euro 6</b>	0.035	0.045	0.047	0.042	0.004	0.015	0.010	0.010	100.0	100.0	100.0	-	-
<b>Transit 350 Luton L4/ Euro 6</b>	0.023	0.076	0.066	0.055	0.005	0.065	0.065	0.045	100.0	76.6	28.2	-	-

Note: Cars above the thick green line, vans are below the line

Table 14: Change in NO<sub>2</sub> emissions (absolute and percentage)

Model	Urban		Rural		Motorway		Combined	
	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)
<b>Focus Zetec/ Euro 5</b>	0.02	16.3	0.03	15.0	0.01	3.1	0.02	11.2
<b>Cooper S/ Euro 5</b>	-0.01	-4.8	0.01	5.6	0.02	10.3	0.01	4.3
<b>Astra Design/ Euro 5</b>	-0.02	-7.6	0.00	0.0	-0.02	-5.0	-0.01	-3.8
<b>Polo/ Euro 5</b>	0.13	37.0	0.04	16.1	0.05	18.0	0.07	25.0
<b>Qashqai Acenta Premium/Euro 5</b>	0.03	11.3	-0.04	-21.4	-0.11	-34.6	-0.04	-16.6
<b>308 Active/ Euro 5</b>	0.02	16.3	-0.01	-10.5	-0.02	-25.4	0.00	-4.3
<b>Mondeo Titanium X Sport/ Euro 5</b>	0.07	94.4	-0.01	-4.0	-0.01	-6.6	0.02	9.1
<b>Passat GT Tech Estate/ Euro 5</b>	0.00	-5.8	-0.02	-21.2	-0.03	-21.5	-0.02	-17.9
<b>Qashqai N-Connect/ Euro 6</b>	-0.01	-2.7	-0.03	-9.0	-0.03	-12.0	-0.02	-7.8
<b>Focus ST-Line/ Euro 6</b>	0.02	53.7	0.02	25.0	-0.01	-7.9	0.01	12.1
<b>Vivaro 2900 SWB/ Euro 4</b>	0.04	10.2	-0.01	-1.7	0.03	3.8	0.02	3.2
<b>Crafter CR35 MWB High Roof/ Euro 4</b>	-0.06	-37.3	-0.05	-19.1	-0.06	-15.2	-0.06	-20.8
<b>Berlingo Enterprise/ Euro 4</b>	0.00	-1.4	-0.02	-4.8	0.04	8.9	0.01	1.7
<b>Transit 350EF LWB Chassis cab/ Euro 4</b>	0.02	9.8	-0.02	-6.8	0.03	11.3	0.01	3.3
<b>Transit Connect Trend/ Euro 5</b>	0.03	7.7	0.05	14.0	-0.01	-4.1	0.02	6.2
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	0.05	71.1	0.03	10.1	-0.02	-20.2	0.02	12.8
<b>Transit 280/ Euro 5</b>	0.03	37.0	0.01	3.7	0.03	20.6	0.02	16.3
<b>Partner 850 Professional/ Euro 5</b>	0.00	-1.4	-0.01	-6.1	-0.01	-7.6	-0.01	-4.4
<b>Traffic SL27 Business + / Euro 5</b>	0.03	10.1	0.13	44.0	0.15	64.8	0.10	38.8
<b>Partner Professional 850/ Euro 6</b>	-0.01	-3.5	0.02	9.0	0.01	6.8	0.01	3.3
<b>Crafter CR35 Startline/ Euro 6</b>	-0.03	-88.6	-0.03	-66.7	-0.04	-78.7	-0.03	-76.2
<b>Transit 350 Luton L4/ Euro 6</b>	-0.02	-78.3	-0.01	-14.5	0.00	-1.5	-0.01	-18.2

Note: Cars above the thick green line, vans are below the line

Table 15: NO emissions for fuels A and B (g/km) and statistical significance (%)

Model	A (diesel)				B (GTL)				Statistical Significance (A vs B) (%)				Limit g/km
	U	R	M	C	U	R	M	C	U	R	M	C	
<b>Focus Zetec/ Euro 5</b>	0.408	0.709	0.804	0.640	0.405	0.639	0.783	0.609	7.5	87.1	88.4	-	-
<b>Cooper S/ Euro 5</b>	0.749	0.510	0.466	0.575	0.750	0.508	0.440	0.566	5.9	9.7	99.5	-	-
<b>Astra Design/ Euro 5</b>	1.488	0.878	0.850	1.072	1.421	0.904	0.810	1.045	86.2	64.1	97.3	-	-
<b>Polo/ Euro 5</b>	0.298	0.385	0.579	0.421	0.377	0.405	0.530	0.437	100.0	82.2	100.0	-	-
<b>Qashqai Acenta Premium/Euro 5</b>	0.710	0.618	0.851	0.726	0.677	0.598	0.758	0.678	37.0	64.4	94.5	-	-
<b>308 Active/ Euro 5</b>	0.245	0.478	0.601	0.441	0.254	0.502	0.584	0.446	71.7	62.7	96.9	-	-
<b>Mondeo Titanium X Sport/ Euro 5</b>	0.438	0.542	0.641	0.540	0.385	0.469	0.595	0.483	100.0	99.9	99.9	-	-
<b>Passat GT Tech Estate/ Euro 5</b>	0.270	0.324	0.406	0.333	0.258	0.324	0.394	0.325	40.3	0.3	44.2	-	-
<b>Qashqai N-Connect/ Euro 6</b>	0.512	0.844	0.911	0.756	0.571	0.789	0.953	0.771	92.7	69.1	83.7	-	-
<b>Focus ST-Line/ Euro 6</b>	0.193	0.438	0.626	0.419	0.199	0.524	0.596	0.440	18.9	94.9	59.8	-	-
<b>Vivaro 2900 SWB/ Euro 4</b>	0.779	0.835	1.153	0.922	0.673	0.803	1.170	0.882	76.9	55.2	36.3	-	-
<b>Crafter CR35 MWBHigh Roof/E4</b>	1.569	1.029	0.955	1.185	1.467	0.957	0.904	1.109	100.0	97.0	99.9	-	-
<b>Berlingo Enterprise/ Euro 4</b>	0.170	0.388	0.707	0.422	0.174	0.363	0.708	0.415	42.4	53.3	2.2	-	-
<b>Transit 350EFLWBChassisCab/ E4</b>	0.412	0.888	1.228	0.843	0.449	0.867	1.239	0.852	89.8	16.9	23.3	-	-
<b>Transit Connect Trend/ Euro 5</b>	0.417	0.883	0.723	0.674	0.403	0.890	0.687	0.660	77.5	10.6	81.6	-	-
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	1.408	1.393	0.821	1.208	1.376	1.377	0.778	1.177	70.2	27.6	66.7	-	-
<b>Transit 280/ Euro 5</b>	0.665	1.198	1.001	0.955	0.702	1.267	1.088	1.019	86.7	74.4	100.0	-	-
<b>Partner 850 Professional/ Euro 5</b>	0.375	0.578	0.749	0.567	0.345	0.499	0.760	0.535	100.0	99.7	61.8	-	-
<b>Traffic SL27 Business + / Euro 5</b>	0.916	0.853	0.822	0.864	1.055	0.972	1.014	1.014	93.5	99.1	98.3	-	-
<b>Partner Professional 850/ Euro 6</b>	0.479	0.856	0.899	0.745	0.479	0.785	0.832	0.699	0.4	92.6	100.0	-	-
<b>Crafter CR35 Startline/ Euro 6</b>	0.028	0.066	0.102	0.066	0.024	0.062	0.055	0.047	59.8	29.8	100.0	-	-
<b>Transit 350 Luton L4/ Euro 6</b>	0.086	0.657	0.793	0.512	0.098	0.621	0.750	0.490	48.9	41.4	89.9	-	-

Note: Cars above the thick green line, vans are below the line

Table 16: Change in NO emissions (absolute and percentage)

Model	Urban		Rural		Motorway		Combined	
	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)
<b>Focus Zetec/ Euro 5</b>	0.00	-0.7	-0.07	-9.9	-0.02	-2.6	-0.03	-4.8
<b>Cooper S/ Euro 5</b>	0.00	0.1	0.00	-0.4	-0.03	-5.6	-0.01	-1.6
<b>Astra Design/ Euro 5</b>	-0.07	-4.5	0.03	3.0	-0.04	-4.7	-0.03	-2.5
<b>Polo/ Euro 5</b>	0.08	26.5	0.02	5.2	-0.05	-8.5	0.02	3.8
<b>Qashqai Acenta Premium/Euro 5</b>	-0.03	-4.6	-0.02	-3.2	-0.09	-10.9	-0.05	-6.6
<b>308 Active/ Euro 5</b>	0.01	3.7	0.02	5.0	-0.02	-2.8	0.01	1.1
<b>Mondeo Titanium X Sport/ Euro 5</b>	-0.05	-12.1	-0.07	-13.5	-0.05	-7.2	-0.06	-10.6
<b>Passat GT Tech Estate/ Euro 5</b>	-0.01	-4.4	0.00	0.0	-0.01	-3.0	-0.01	-2.4
<b>Qashqai N-Connect/ Euro 6</b>	0.06	11.5	-0.05	-6.5	0.04	4.6	0.02	2.0
<b>Focus ST-Line/ Euro 6</b>	0.01	3.1	0.09	19.6	-0.03	-4.8	0.02	5.0
<b>Vivaro 2900 SWB/ Euro 4</b>	-0.11	-13.6	-0.03	-3.8	0.02	1.5	-0.04	-4.3
<b>Crafter CR35 MWB High Roof/ Euro 4</b>	-0.10	-6.5	-0.07	-7.0	-0.05	-5.3	-0.08	-6.4
<b>Berlingo Enterprise/ Euro 4</b>	0.00	2.4	-0.03	-6.4	0.00	0.1	-0.01	-1.7
<b>Transit 350EF LWB Chassis cab/ Euro 4</b>	0.04	9.0	-0.02	-2.4	0.01	0.9	0.01	1.1
<b>Transit Connect Trend/ Euro 5</b>	-0.01	-3.4	0.01	0.8	-0.04	-5.0	-0.01	-2.1
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	-0.03	-2.3	-0.02	-1.1	-0.04	-5.2	-0.03	-2.6
<b>Transit 280/ Euro 5</b>	0.04	5.6	0.07	5.8	0.09	8.7	0.06	6.7
<b>Partner 850 Professional/ Euro 5</b>	-0.03	-8.0	-0.08	-13.7	0.01	1.5	-0.03	-5.6
<b>Traffic SL27 Business + / Euro 5</b>	0.14	15.2	0.12	14.0	0.19	23.4	0.15	17.4
<b>Partner Professional 850/ Euro 6</b>	0.00	0.0	-0.07	-8.3	-0.07	-7.5	-0.05	-6.2
<b>Crafter CR35 Startline/ Euro 6</b>	0.00	-14.3	0.00	-6.1	-0.05	-46.1	-0.02	-28.8
<b>Transit 350 Luton L4/ Euro 6</b>	0.01	14.0	-0.04	-5.5	-0.04	-5.4	-0.02	-4.3

Note: Cars above the thick green line, vans are below the line

Table 17: PN

Model	A (diesel)				B (GTL)				Statistical Significance (A vs B) (%)				Limit Values /km
	U	R	M	C	U	R	M	C	U	R	M	C	
<b>Polo/ Euro 5</b>	1.650	0.232	0.133	0.672	0.130	0.075	0.079	0.094	99.7	97.9	98.9	-	6.0
<b>Qashqai N-Connect/ Euro 6</b>	1.290	0.103	0.023	0.472	0.036	0.031	0.061	0.043	99.3	96.6	96.8	-	6.0
<b>Crafter CR35 MWB High Roof/E4</b>	250.60	117.13	95.30	154.34	8.920	4.724	2.788	5.477	100.0	100.0	100.0	-	-
<b>Berlingo Enterprise/ Euro 4</b>	1.957	0.160	0.095	0.738	3.261	0.070	0.076	1.136	100.0	99.7	94.9	-	-
<b>Partner 850 Professional/ Euro 5</b>	0.286	0.156	0.110	0.184	0.418	0.101	0.106	0.208	97.8	97.7	73.5	-	6.0

Note: Cars above the thick green line, vans are below the line

Table 18: Change in PN

Model	Urban		Rural		Motorway		Combined	
	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)	A-B g/km	(B-A)/A (%)
<b>Polo/Euro 5</b>	-1.52	-92.1	-0.16	-67.7	-0.05	-40.6	-0.58	-86.0
<b>Qashqai N-Connect/Euro 6</b>	-1.25	-97.2	-0.07	-69.9	0.04	165.2	-0.43	-90.9
<b>Crafter CR35 MWB High Roof/Euro 4</b>	-241.68	-96.4	-112.40	-96.0	-92.51	-97.1	-148.86	-96.5
<b>Berlingo Enterprise/Euro 4</b>	1.30	66.6	-0.09	-56.3	-0.02	-20.0	0.40	53.9
<b>Partner 850 Professional/Euro 5</b>	0.13	46.2	-0.06	-35.3	0.00	-3.6	0.02	13.0

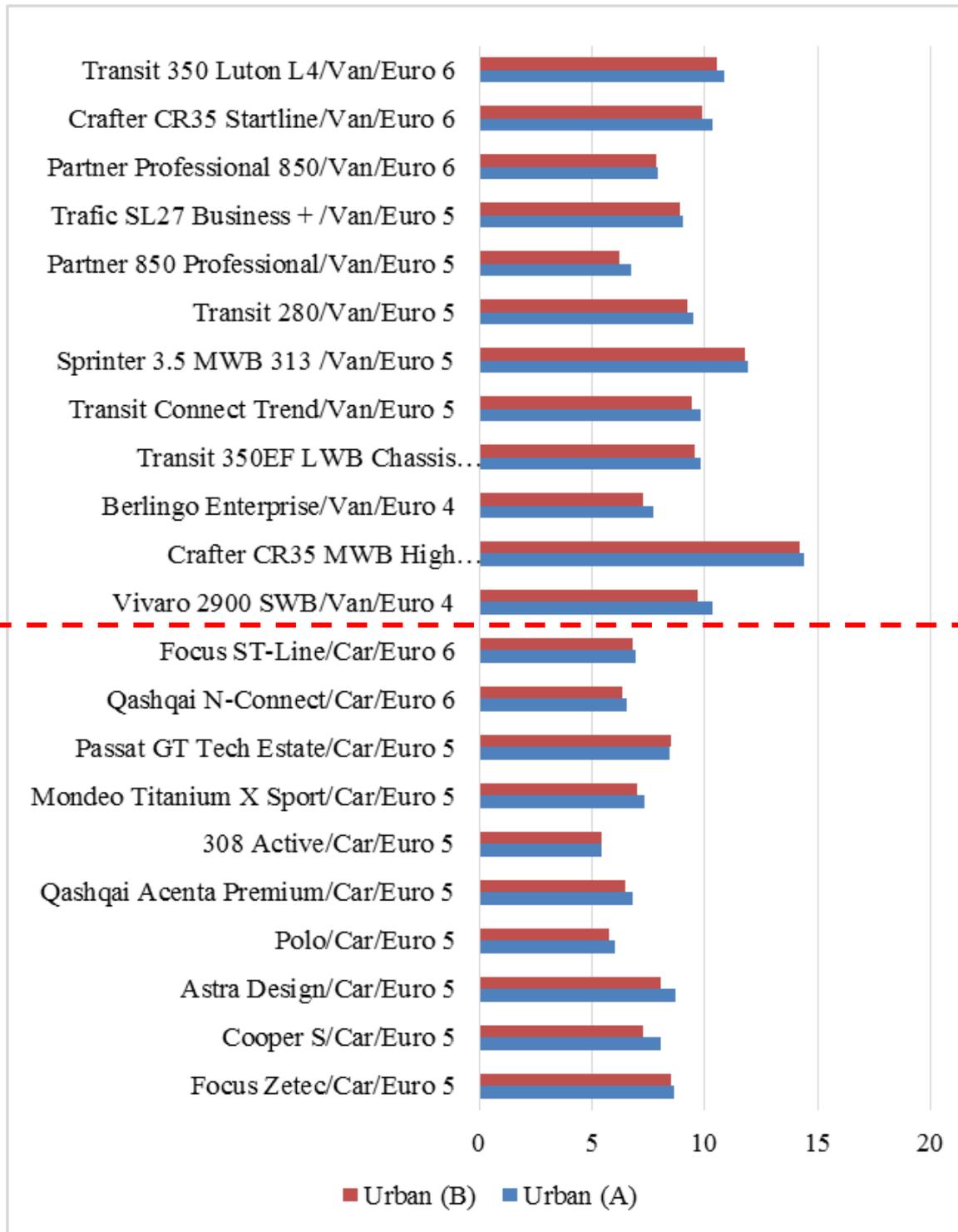
Note: Cars above the thick green line, vans are below the line

Table 19: Change in primary NO<sub>2</sub> (fraction)

Model	fNO <sub>2</sub> [A]	fNO <sub>2</sub> [B]	fNO <sub>2</sub> [B]-[A]
<b>Focus Zetec/ Euro 5</b>	0.21	0.24	0.03
<b>Cooper S/ Euro 5</b>	0.27	0.28	0.01
<b>Astra Design/ Euro 5</b>	0.25	0.25	0.00
<b>Polo/ Euro 5</b>	0.40	0.44	0.04
<b>Qashqai Acenta Premium/Euro 5</b>	0.26	0.24	-0.02
<b>308 Active/ Euro 5</b>	0.17	0.17	-0.01
<b>Mondeo Titanium X Sport/ Euro 5</b>	0.23	0.27	0.04
<b>Passat GT Tech Estate/ Euro 5</b>	0.22	0.19	-0.03
<b>Qashqai N-Connect/ Euro 6</b>	0.27	0.25	-0.02
<b>Focus ST-Line/ Euro 6</b>	0.18	0.19	0.01
<b>Vivaro 2900 SWB/ Euro 4</b>	0.37	0.39	0.02
<b>Crafter CR35 MWB High Roof/ Euro 4</b>	0.18	0.16	-0.02
<b>Berlingo Enterprise/ Euro 4</b>	0.46	0.47	0.01
<b>Transit 350EF LWB Chassis cab/ Euro 4</b>	0.22	0.23	0.00
<b>Transit Connect Trend/ Euro 5</b>	0.32	0.34	0.02
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	0.11	0.12	0.02
<b>Transit 280/ Euro 5</b>	0.12	0.13	0.01
<b>Partner 850 Professional/ Euro 5</b>	0.22	0.22	0.00
<b>Traffic SL27 Business + / Euro 5</b>	0.23	0.26	0.03
<b>Partner Professional 850/ Euro 6</b>	0.22	0.24	0.02
<b>Crafter CR35 Startline/ Euro 6</b>	0.39	0.18	-0.21
<b>Transit 350 Luton L4/ Euro 6</b>	0.10	0.08	-0.01

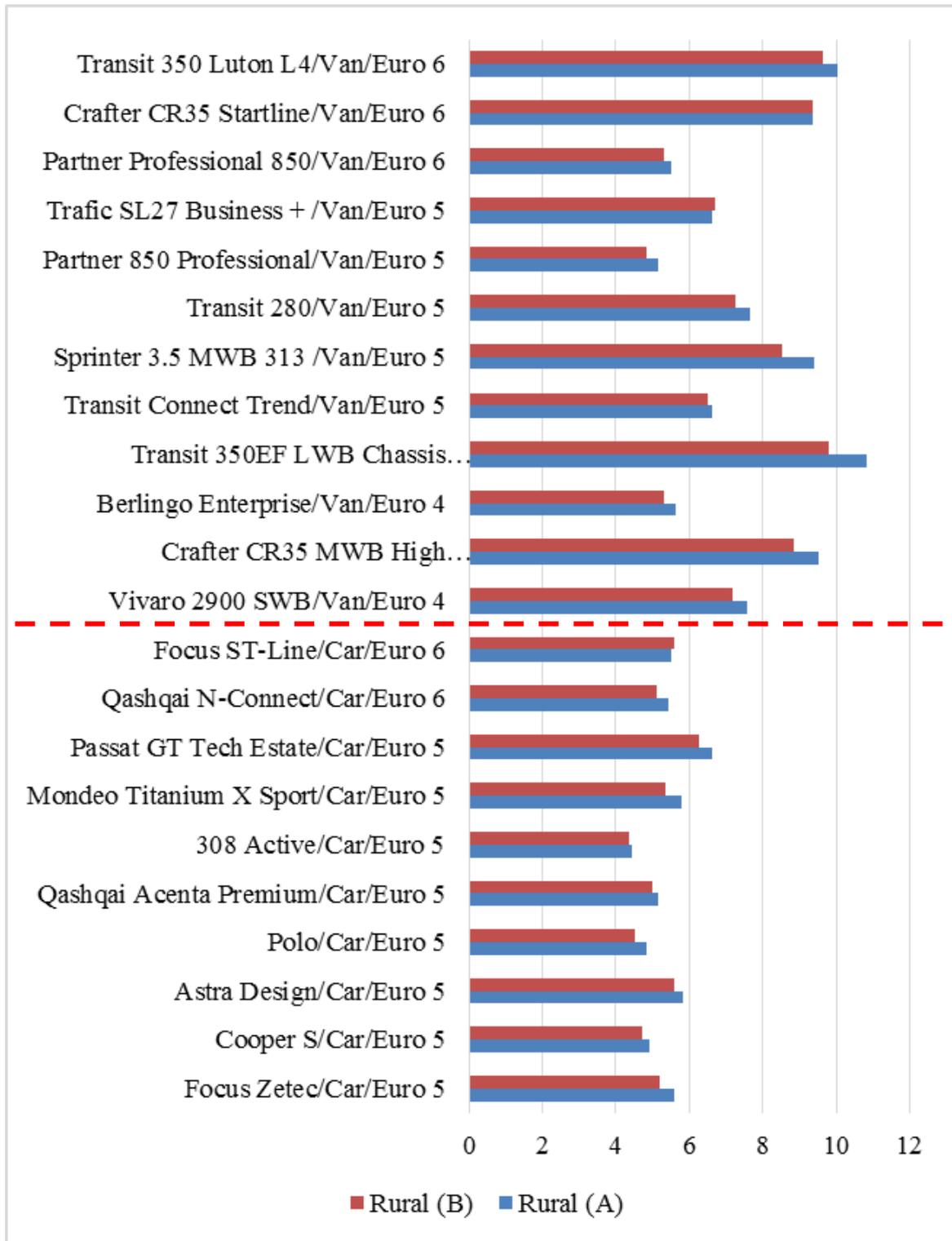
Note: Cars above the thick green line, vans are below the line

Figure 3: Fuel consumption (Urban) (l/100km)



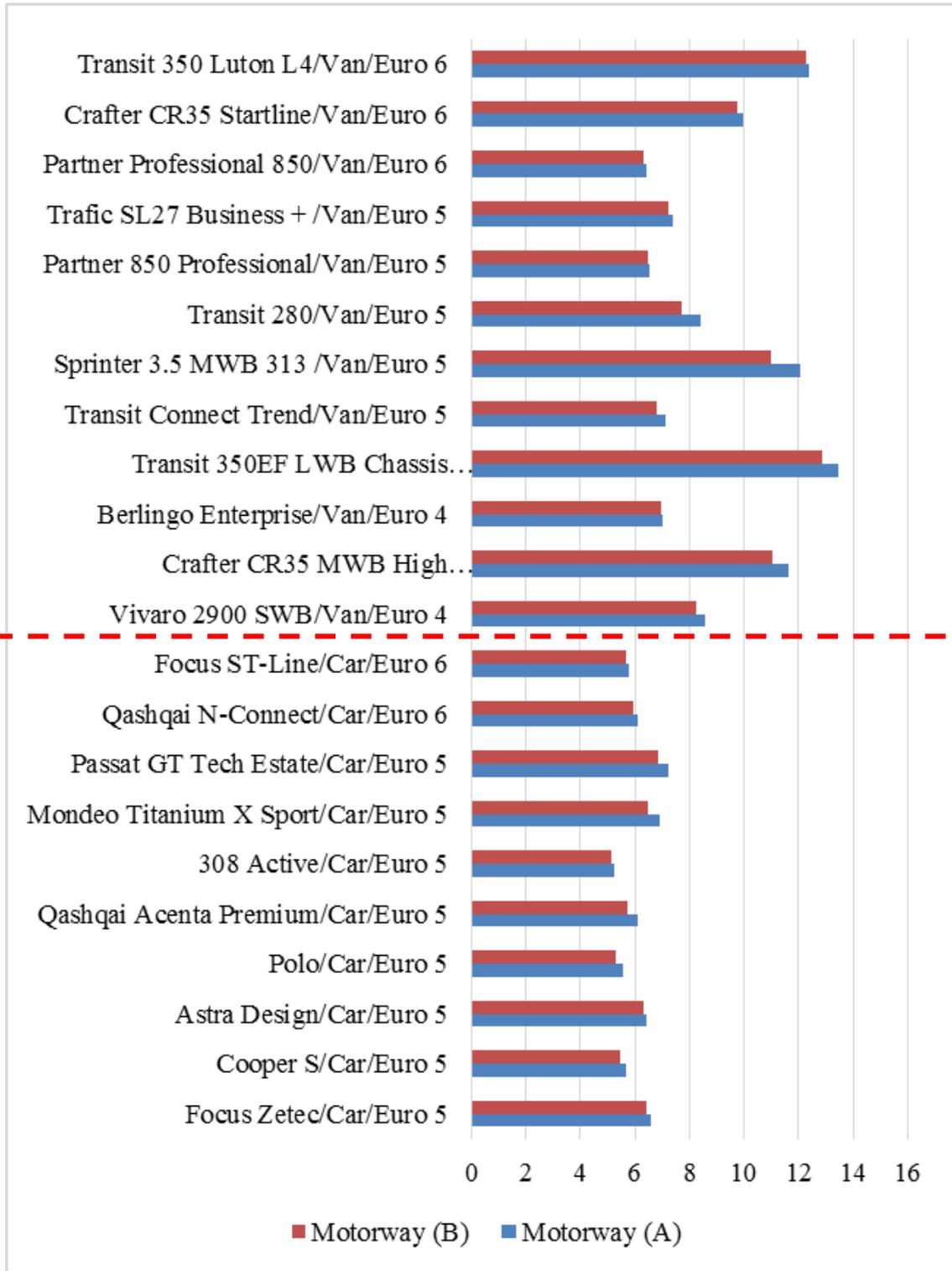
Note: Cars below the red dashed line, vans are above the line

Figure 4: Fuel consumption (Rural) (l/100km)



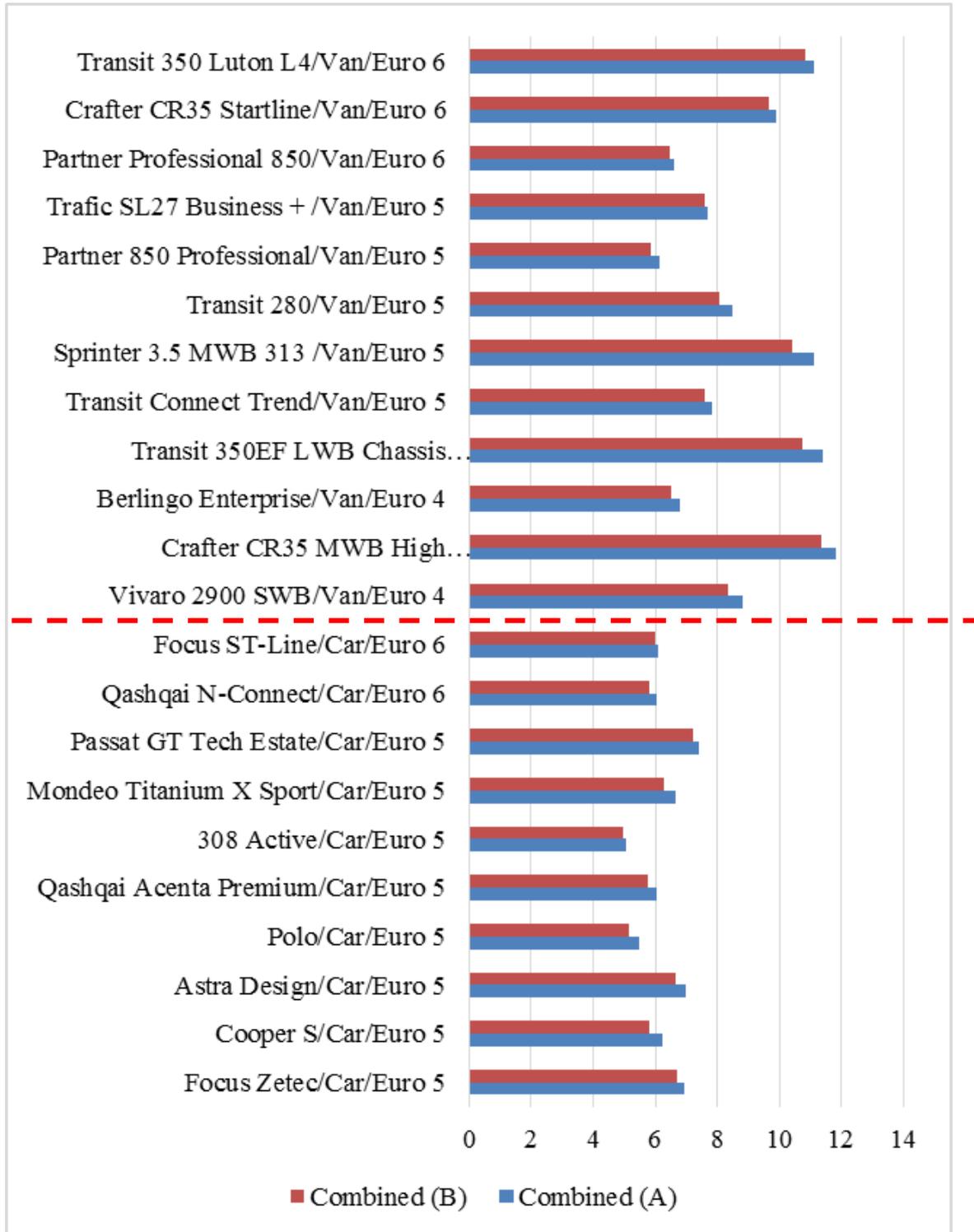
Note: Cars below the red dashed line, vans are above the line

Figure 5: Fuel consumption (Motorway) (l/100km)



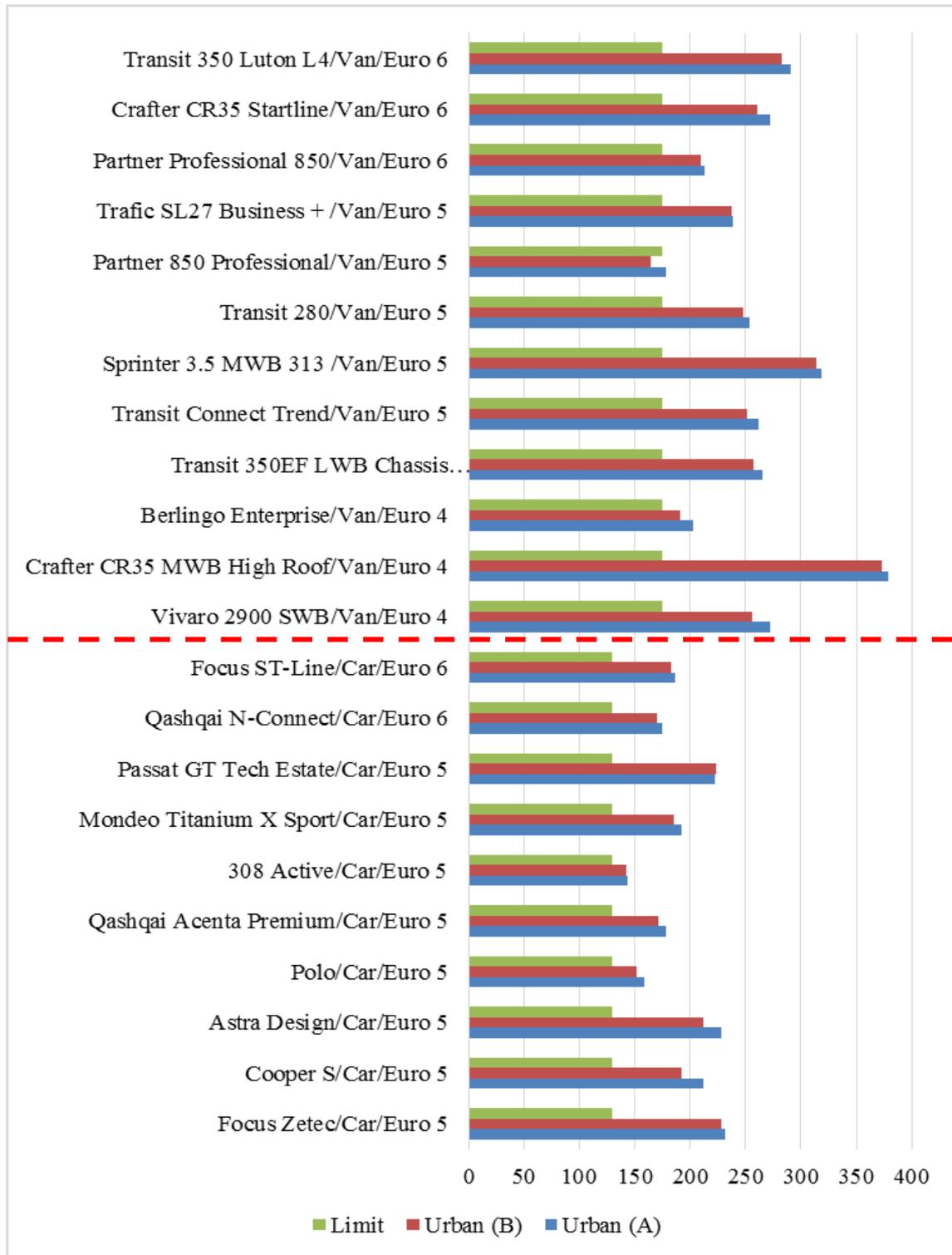
Note: Cars below the red dashed line, vans are above the line

Figure 6: Fuel consumption (Combined) (l/100km)



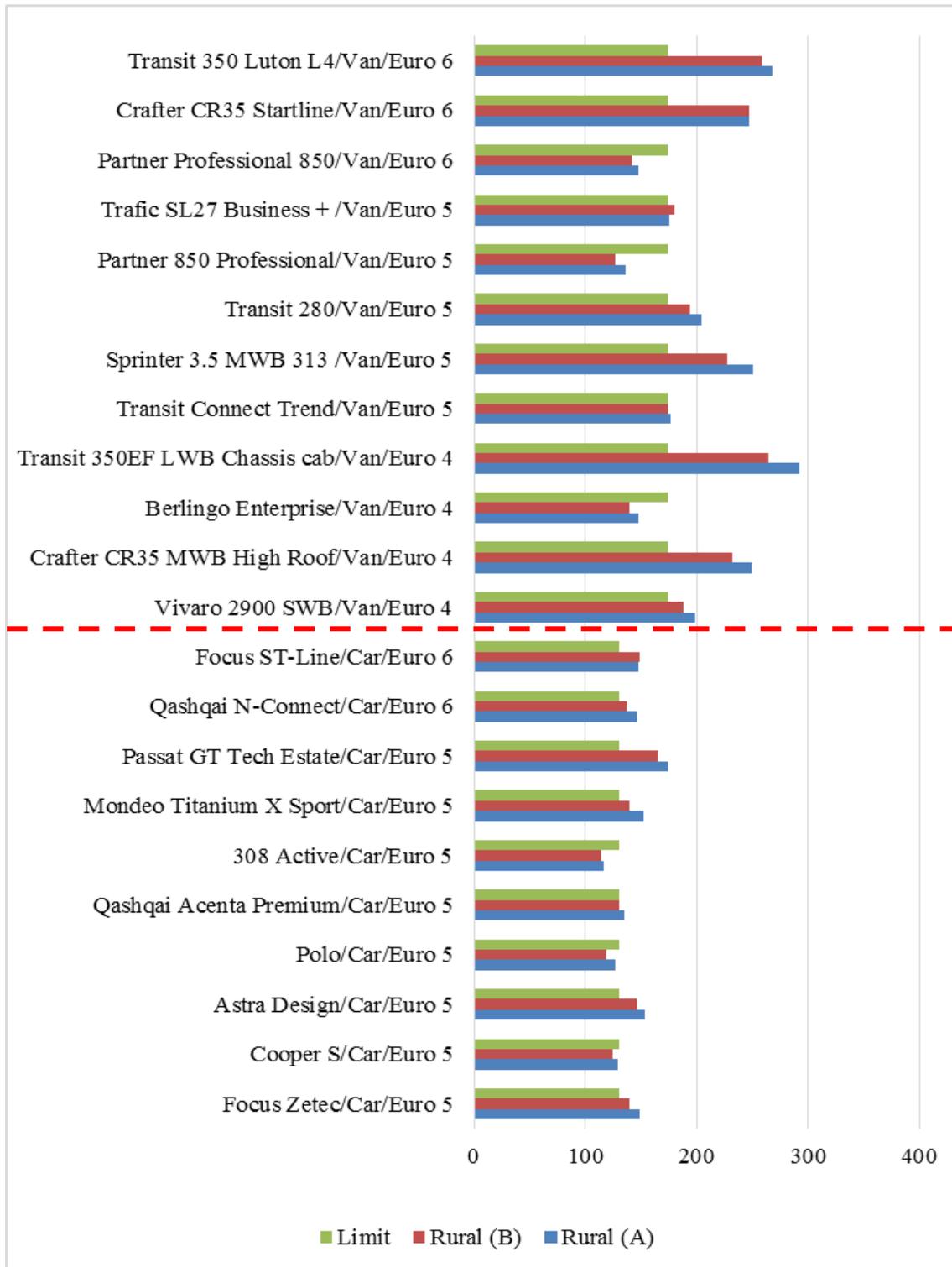
Note: Cars below the red dashed line, vans are above the line

Figure 7: CO<sub>2</sub> emissions (Urban) (g/km)



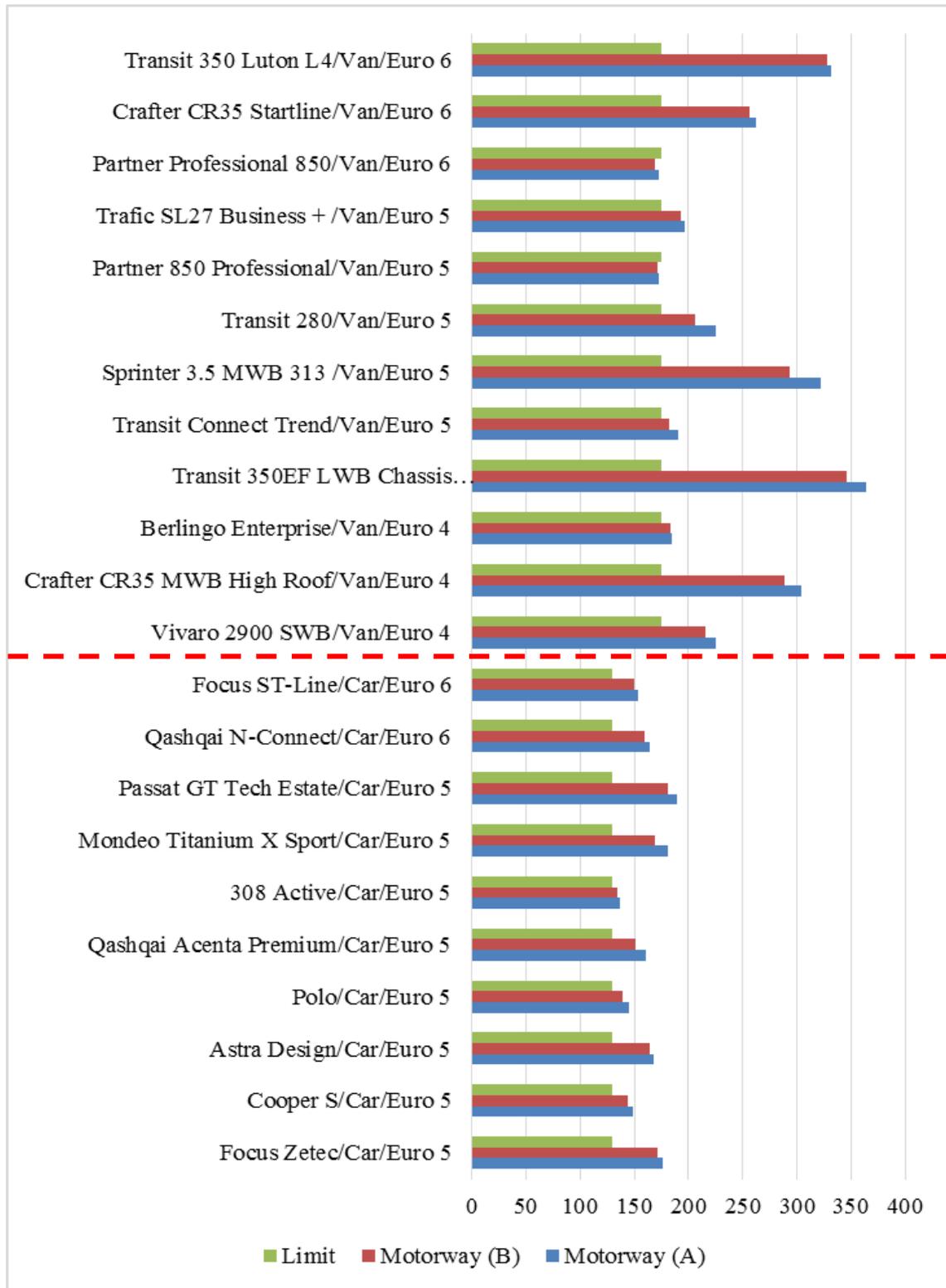
Note: Cars below the red dashed line, vans are above the line

Figure 8: CO<sub>2</sub> emissions (Rural) (g/km)



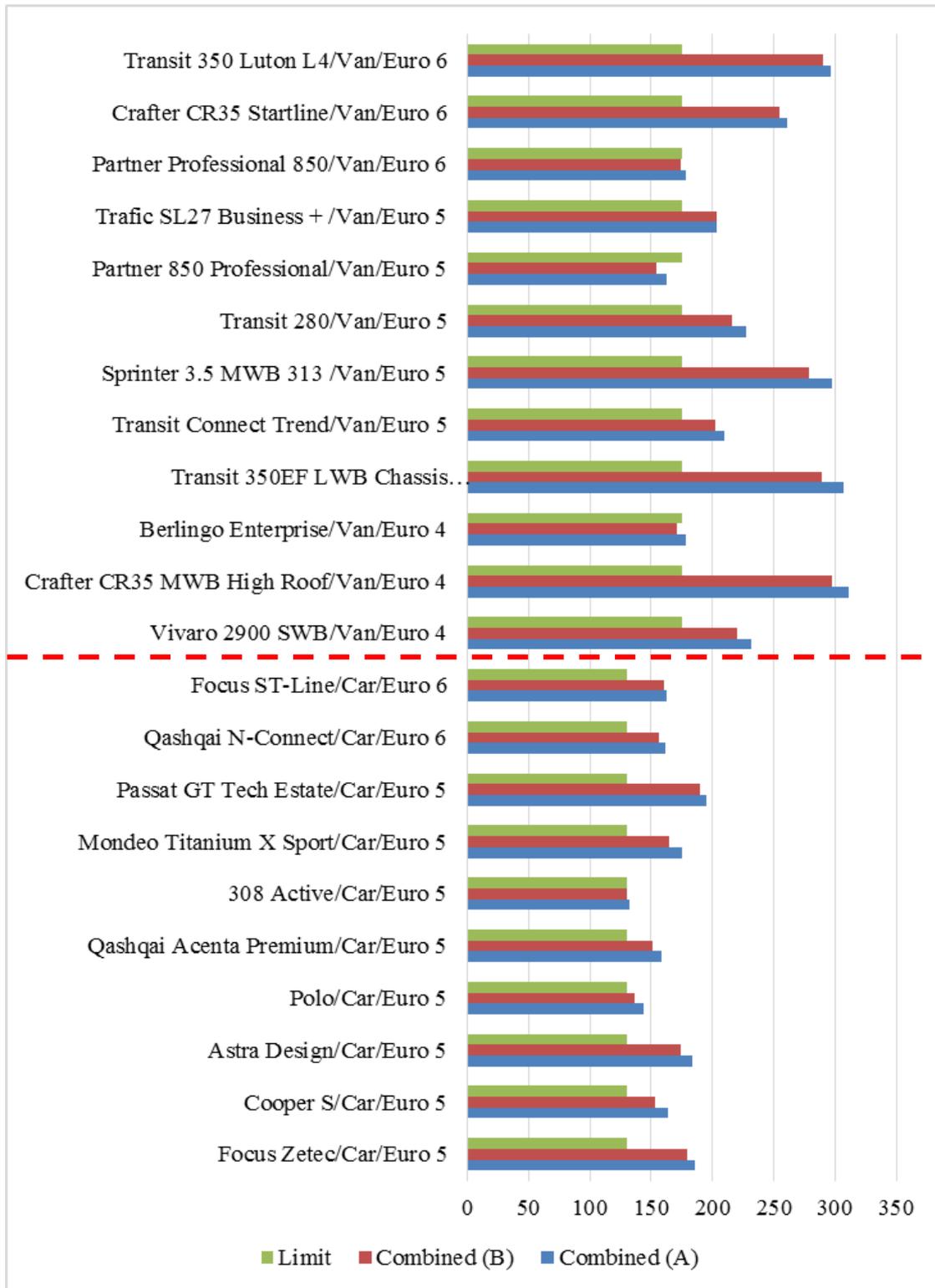
Note: Cars below the red dashed line, vans are above the line

Figure 9: CO<sub>2</sub> emissions (Motorway) (g/km)



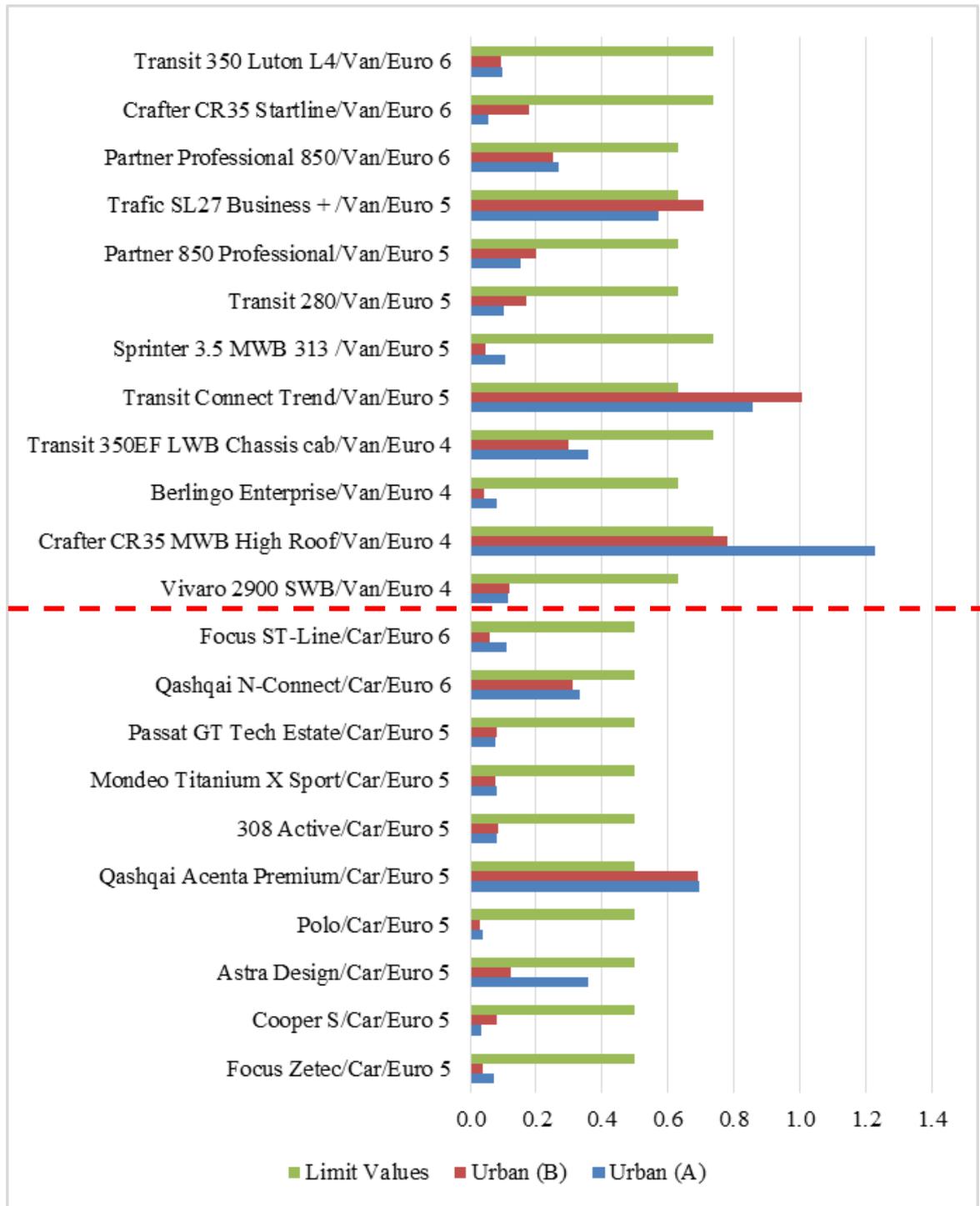
Note: Cars below the red dashed line, vans are above the line

Figure 10: CO<sub>2</sub> emissions (Combined) (g/km)



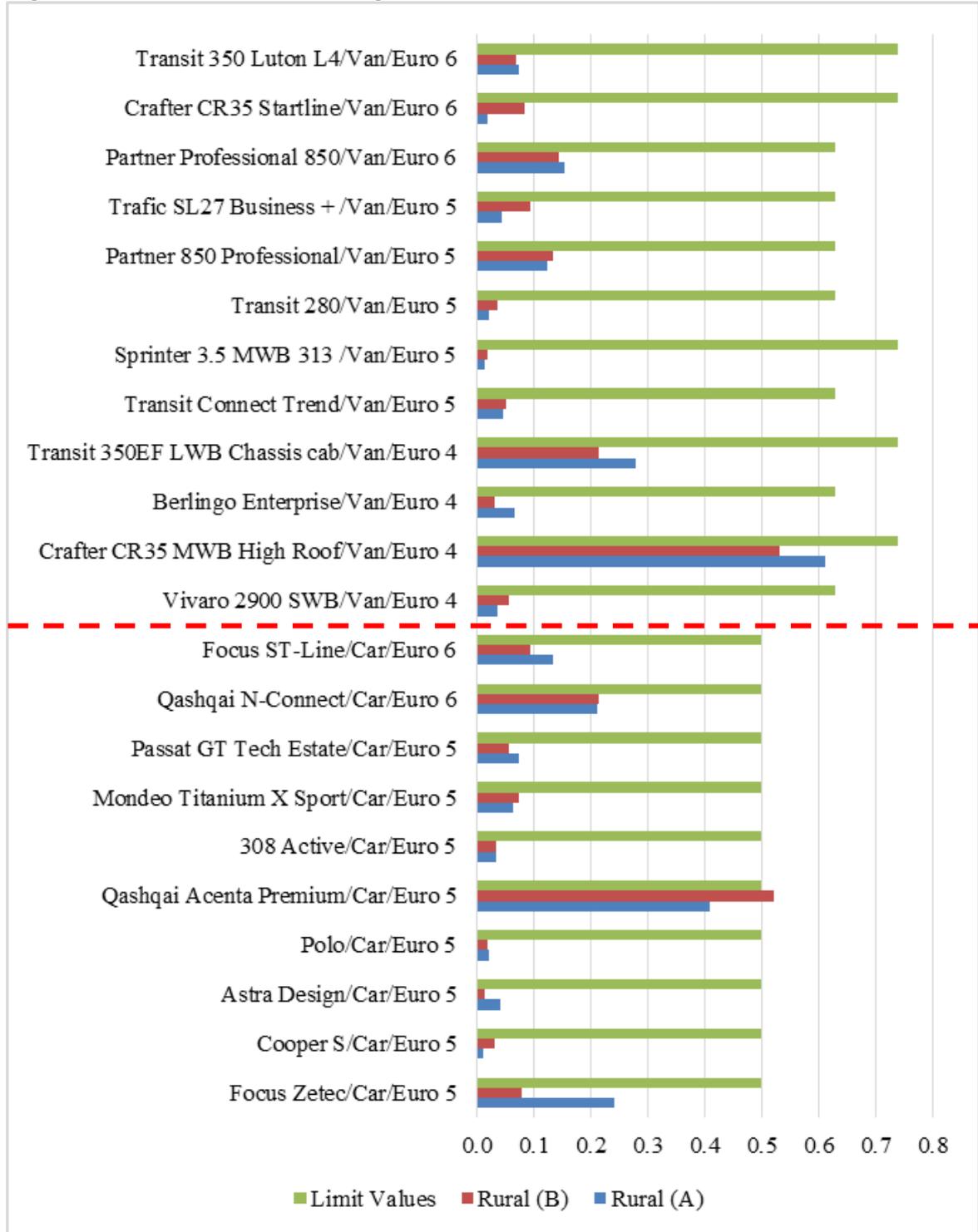
Note: Cars below the red dashed line, vans are above the line

Figure 11: CO emissions (Urban) (g/km)



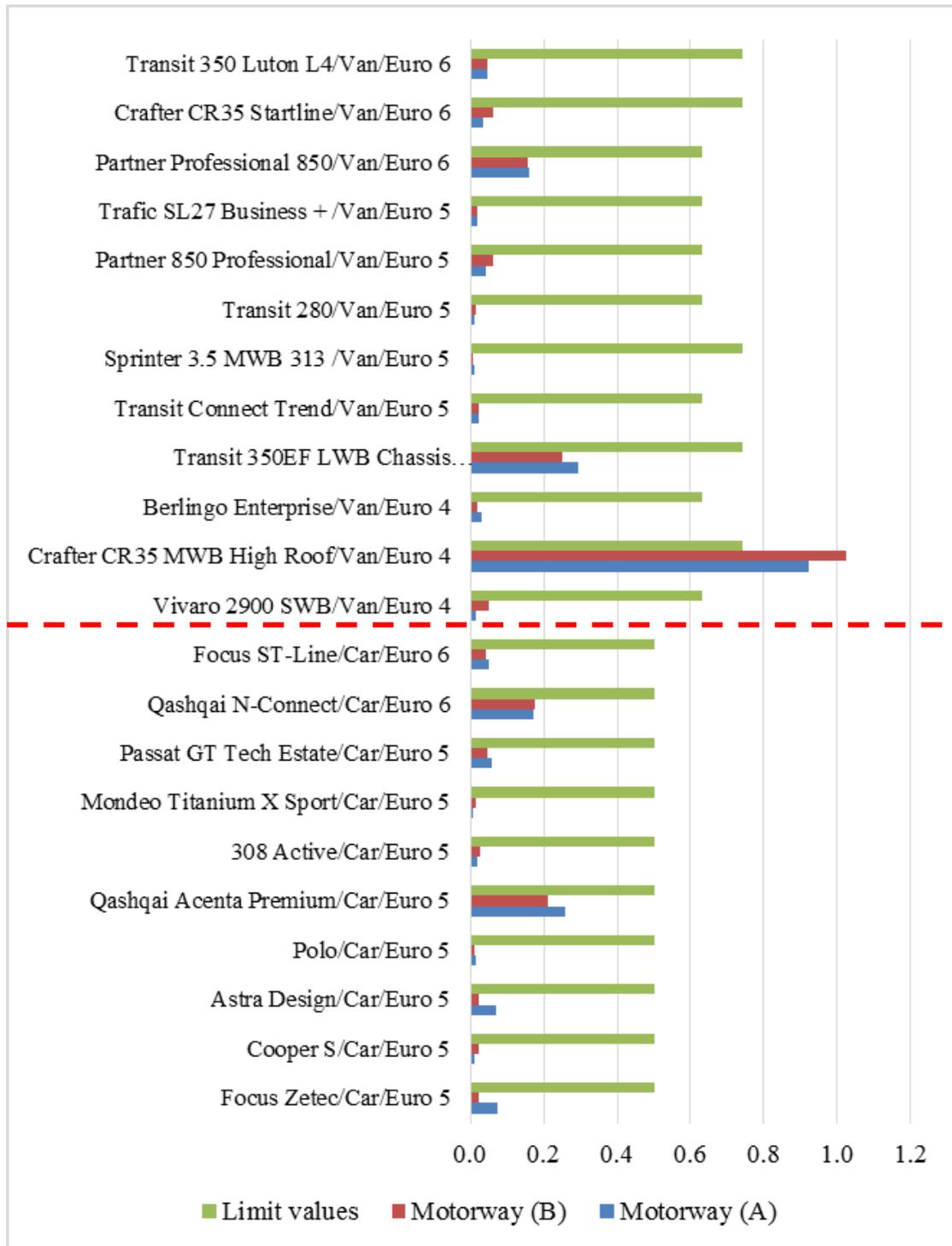
Note: Cars below the red dashed line, vans are above the line

Figure 12: CO emissions (Rural) (g/km)



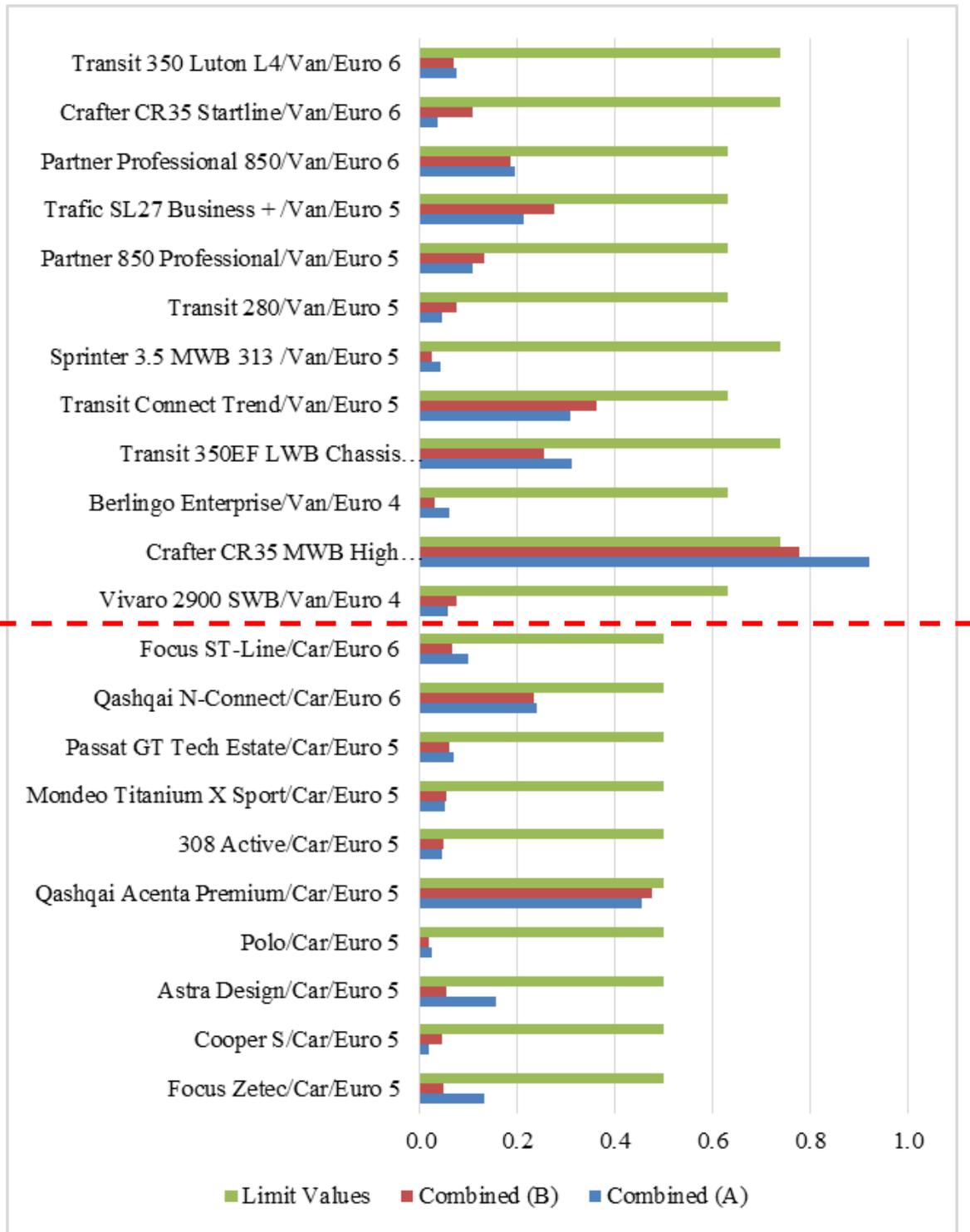
Note: Cars below the red dashed line, vans are above the line

Figure 13: CO emissions (Motorway) (g/km)



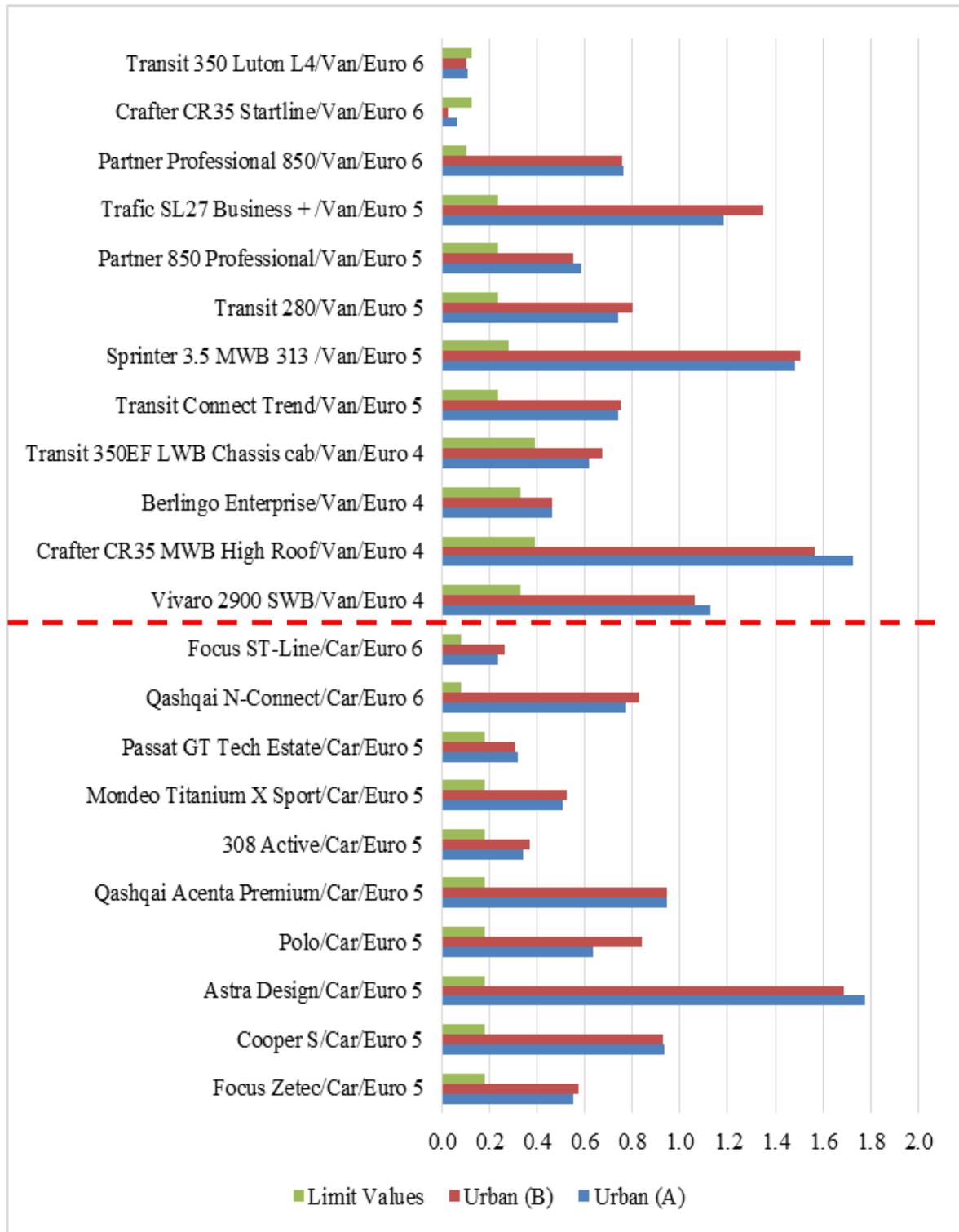
Note: Cars below the red dashed line, vans are above the line

Figure 14: CO emissions (Combined) (g/km)



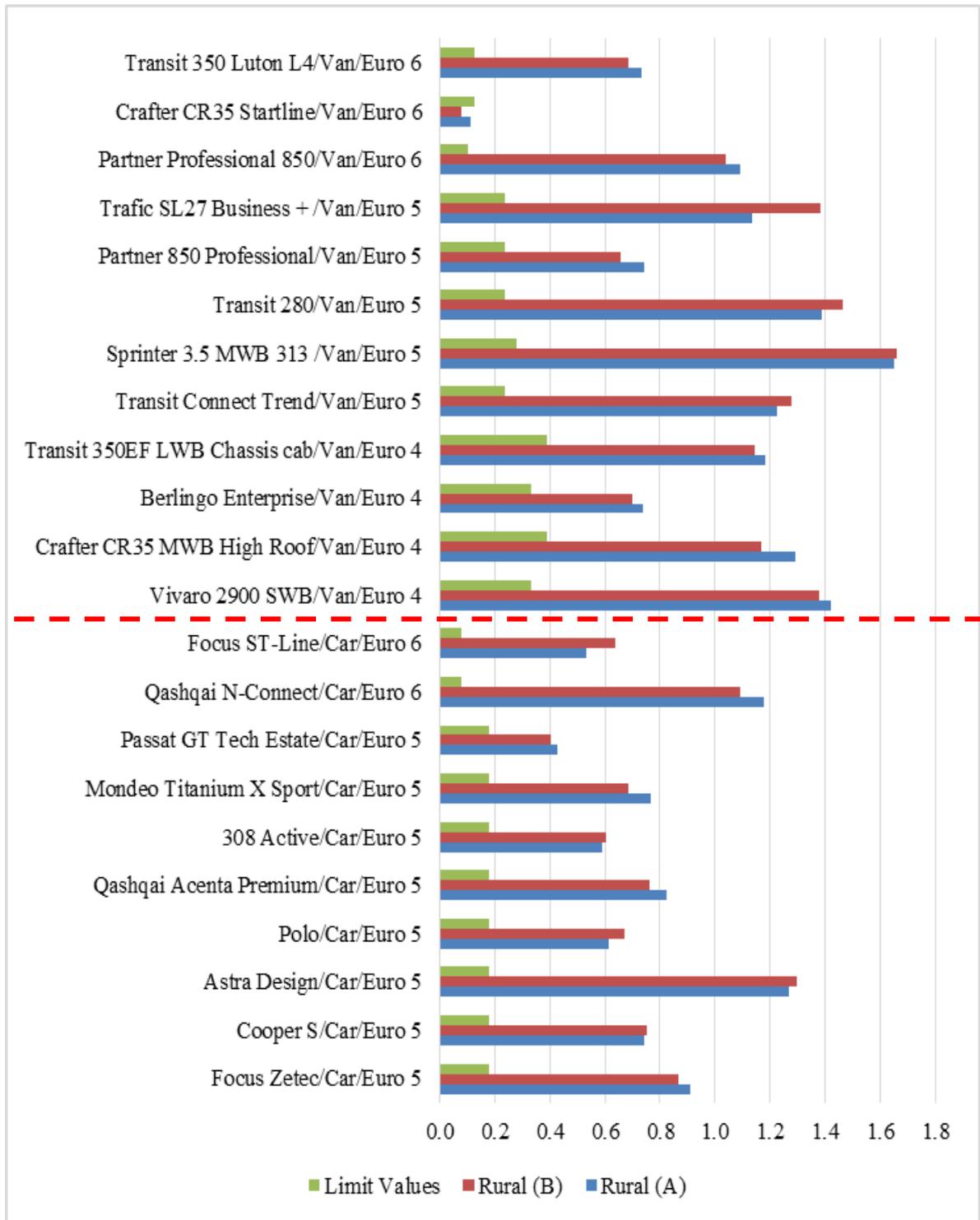
Note: Cars below the red dashed line, vans are above the line

Figure 15: NO<sub>x</sub> emissions (Urban) (g/km)



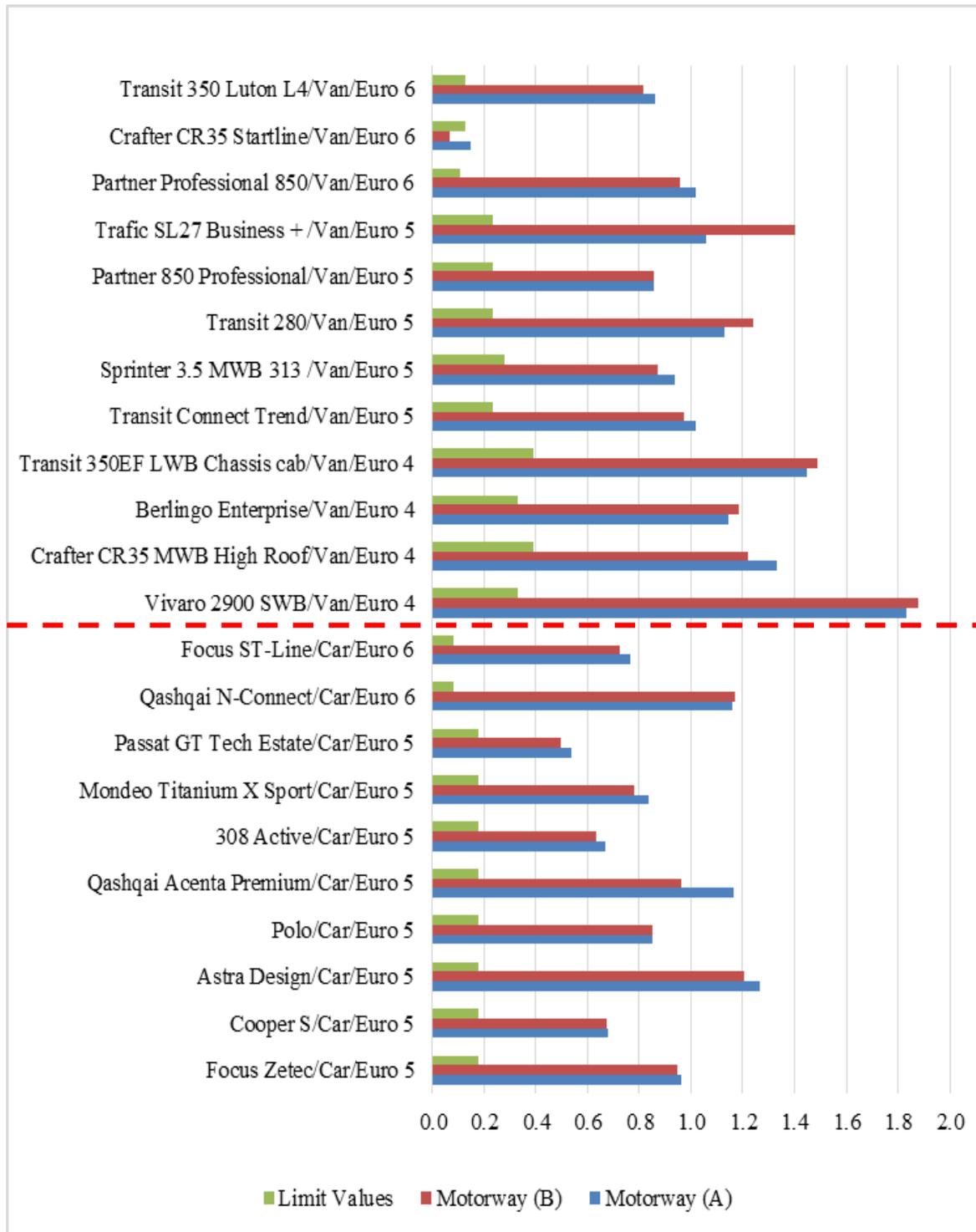
Note: Cars below the red dashed line, vans are above the line

Figure 16: NO<sub>x</sub> emissions (Rural) (g/km)



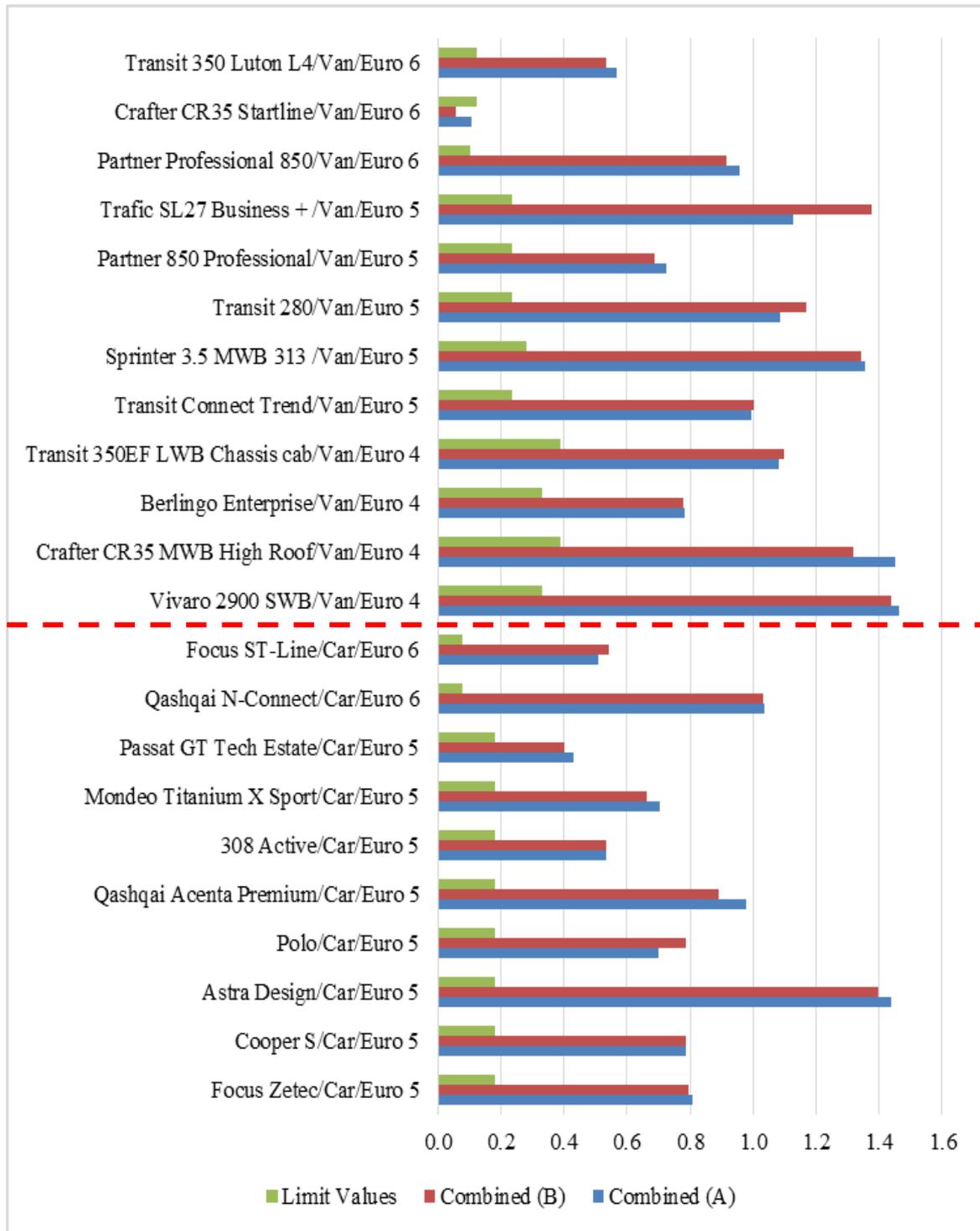
Note: Cars below the red dashed line, vans are above the line

Figure 17: NO<sub>x</sub> emissions (Motorway) (g/km)



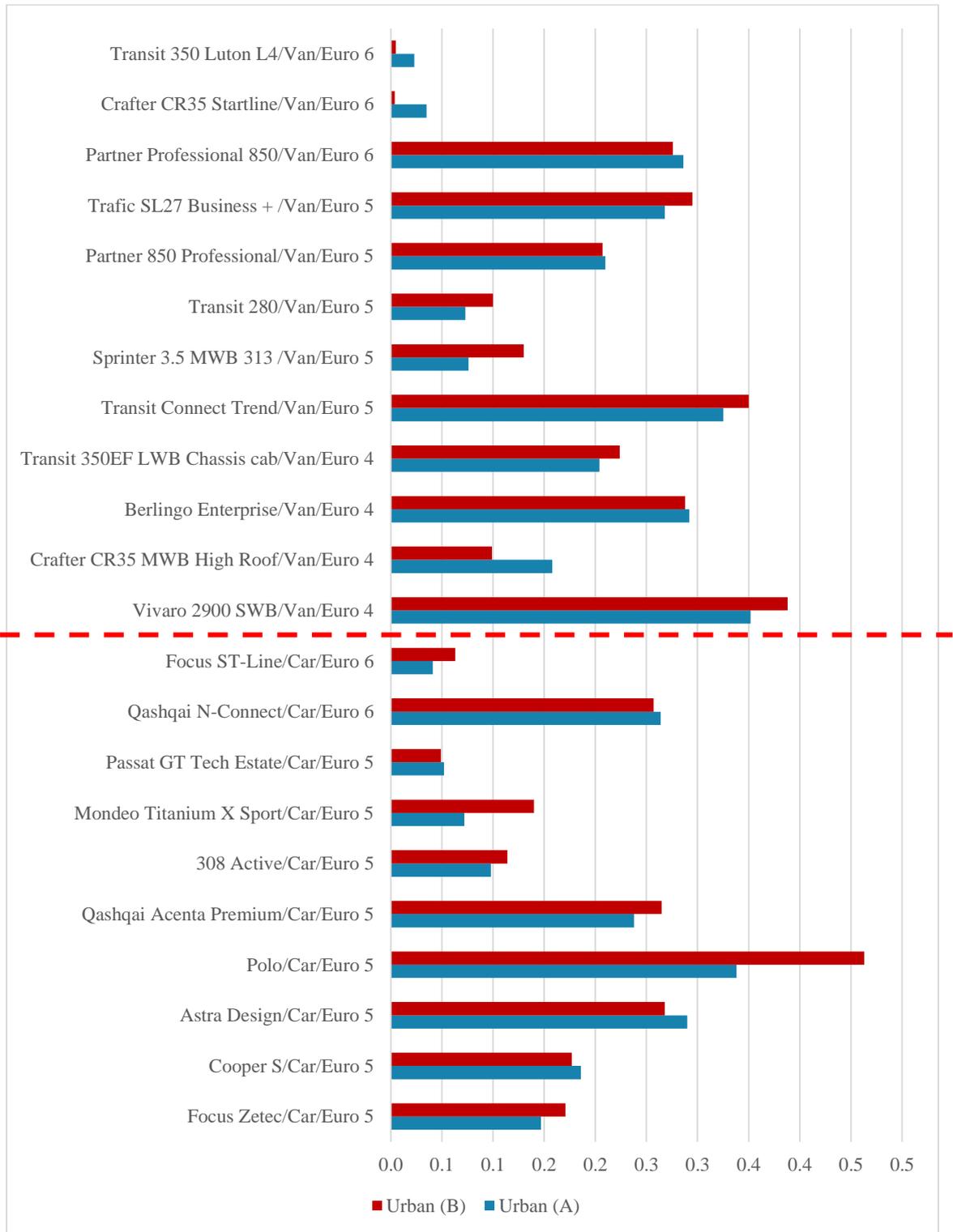
Note: Cars below the red dashed line, vans are above the line

Figure 18: NO<sub>x</sub> emissions (Combined) (g/km)



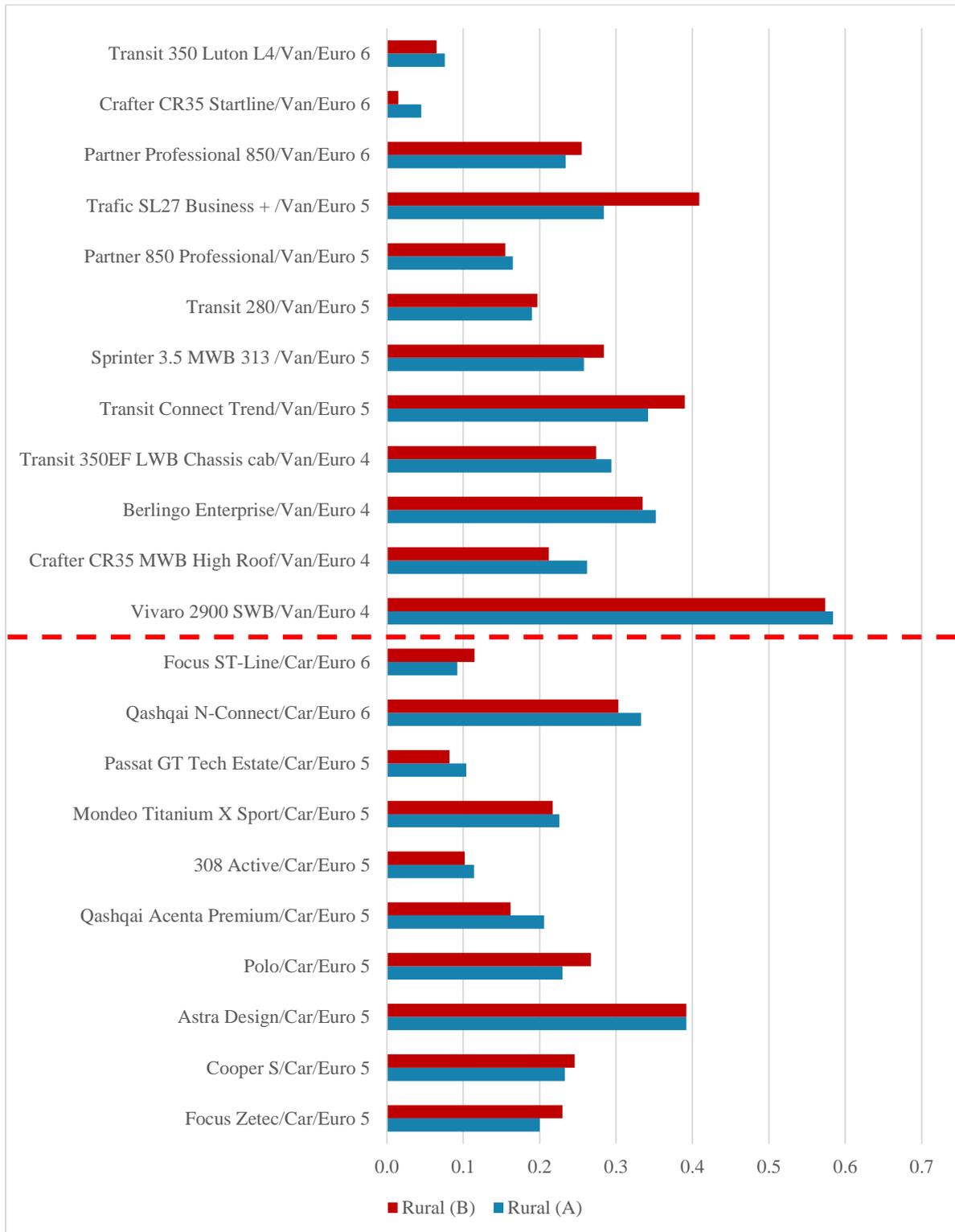
Note: Cars below the red dashed line, vans are above the line

Figure 19: NO<sub>2</sub> emissions (Urban) (g/km)



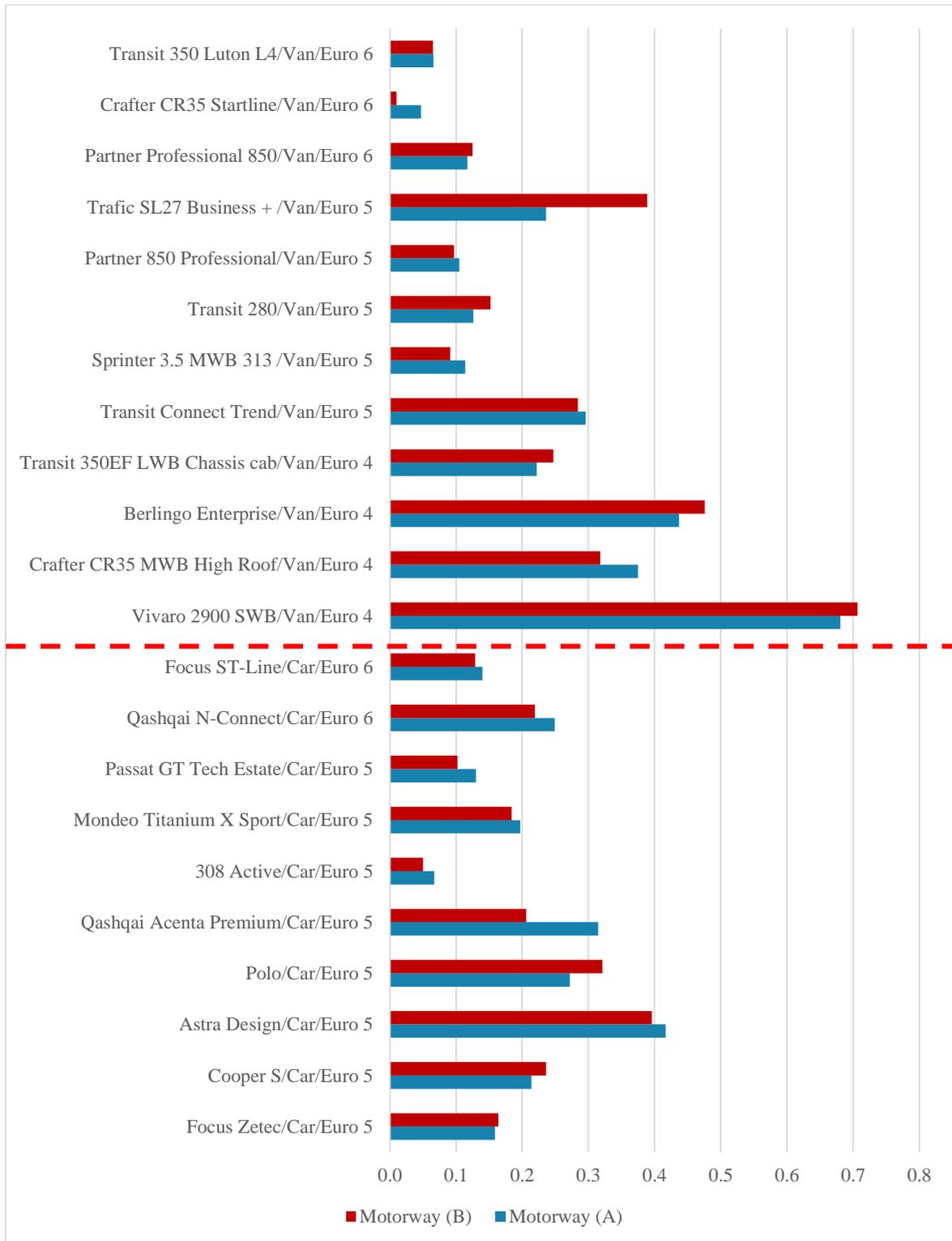
Note: Cars below the red dashed line, vans are above the line

Figure 20: NO<sub>2</sub> emissions (Rural) (g/km)



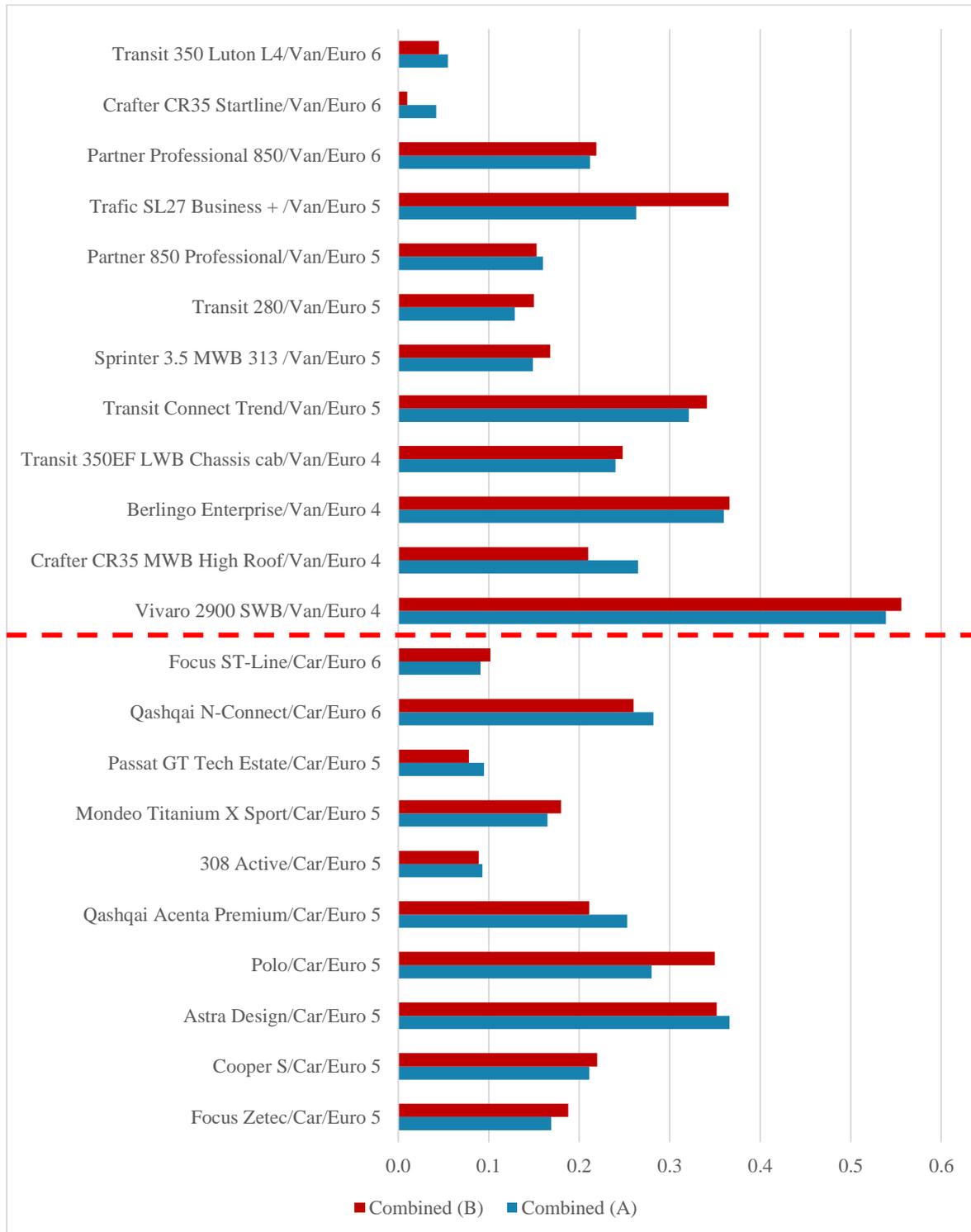
Note: Cars below the red dashed line, vans are above the line

Figure 21: NO<sub>2</sub> emissions (Motorway) (g/km)



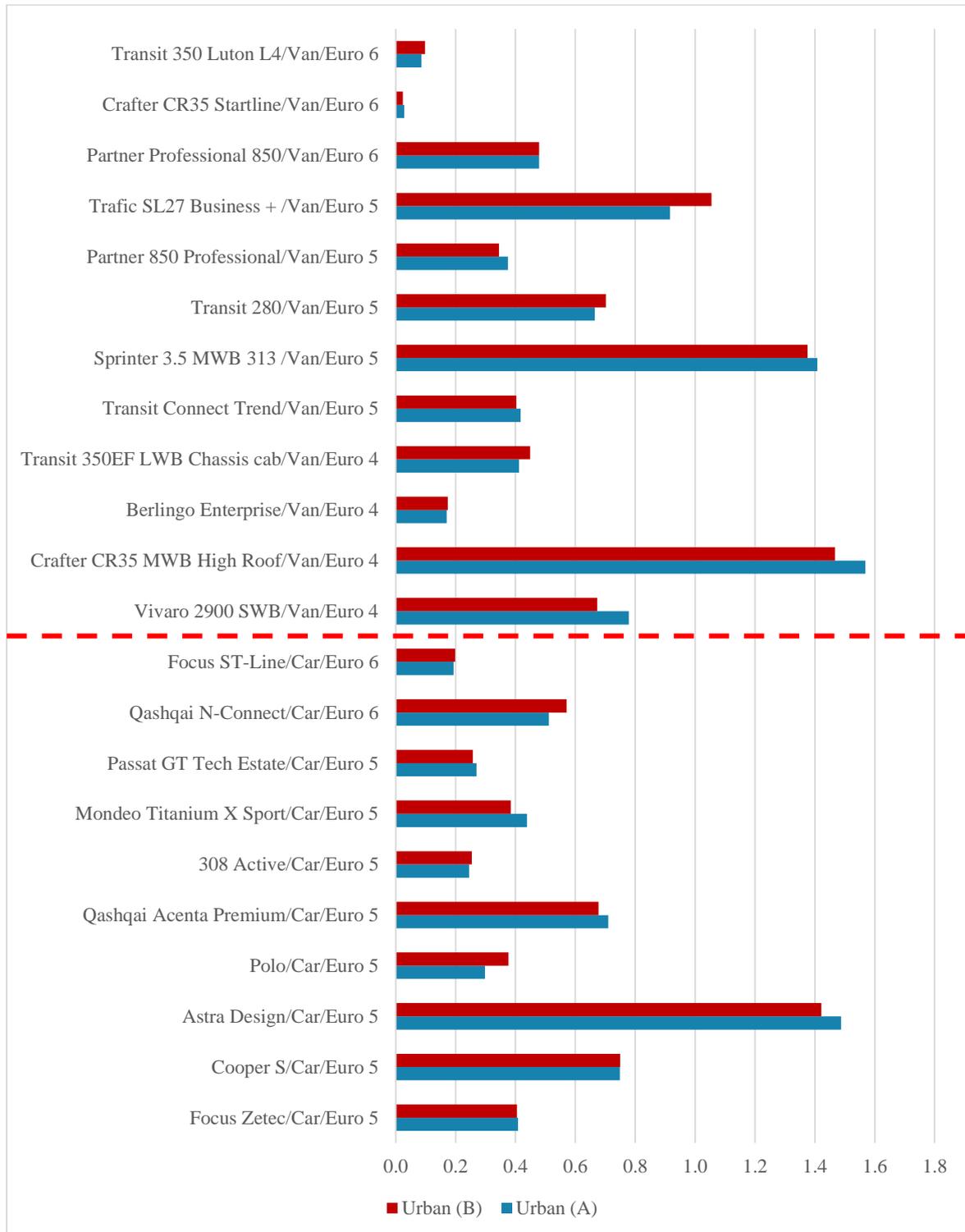
Note: Cars below the red dashed line, vans are above the line

Figure 22: NO<sub>2</sub> emissions (Combined) (g/km)



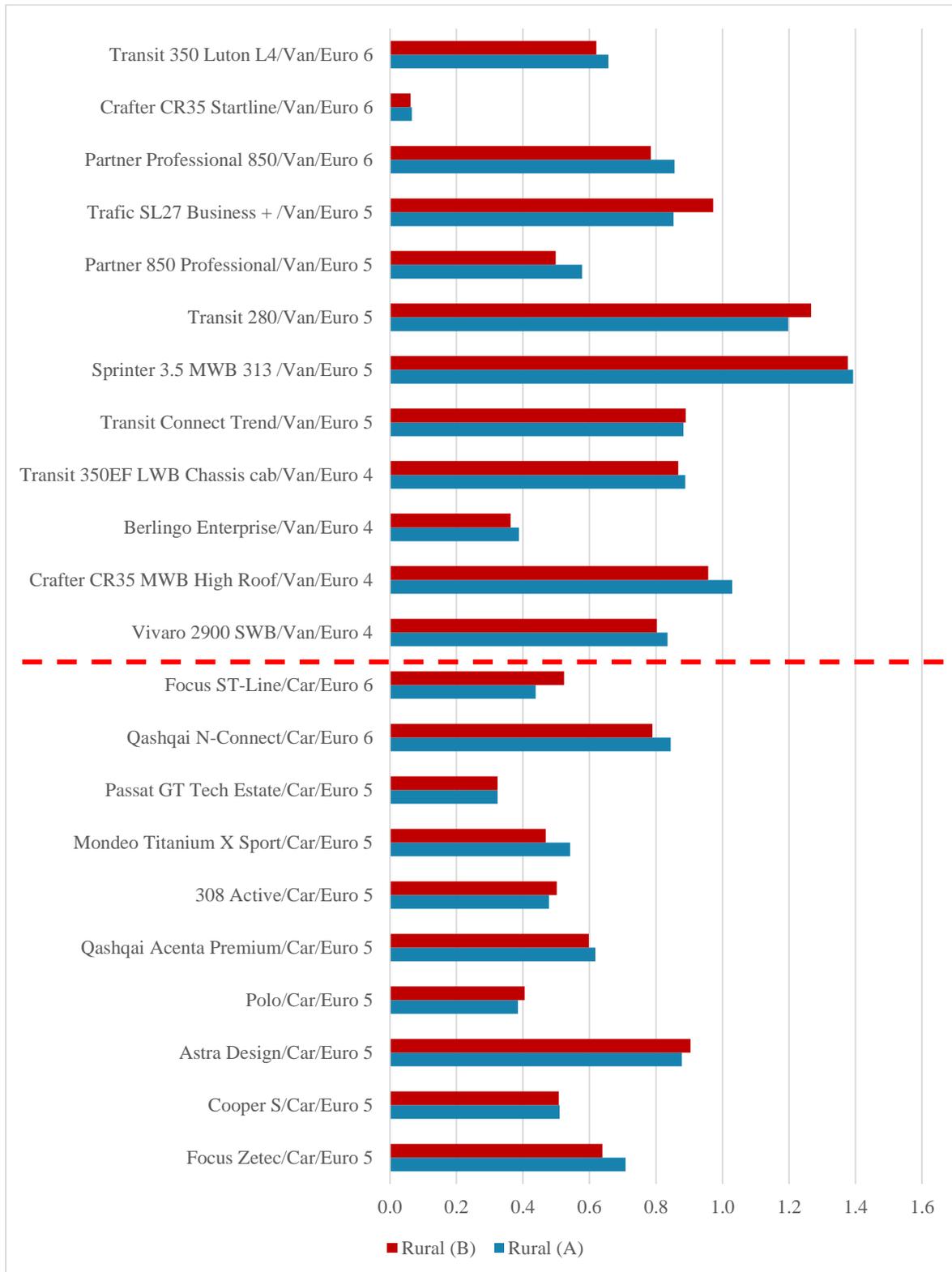
Note: Cars below the red dashed line, vans are above the line

Figure 23: NO emissions (Urban) (g/km)



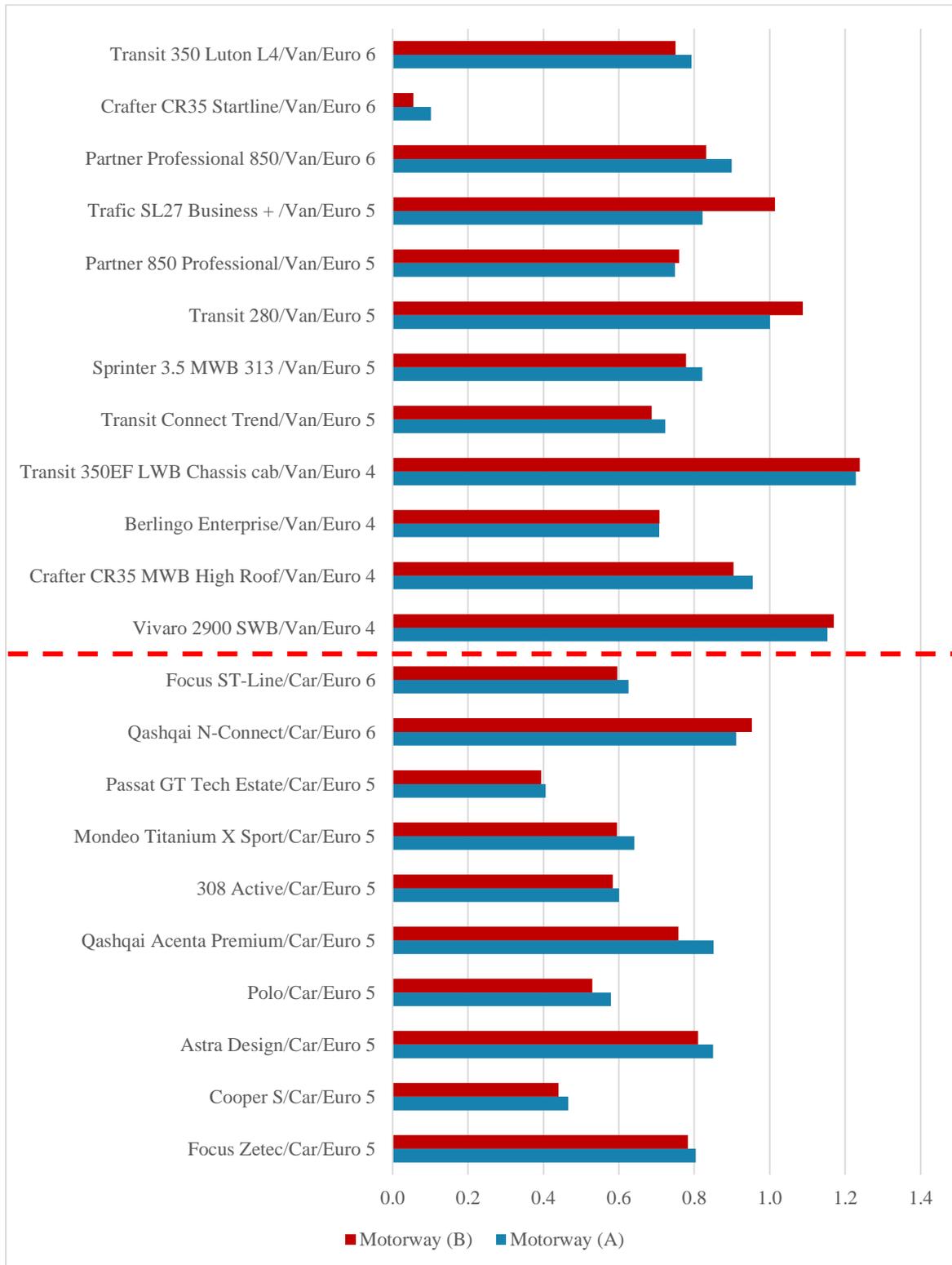
Note: Cars below the red dashed line, vans are above the line

Figure 24: NO emissions (Rural) (g/km)



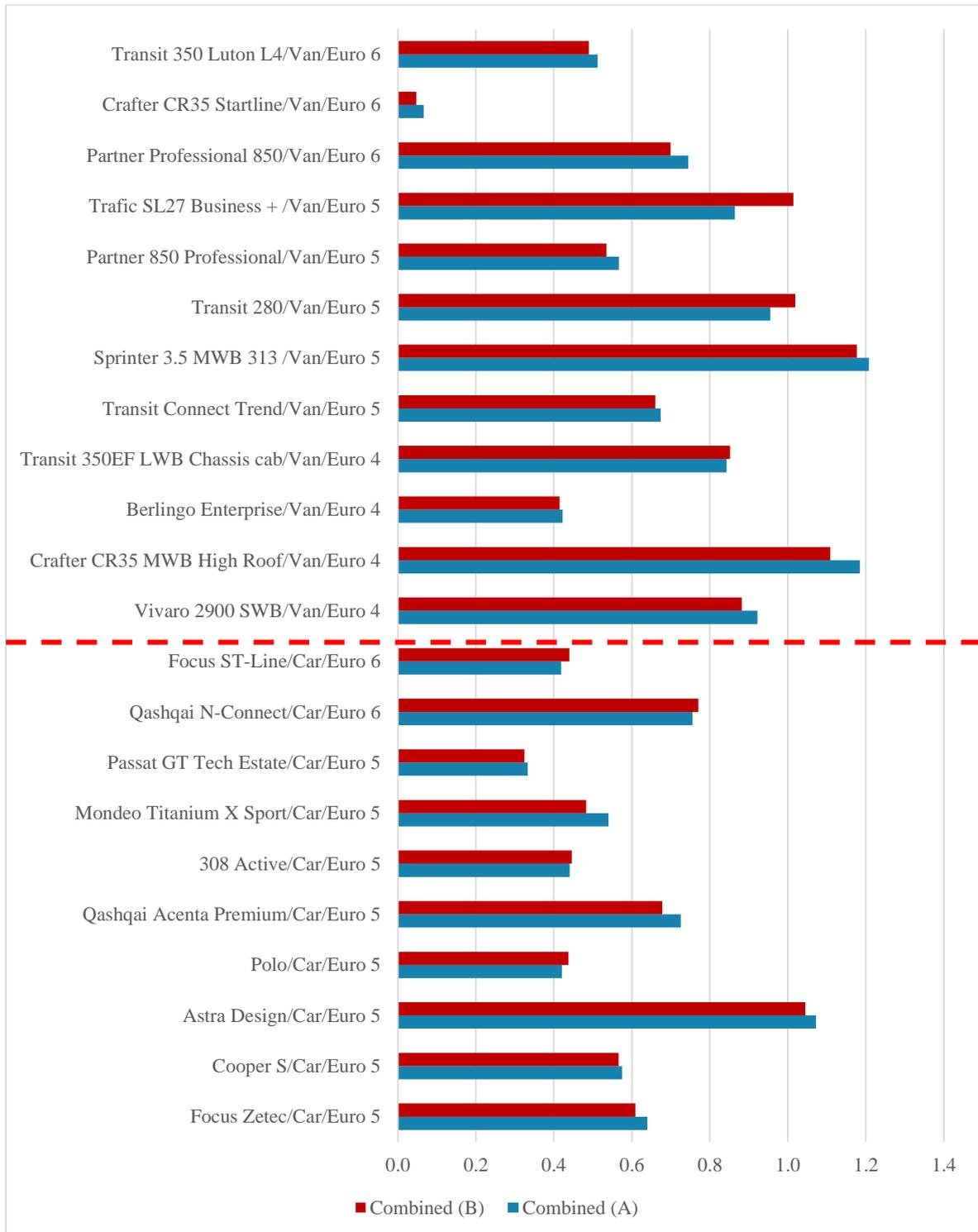
Note: Cars below the red dashed line, vans are above the line

Figure 25: NO emissions (Motorway) (g/km)



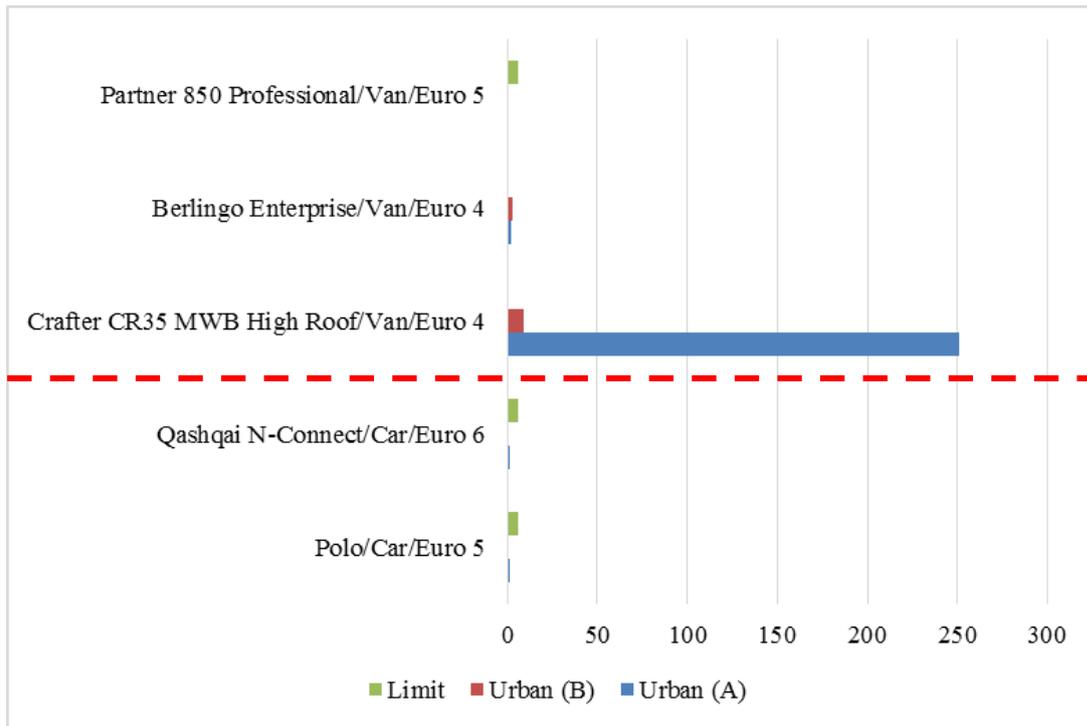
Note: Cars below the red dashed line, vans are above the line

Figure 26: NO emissions (Combined) (g/km)



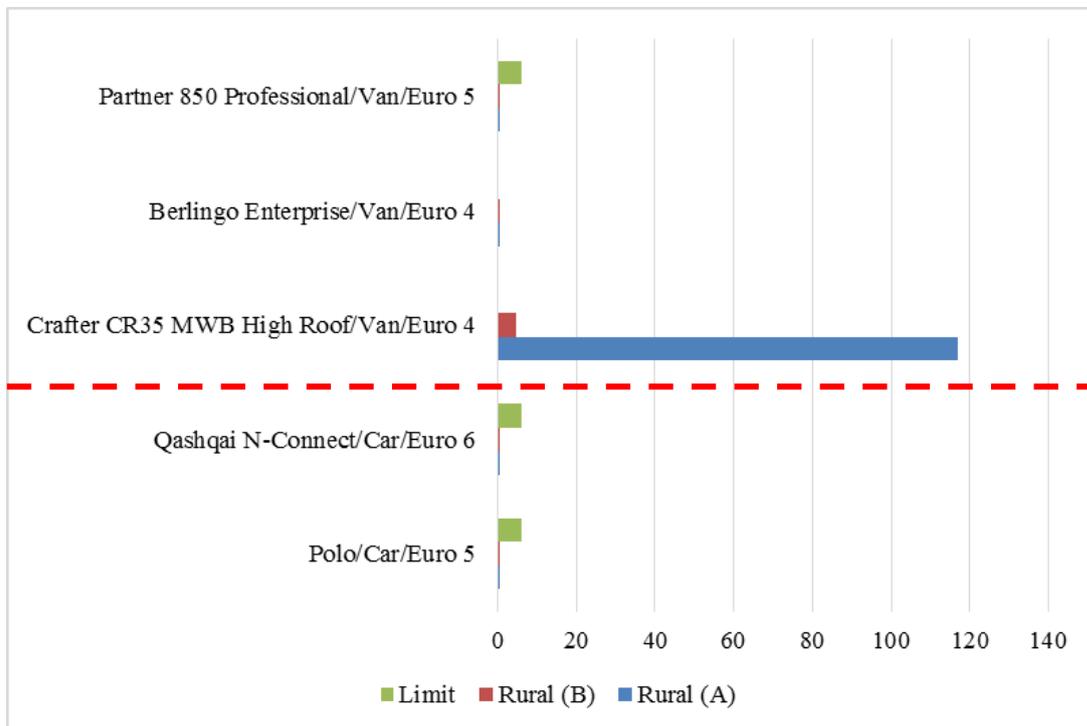
Note: Cars below the red dashed line, vans are above the line

Figure 27: PN (Urban)



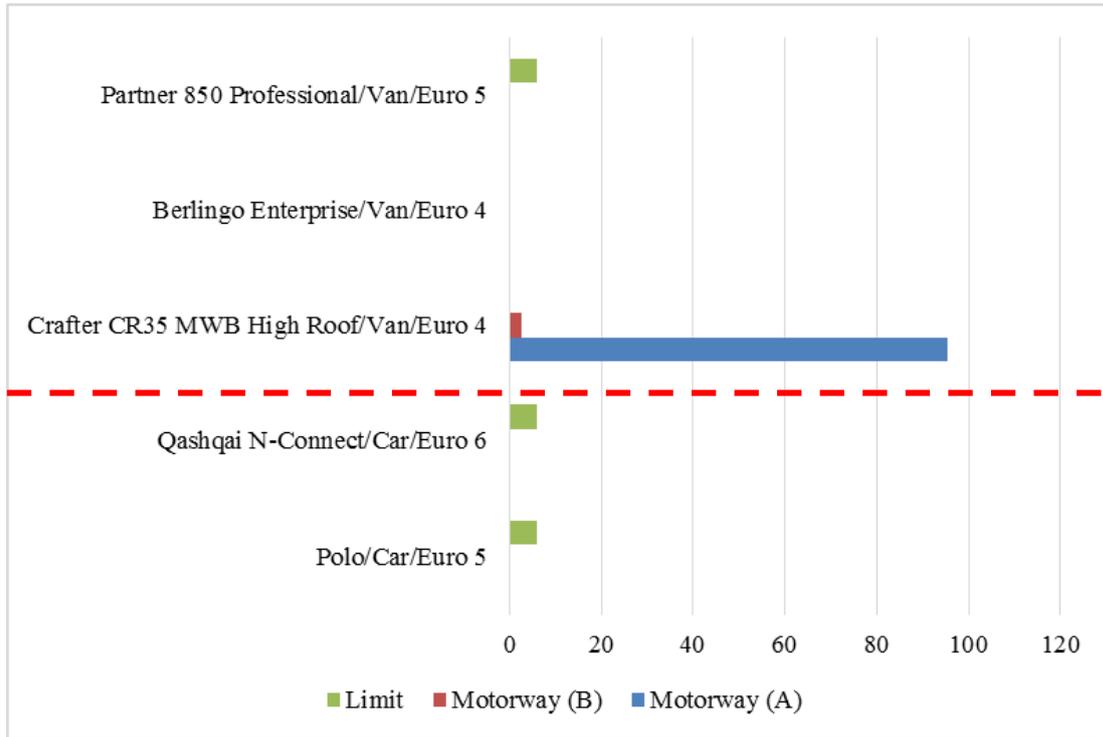
Note: Cars below the red dashed line, vans are above the line

Figure 28: PN (Rural)



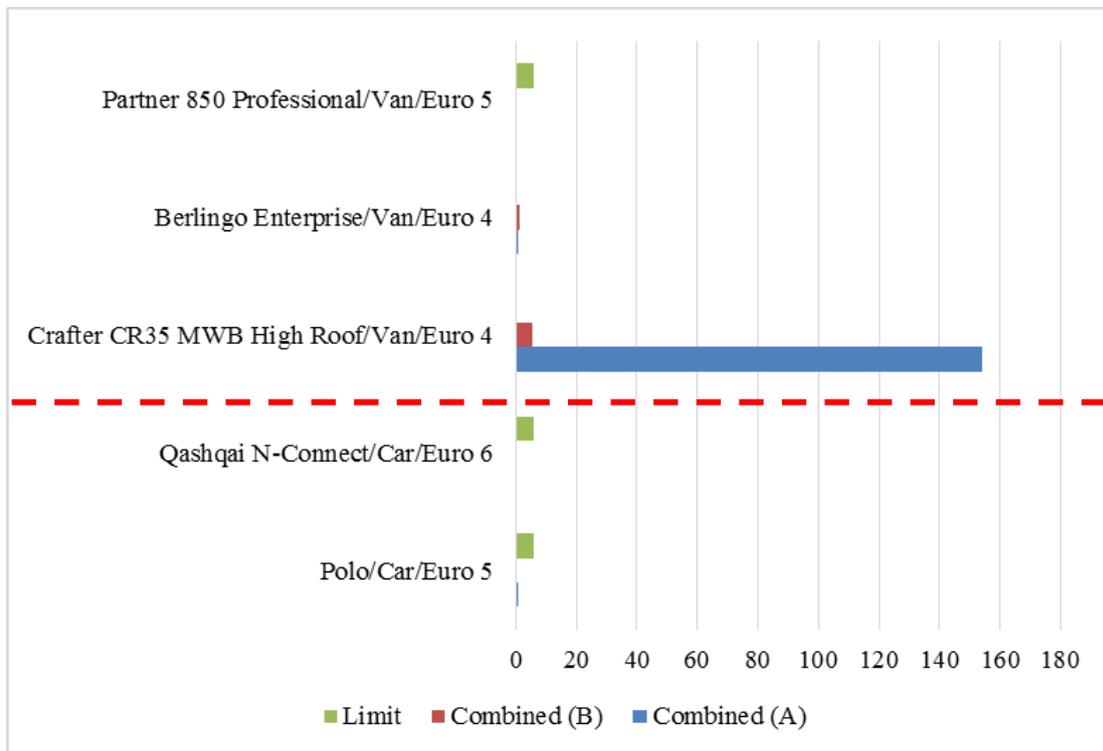
Note: Cars below the red dashed line, vans are above the line

Figure 29: PN (Motorway)



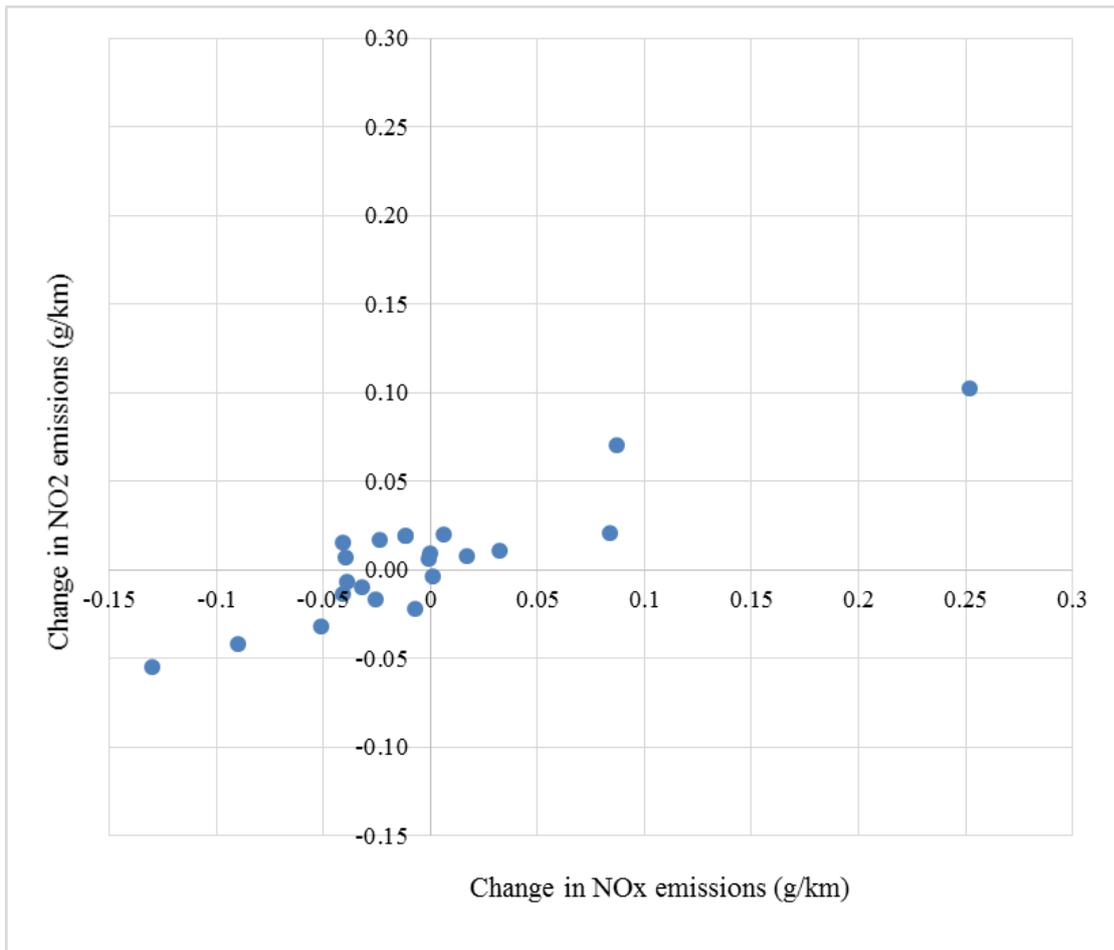
Note: Cars below the red dashed line, vans are above the line

Figure 30: PN (Combined)



Note: Cars below the red dashed line, vans are above the line

Figure 31: Change in NO<sub>x</sub> and NO<sub>2</sub> emissions (g/km)



## 6 Conclusions

---

68. Emissions testing of 22 light duty vehicles (12 vans and 10 cars) was carried out between April and October 2017 to examine whether GTL fuels result in significant changes in pollutant and carbon emissions.
69. The type of vehicles and their make were agreed with Highways England, with the aim of covering popular models and makes of vehicles that would be representative of the vehicle parc in England.
70. The drive cycle was agreed with Highways England and comprised elements of urban, rural and motorway driving as well as different dynamic modes of driving including gentle and hard acceleration and deceleration, and “Smart Motorway” driving practices. The cars and vans were tested with a consistent payload throughout.
71. As the 22 vehicles testing (five vehicles for PN) underwent six repetitions of the different drive cycle elements, the effective sample size was 132 for the gaseous pollutants, and 30 for the particulate measurements.
72. For each test the fuel consumption and the following pollutants were measured: NO<sub>x</sub>, NO<sub>2</sub>, CO, CO, and for a subset of vehicles (three vans and two cars), PN was also measured.
73. The emissions data was gathered using PEMS equipment which was chosen for this project due to its combination of accuracy and ability to measure emissions under real world driving conditions. The equipment was installed on board the test vehicles that were tested in real world driving conditions on the public highway and at a vehicle proving ground.
74. The results using conventional diesel (fuel A) were compared with the results using GTL fuel (fuel B).
75. The test pattern was A, B, B, A (A1, B1, A2, B2) and therefore a check on A1 vs A2, B1 vs B2, A1 vs B2, and A2 vs B1, to assess whether time of day and day of testing were confounding factors. CO<sub>2</sub> emissions were used to determine whether test results were different. Comparing A on day 1 to A on day 2, the difference in CO<sub>2</sub> emissions is -1.7%, and for B on day 1 to B on day 2 the difference is 0.6%. Compared with the average difference between A and B (-3.9%), it can be concluded that the time of day of the test, or the order of the test, was not a confounding factor.
76. Comparing A on day 1 to B on day 1 the difference in CO<sub>2</sub> emissions is -5.0% (A1 greater than B1), A on day 2 to B on day 1 is -3.1% (A2 greater), A on day 1 to B on day 2 is -5.0% (A1 greater), and A on day 2 to B on day 2 is -2.6% (A2 greater). All of these results cluster close to the overall average and therefore the day of the test is not a confounding factor.

### Fuel consumption and CO<sub>2</sub>

77. Fuel consumption was lower using GTL fuel compared with conventional diesel for almost all vehicles and all elements of the drive cycle. Considering the combined cycle, the change in fuel consumption varied from a decrease of 0.007 to 0.71 l/100km. Most of the changes measured were statistically significant.

78. For the combined cycle the average decrease in fuel consumption from the use of GTL fuels was 0.31 l/100km and the average percentage decrease was 3.9%.
79. Trends in CO<sub>2</sub> emissions followed the same trend as the fuel consumption. For the combined cycle the average decrease in CO<sub>2</sub> emissions was 8.1g/km and the average percentage decrease was 3.9%. Most of the changes measured were statistically significant.

### Other pollutants

80. There were no clear trends in CO emissions with large percentage increases and decreases measured. Most of the changes measured were not statistically significant.
81. There were no clear trends in NO<sub>x</sub>, NO<sub>2</sub> and NO emissions and most of the changes measured were not statistically significant.
82. The change in the primary NO<sub>2</sub> fraction (fNO<sub>2</sub>) was less than 20%, except for one vehicle, and increases or decreases in fNO<sub>2</sub> were equally likely.
83. Results showed large percentage increases in PN for the two cars tested (86% to 91%), and smaller percentage decreases (13% to 54%) when using GTL fuel for the two other vans tested. The changes measured were statistically significant.
84. For the Volkswagen Crafter CR35 MWB Euro 4 van, the recorded PN using conventional diesel was very high compared to the other vehicles which was thought to be due to the DPF having just been replaced, and despite degreasing the DPF with about 150 miles of driving before the first test.

### Comparison against limit values

85. Testing found that almost all the Euro 6 vehicles tested exceeded the CO<sub>2</sub> emission limits for new vehicles manufactured in 2016/2017 (130g/km for cars and 175g/km for light duty vehicles), with fuel A and fuel B.
86. Almost all the vehicles complied with the limit of CO under almost all conditions and drive cycle elements whereas the NO<sub>x</sub> limit was exceeded in almost all cases, by up to 13 times.

### Comparison against the Emissions Analytics database

87. Highways England requested a comparison between the vehicles tested and those in the Emissions Analytics database. This was undertaken and showed the vehicles tested, when using conventional diesel, had higher fuel consumption and CO<sub>2</sub> emissions than those in the database. There were several reasons why the comparison was not a like-for-like comparison:

- The vehicles tested were not all in the database and therefore the comparison was with the vehicle judged to be the nearest equivalent;
- The drive cycle for this test was different from the Emissions Analytics standard cycle; and
- The database includes mainly vehicles test at new, whereas the vehicles tested under this work package were used vehicles.

## Appendix A

### Equipment

## A1 Equipment

---

### A1.1 Portable Emissions Measurement System (PEMS)

A Portable Emissions Measurement System (PEMS) is the same technology used for measuring tailpipe emissions as found in a typical test laboratory but packaged for on-board vehicle use. It measures performance while the vehicle is being driven and has been used by government test facilities around the world for decades. Our PEMS equipment is manufactured by Sensors Inc. and meets the following standards: UN-ECE R-49 and Commission Regulation (EU) No. 582/2011 in the European Union and 40CFR part 1065 in the USA. The repeatability according to Sensors Inc is +/-2% and this is supported by our own use and analysis of results. It is shown in Figure 32.

Figure 32 PEMS



### A1.2 Sensors LDV

The SEMTECH LDV, Sensors' 5th generation PEMS, is the culmination of 15 years of experience in the design, development, and application of PEMS. The system directly addresses the challenges created by the RDE-LDV standards recently promulgated by the European Union, which require that passenger cars be tested under real world conditions as part of the certification process. SEMTECH LDV directly addresses these new challenges yielding a dedicated solution focused on the LDV core application needs.

Figure 33 SEMTECH LDV



### A1.3 Pegasor Mi2

Particulates are measured by the Pegasor Mi2, which is a real-time sampler of the raw exhaust. It uses a corona diffusion charger for estimating both particle number and mass. It can be configured to measure either particle mass concentration or number concentration. It is an alternative method to the filter-paper-based regulatory approach, but has the advantages that:

- It can measure sub-23nm particles
- The results are real-time
- It reports both particle number by size class and mass

Figure 31: Pegasor Mi2



## Appendix B

### Equipment Calibration

## B1 Equipment Calibration

At the start and end of each ISO cycle of tests the gaseous measurement equipment had a span and zero calibration performed: the span was calibrated against calibration gas bottles of traceable provenance, and the zero calibrated using ambient air. The span values calibrated to the values shown in **Error! Reference source not found.**

Table 20: Calibration values

Channel	Unit	Value
CO	ppm	1,212
CO <sub>2</sub>	%	12
O <sub>2</sub>	%	20.9
HC	ppm	2,010
NO	ppm	1,495
NO <sub>2</sub>	ppm	249
<b>Total hydrocarbons</b>	ppm	244.2

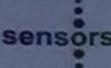
The equipment had current certificates of calibration compliance, for the linearity of the analyser and flow tube, from Sensors, Inc. which are shown below.

## B1.1 Calibration certificates

Figure 32: SEMTECH-DS System Specifications

SEMTECH-DS System Specifications								
Gas	CO	CO2	NO	NO2	THC			
Range	0 - 8%	0 - 20%	0 - 2,500 ppm	0 - 500 ppm	0 - 100 ppmC	0 - 1,000 ppmC	0 - 10,000 ppmC	0 - 40,000 ppmC
Resolution	10 ppm	0.01%	1 ppm	1 ppm	0.1 ppmC	1 ppmC	1 ppmC	10 ppmC
Accuracy	±3% of reading or ± 50 ppm	±3% of reading or ± 0.1%	±3% of reading or ± 15 ppm	±3% of reading or ± 10 ppm	±2.0 % of reading or ±5 ppmC	±2.0 % of reading or ±5 ppmC	±2.0 % of reading or ±25 ppmC	±2.0 % of reading or ±100 ppmC
Linearity	Intercept ≤0.5 % of range 0.990 ≤Slope ≤1.01 SEE ≤1.0 % of range r <sup>2</sup> ≥0.998			Intercept ≤1.0 % of range 0.985≤Slope ≤1.015 SEE ≤1.0 % of range r <sup>2</sup> ≥0.998	Intercept ≤0.5 % of range 0.990 ≤Slope ≤1.01 SEE ≤1.0 % of range r <sup>2</sup> ≥0.998			
Repeatability	±2 % of reading or 20 ppm	±2 % of reading or ±0.05 %	±2 % of reading or 5 ppm	±2 % of reading or 5 ppm	±1.0 % of reading or ±2 ppmC	±1.0 % of reading or ±2 ppmC	±1.0 % of reading or ±10 ppmC	±1.0 % of reading or ±40 ppmC
Noise	±20 ppm	±0.02%	± 2 ppm	± 2 ppm	± 2 ppmC	± 2 ppmC	± 10 ppmC	± 40 ppmC
Span Drift	±2 % of reading or 20 ppm	±2 % of reading or 0.1 %	±2 % of reading or 20 ppm	± 10 ppm	±1.0 % of reading or 3 ppmC	±1.0 % of reading or 3 ppmC	±1.0 % of reading or 15 ppmC	±1.0 % of reading or 60 ppmC
Zero Drift	±0.005 % (50 ppm)	±0.1 %	± 10 ppm	± 10 ppm	± 5 ppmC	± 5 ppmC	± 10 ppmC	± 20 ppmC
Response Time	T90 ≤ 3 seconds	T90 ≤ 3 seconds	T90 ≤ 2 seconds	T90 ≤ 2 seconds	T90 ≤ 2 seconds	T90 ≤ 2 seconds	T90 ≤ 2 seconds	T90 ≤ 2 seconds
Flow Rate	2 lpm	2 lpm	3 lpm	3 lpm	2 lpm	2 lpm	2 lpm	2 lpm
Data Rate	0.833 Hz	0.833 Hz	up to 4 Hz	up to 4 Hz	up to 4 Hz	up to 4 Hz	up to 4 Hz	up to 4 Hz

Figure 33: EFT Calibration



### EFM Calibration: Certificate of Compliance

Flow Tube Linearity

B13106441 Wed, Nov 09, 2016, 3-18 PM Flow Flow Certificate.xls

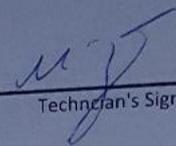
Filename

Main Module Serial Number: K13111667

Tube Serial Number: B13106441

Tube Diameter: 0.12700 m

Calibration Date: 11-9-2016

Technician: Markus Jericho 

System Pass / Fail: Pass

Date of Last Calibration: None

Current Calibration Valid Until: 2017-11-09

Technician's Signature

**Linearity results**

Statistic	Result	Criteria	Pass/Fail
Intercept	-0.12%	+/- 1% max	Pass
Slope	1.001	0.98-1.02	Pass
Standard Error	0.37%	+/- 2% max	Pass
R <sup>2</sup>	0.9999	≥ 0.990	Pass

Specification	Pass/Fail
Reg. 49	Pass

**LFE Traceability**

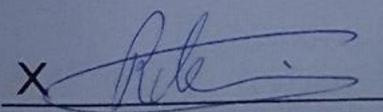
Model	S / N	Calibration Date	Calibration Due Date
EFM_CAL	I11-ECS01	2016-09-08	2016-12-08
LFE Element Z50MC2-4	1343000240	2015-06-17	2016-12-17

This document certifies that the Exhaust Flowmeter listed above meets the linearization verification requirements listed in UN/ECE Regulation No. 49. Linearization testing was performed using procedures specified in UN ECE reg. 49 and EC 582/2011 with flow standards that are traceable to the National Institute of Standards (NIST). The PEMS listed herein is in compliance with UN ECE reg. 49 and EC 582/2011 provided that emissions testing is performed within 360 days from the issue date of this document.

**Certificate Number:** 1378

**Issued by:**  
 Sensors Europe GmbH  
 Feldheiderstrasse 60  
 D-40699 Erkrath  
 Germany

  
 X \_\_\_\_\_  
 Quality Assurance Manager

SEMTECH EFM-HS NIST Traceability Document  
 April 2010 available on request.

Approved by:  
 O Booker 7/2/14

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9337-001E REV A

Figure 34: Example of the technical specification of a typical gas analyser

		<h2>Linearisation Check with Gasdivider</h2>				
<b>Analyzer:</b> SEMTECH-DS	<b>Serial Number:</b> L10-SDS01		<b>Customer:</b> Emissions Analy.	<b>Date:</b> 04.05.2016		
<b>Gas Divider:</b> Horiba SGD-710D	<b>Serial Number:</b> UDHH 9DDD	<b>Next Check:</b> 10-Dec-16	<b>Case Number:</b> Technician: M.Jericho			
<b>Used Gases:</b>						
Bottle:	Gas:	Range:	Bottle:	Unit:	Valid until:	Mix No.:
4 Gas span	CO	5000	5103	ppm	Jun-16	27600503525966
4 Gas span	CO <sub>2</sub>	20	16.00	%	Aug-16	27600503525966
4 Gas span	NO	1500	1460	ppm	Nov-16	27600503525966
4 Gas span	C <sub>3</sub> H <sub>8</sub>	200	200	ppm	Dec-16	27600503525966
NO <sub>2</sub> Monoblend	NO <sub>2</sub>	500	510	ppm	Sep-16	27600503530064
<b>Test Summary:</b>						
Gas	Lin Check Result		Technician Signature:			
THC	Pass					
CO	Pass					
CO <sub>2</sub>	Pass					
NO	Pass					
NO <sub>2</sub>	Pass					

Figure 35: Semtech LTD certificate of compliance

Sensors, Inc.  
6812 State Road  
Saline, MI 48176



**Certificate No.** 3864  
**Issue date:** 12-Jul-17

### SEMTECH LDV CERTIFICATE OF COMPLIANCE

This document certifies that the PEMS listed below meets the audit requirements of RDE 692/2008 as indicated. Testing was performed using procedures specified in RDE with equipment traceable to the National Institute of Standards (NIST). The PEMS listed below is in compliance with UN/ECE regulations provided that emissions testing is performed within 1 year from the test date listed on this document.

**SEMTECH LDV Instrument information:**  
**LDV EFM4 Module S/N:** G17139277  
**Software Version:** 16.07B

692/2008 Subpart	Description	Test date	Due date	Pass/Fail
Appx. 2, 7.2.3	Accuracy of Flowmeter	17-Jul-17	initial installation or major maintenance, 1 year before testing	Pass
Appx. 2, 7.2.4	Precision of Flowmeter	17-Jul-17	initial installation or major maintenance, 1 year before testing	Pass
Appx. 2, 7.2.5	Noise of Flowmeter	17-Jul-17	initial installation or major maintenance, 1 year before testing	Pass
Appx. 2, 7.2.6	Zero response drift of Flowmeter	18-Jul-17	initial installation or major maintenance, 1 year before testing	Pass
Appx. 2, 7.2.7	Span response drift of Flowmeter	18-Jul-17	initial installation or major maintenance, 1 year before testing	Pass
Appx. 2, 7.2.8	Rise time of Flowmeter	17-Jul-17	initial installation or major maintenance, 1 year before testing	Pass
Appx. 2, 7.2.9	Response time check of Flowmeter	17-Jul-17	initial installation or major maintenance, 1 year before testing	Pass
Appx. 2, 8 (Table 4)	Accuracy of thermocouples	12-Jul-17	initial installation or major maintenance, 1 year before testing	Pass
Appx. 2, 8 (Table 4)	Accuracy of ambient pressure	17-Jul-17	initial installation or major maintenance, 1 year before testing	Pass
Appx. 1, 4.1	Leak check of PEMS system	17-Jul-17	initial installation or major maintenance, 1 year before testing	Pass

Technician: Peter S. Balogh

Q.A.: [Signature]

Date: 7-18-17

Date: 7-18-17

Figure 39: Semtech LTD certificate of compliance (continued)



Figure 40: EFM4 linearity and accuracy certificate of compliance



### EFM4 Linearity and Accuracy Certificate of Compliance

Reg. (EC) No 427/2016 Appx. 2 3.2 Flow Tube Linearity

Customer:	<b>Emission Analytics</b>		
Base Serial Number:	A16129209	Humidity [%RH]:	40,1
Tube Serial Number:	A16129209	Temperature [°C]:	25,2
Tube Diameter (m):	0,0348	Air pressure [hPa]:	1009,2
Calibration Date (MM/DD/YYYY):	7.14.2017		
Technician:	Olaf Brüggemann	<i>O. Brüggemann</i>	
		_____ Technician's Signature	
Current Calibration Valid Until:	14.07.2018		
Software Version:	1.043 Hickory		

**Linearity results**

Statistic	Result	Criteria	Pass/Fail
Intercept	-0,07%	+/- 2% max	Pass
Slope	1,00	0.97-1.03	Pass
Standard Error	0,10%	+/- 2% max	Pass
R <sup>2</sup>	1,000	≥ 0.990	Pass

Linearity Specification	Pass/Fail
Reg. 427/2016 Appx. 2, 3.2 Table 1	Pass

**LFE Traceability**

Model	S /N	Calibration Date	Calibration Due Date	Certificate number
EFM_CAL	I11-ECS01	17.06.2017	17.09.2017	1521
LFE Element Z50MC2-2	1009000004	17.06.2015	17.12.2017	00993
LFE Element Z50MC2-4	710870	17.06.2015	17.12.2017	00994
LFE Element Z50MC2-8	1343000240	17.06.2015	17.12.2017	00995

This document certifies that the Exhaust Flowmeter listed above meets the linearization verification requirements listed in Regulation (EC) No 427/2016. Linearization testing was performed using procedures specified in (EC) No 427/2016 and EC 582/2011 with flow standards that are traceable to the National Institute of Standards (NIST). The PEMS listed herein is in compliance with (EC) No 427/2016 and EC 582/2011 provided that emissions testing is performed within 1 year from the issue date of this document.

**Certificate Number: 1541**

**Issued by:**  
 Sensors Europe GmbH  
 Feldheider Str. 60  
 D-40699 Erkrath  
 Germany  
 SEMTECH EFM NIST Traceability Document  
 April 2010 available on request.

Page 1/4

Figure 41: EFM4 linearity and accuracy certificate of compliance (continued)

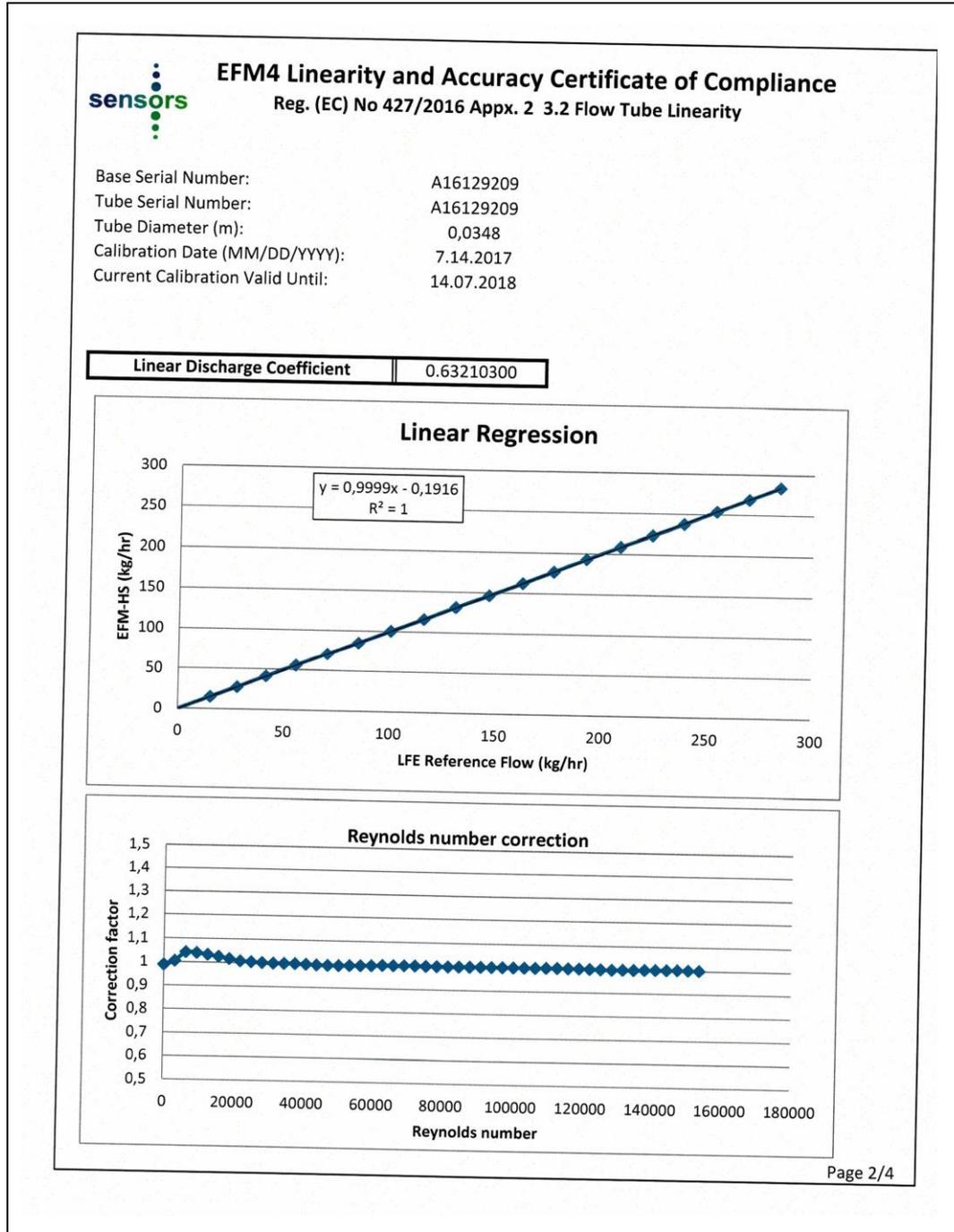


Figure 42: EFM4 linearity and accuracy certificate of compliance (continued 2)

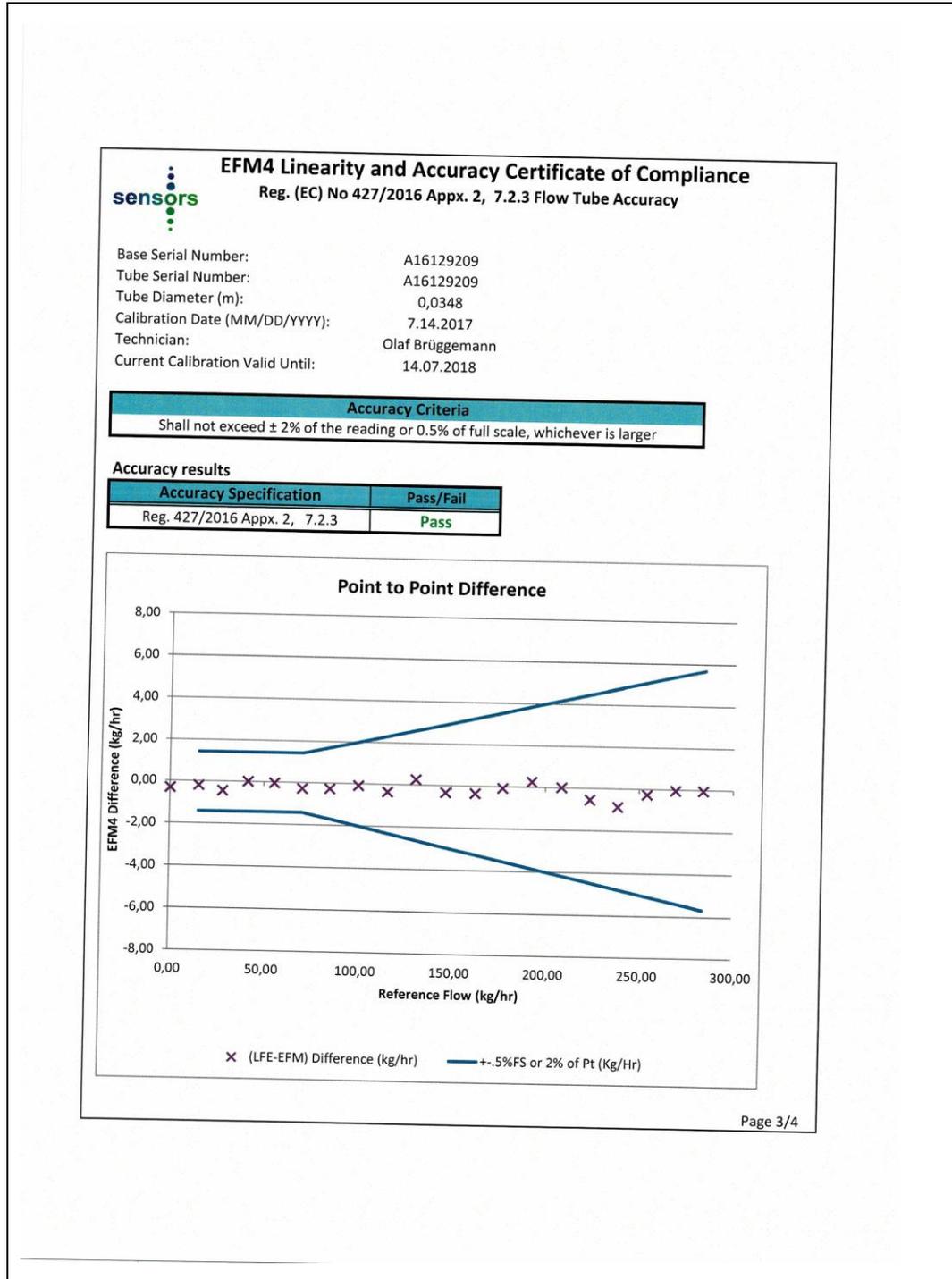


Figure 43: EFM4 linearity and accuracy certificate of compliance (continued 3)

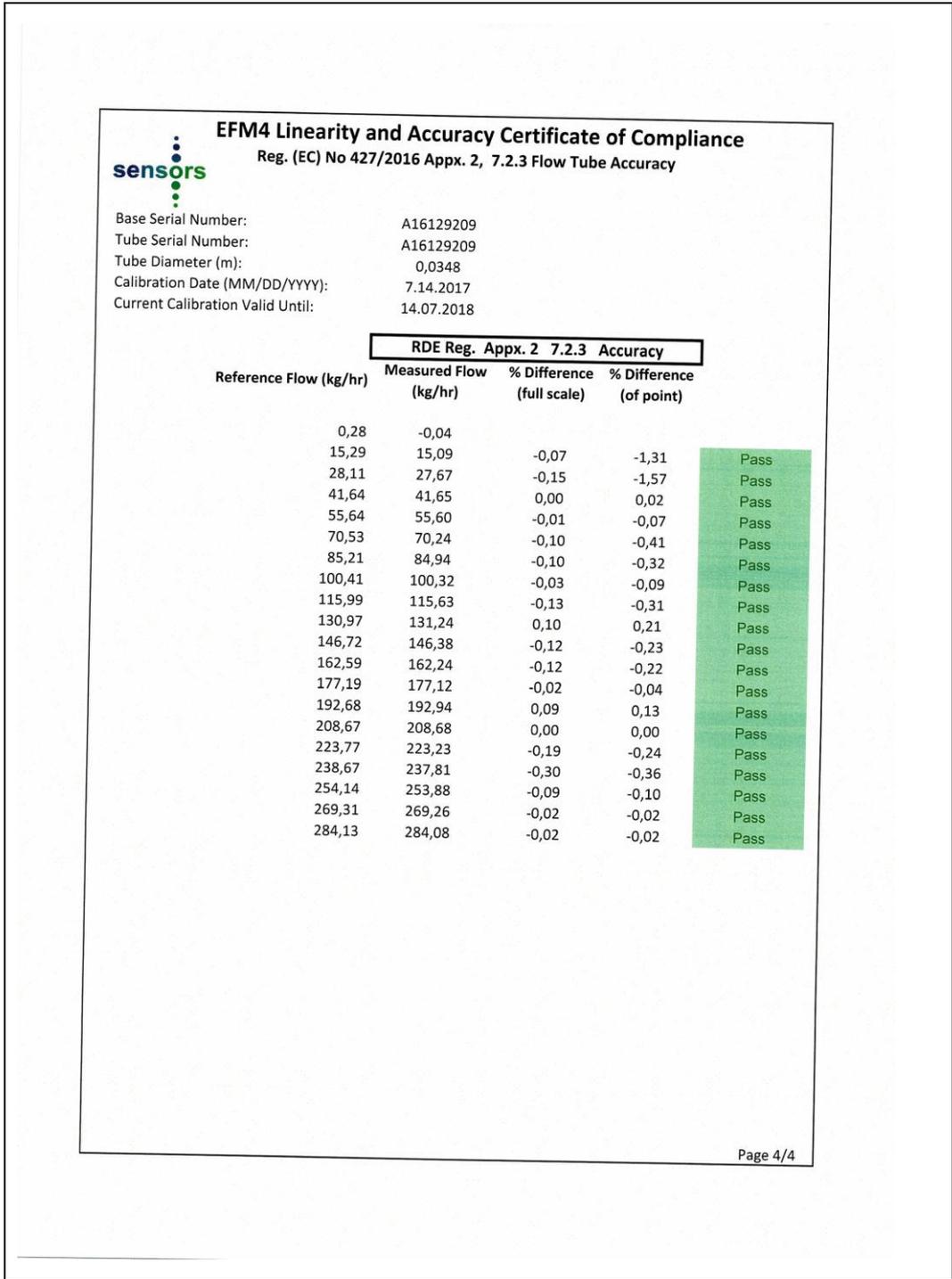


Figure 44: Semtech LTD certificate of compliance

Sensors, Inc.  
6812 State Road  
Saline, MI 48176



Certificate No. 3438  
Issue date: 10-Feb-17

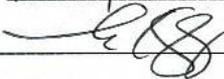
### SEMTECH LDV CERTIFICATE OF COMPLIANCE

This document certifies that the PEMS listed below meets the audit requirements of CFR40 Part 1065 as indicated. Testing was performed using procedures specified in CFR40 Part 1065 with equipment traceable to the National Institute of Standards (NIST). Some of these audits may need to be repeated as indicated or if major maintenance is performed to this PEMS system.

**SEMTECH LDV Instrument information:**  
**LDV SCS Module S/N:** C16130963  
**Software Version:** 16.07A

1065 Subpart	Description	Test date	Due date	Pass/Fail
307	Linearity of internal RH sensor	10-Feb-17	initial installation or major maintenance, within 370 days before testing	Pass
307	Linearity of internal barometric pressure sensor	10-Feb-17	initial installation or major maintenance, within 370 days before testing	Pass
376	Chiller NO <sub>2</sub> penetration	2-Feb-17	initial installation or major maintenance	Pass

Technician: A. McKay

Q.A.: 

Date: 2-10-17

Date: 2-10-17

Page 1 of 2

Figure 45: Semtech LTD certificate of compliance (continued)

Sensors, Inc.  
6812 State Road  
Saline, MI 48176



**Certificate No.** 3438  
**Issue date:** 10-Feb-17

### SEMTECH LDV CERTIFICATE OF COMPLIANCE

**SEMTECH LDV Instrument information:**

**LDV SCS Module S/N:** C16130963  
**Software Version:** 16.07A

**Traceability of Gas Standards**

Gas Bottle Description	Supplier	Cylinder #	Stated Accuracy	Expiration Date
504 ppm NO <sub>2</sub> , balance Air	Airgas	CC418768	±1%	22-Aug-19

**Equipment Traceability**

Model	S/N	Calibration Date	Calibration Due Date	Certificate Number
Digitron 2082P	DPM-004	17-Jul-15	17-Jul-16	318618001
Horiba SGD-710C	GDU-001	17-Nov-16	17-Nov-17	G0000YFR
Vaisala HMP 155	L4540035	18-Feb-16	18-Feb-17	2444

Figure 46: Semtech LTD linearity certificate

Sensors, Inc.  
6812 State Road  
Saline, MI 48176



Certificate No. 992  
Test date: 24-Jan-17

### SEMTECH LDV LINEARITY CERTIFICATE

This document certifies that the PEMS listed below meets the linearization requirements listed in Table 1 of CFR40 Part 1065.307. Linearization testing was performed using procedures specified in CFR40 Part 1065.307 with gas standards traceable to the National Institute of Standards (NIST). The PEMS listed below is in compliance with EPA regulations provided that emissions testing is performed within 35 days from the test date listed on this document.

**SEMTECH LDV Instrument information:**  
**LDV GAS Module S/N:** D16131430  
**NDUV Analyzer S/N:** J15127418  
**Software Version:** 16.07A

**Table 1 CFR40 Part 1065.307 Linearity Regulation Acceptance Criteria:**

1065.307	Intercept	Slope a1	SEE	R <sup>2</sup>
Gas Analyzers	≤1.0% max	0.99 ≤ slope ≤ 1.01	≤1% max	≥ 0.998

**Traceability of Gas Standards**

Gas Bottle Description	Supplier	Cylinder #	Analytical Accuracy	Expiration Date
12.04% CO <sub>2</sub> , 1188 ppm CO, 1496 ppm NO, 326.8 ppm Propane, balance N <sub>2</sub>	AIRGAS	CC23929	±1%	30-Aug-24
504 ppm NO <sub>2</sub> , balance Air	Airgas	CC418768	±1%	22-Aug-19

**Gas Divider Traceability**

Model:	S/N	Calibration Date	Calibration Due date:	Certificate number:
Horiba SGD-710C	GDU-001	17-Nov-16	17-Nov-17	G0000YFR

Technician: A. McKay

Q.A.: [Signature]

Date: 2-10-17

Date: 2-10-17

Figure 47: Semtech LTD linearity certificate (continued)

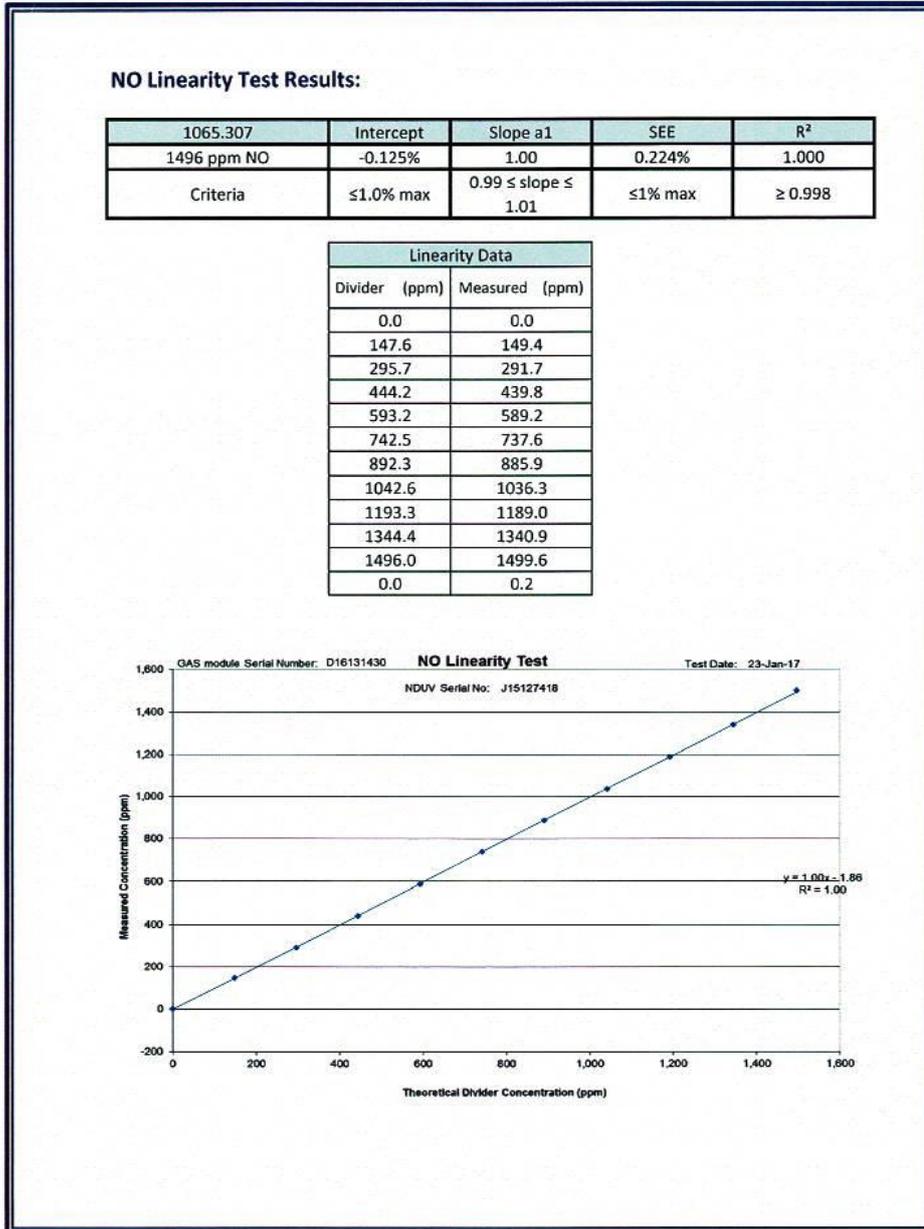
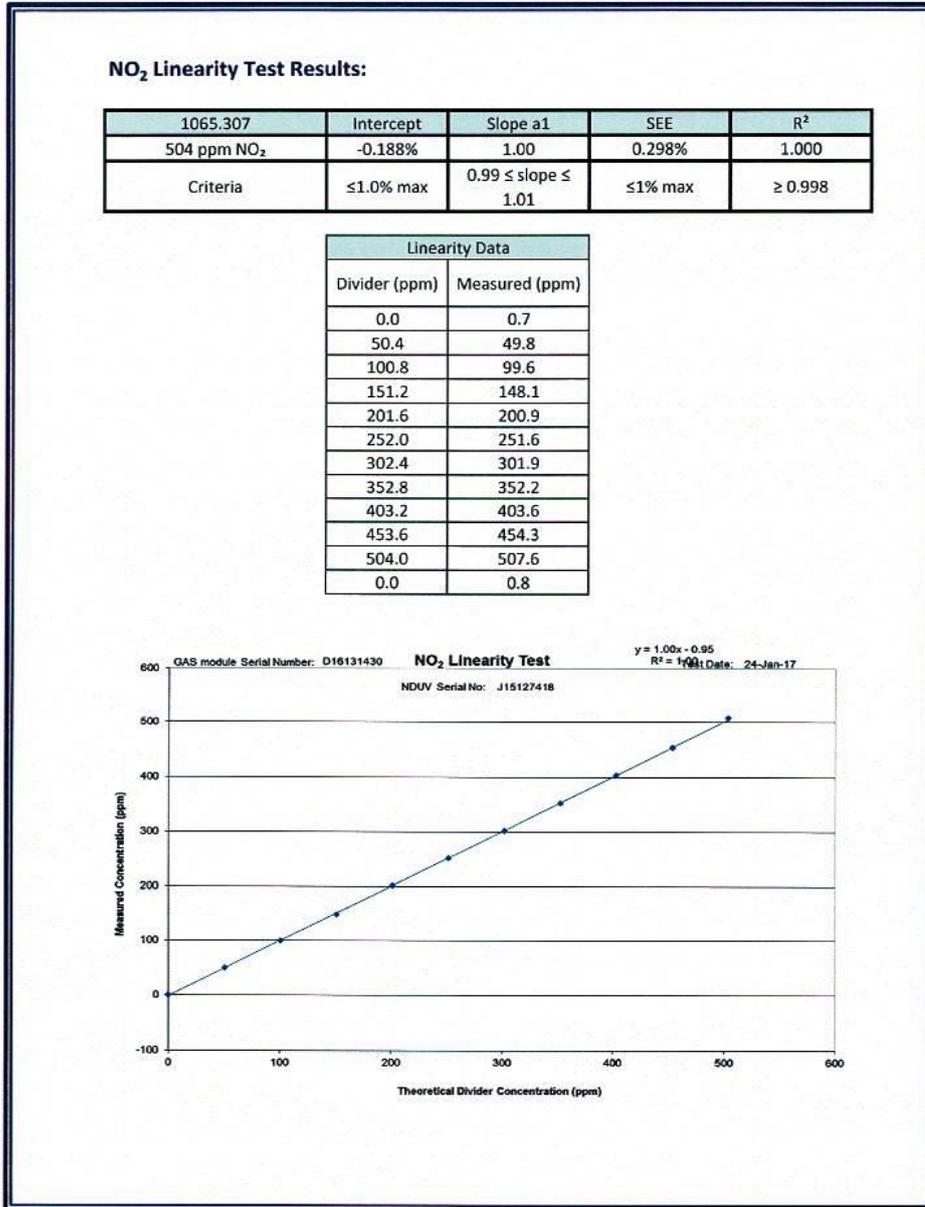


Figure 48: Semtech LTD linearity certificate (continued 2)



## Appendix C

### Photographs

# C1 Test Vehicles

Figure 53: A selection of the test vehicles (cars) with the equipment installed



Figure 54: A selection of the test vehicles (vans and cars) with the equipment installed



## C2 On Location

Figure 55: The equipment inside the vehicle



Figure 56: Refuelling



Figure 57: Setting up the test equipment

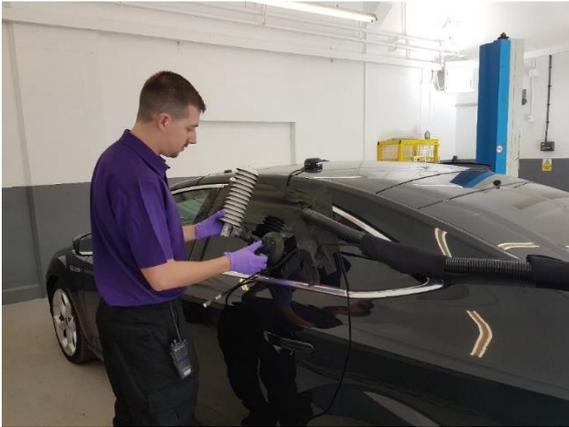


Figure 58: Calibration

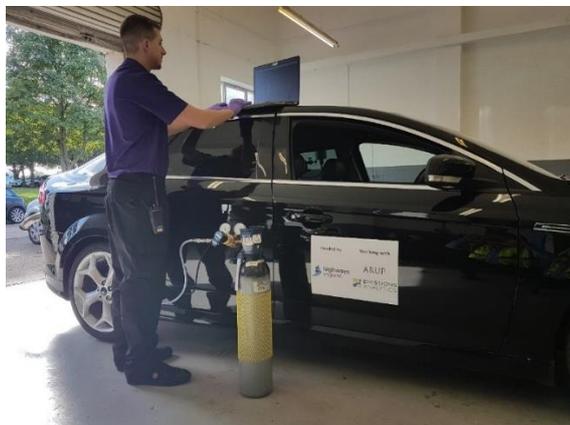
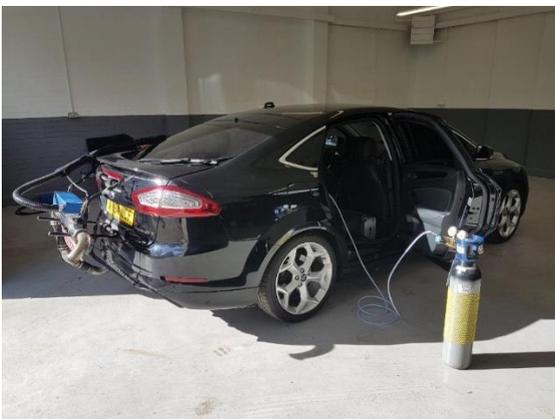


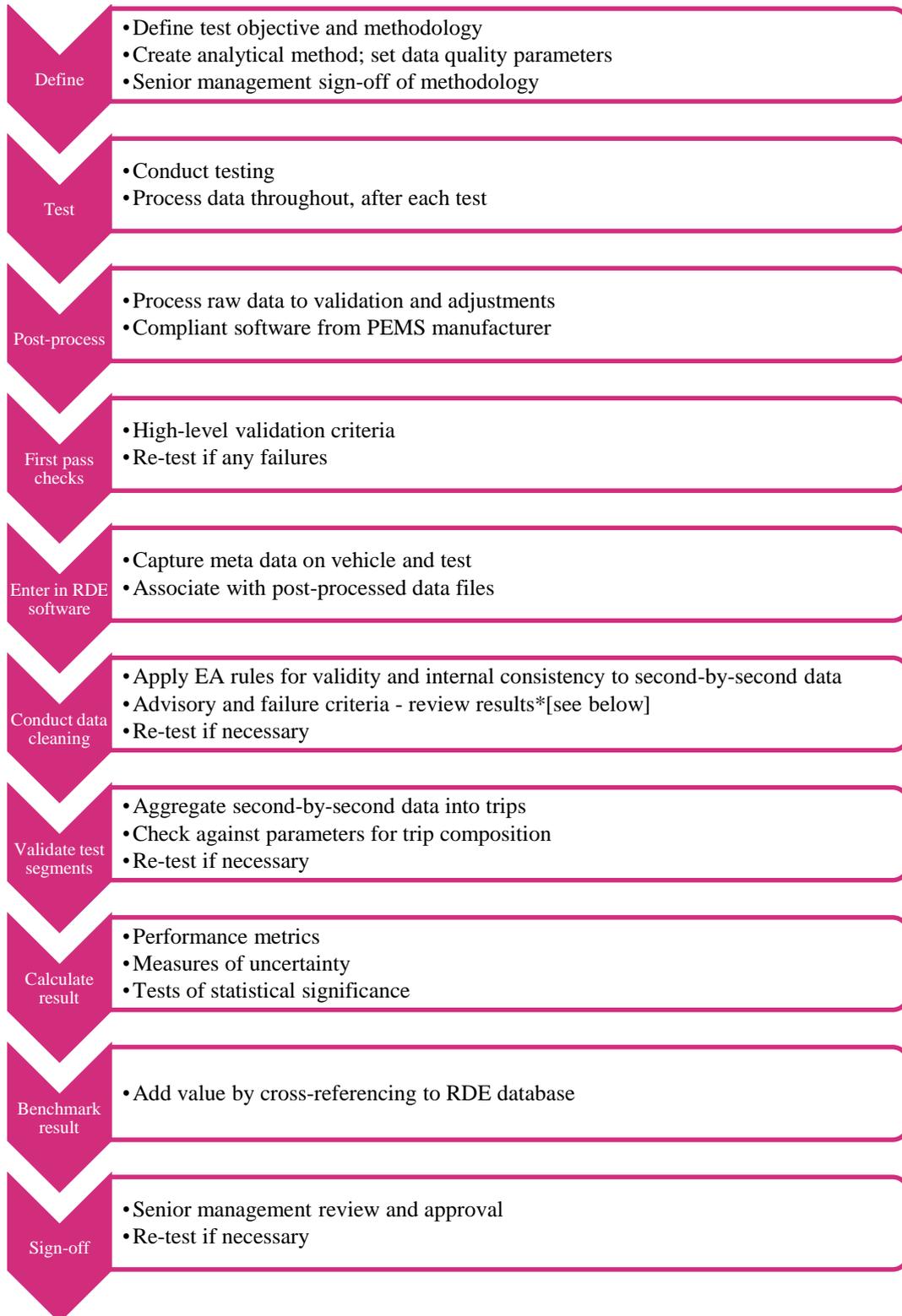
Figure 59: On the proving ground



## Appendix D

### Data Management Process

Figure 49: Schematic of the testing and data management



The following quality control will be performed immediately after each test and before delivery of the data:

- Post-processing of data using software from Sensors Inc, which performs multiple processes including wet-correction of NO<sub>x</sub> data;
- Checking of engine coolant temperature to verify vehicle was operating fully warmed up;
- Checking of exhaust temperature to identify any evidence for diesel particulate filter (DPF) regeneration, if applicable;
- Plotting the time-series graphs of each of the emissions, against speed – by a process of inspection any anomalies such as time alignment or drop-outs can be identified; and
- Analysing the variance between the cycles for evidence of repeatability.

If the data is deemed unsatisfactory, then the affected part(s) of the test will be re-run. Emissions Analytics uses a proprietary online tool to manage the workflow and signoffs. Some example screenshots can be seen in Figure to Figure .

Figure 50: Screenshot from the workflow and sign-off software (1)

The screenshot displays the Emissions Analytics web application interface. The header includes the logo and navigation links (Home, Vehicles, Analysis, Admin) along with user information (Hello Nick Molden, Log out). The main content area shows the test details for a 2015 Volkswagen Transporter T30SE TDI 9-Seat Shuttle, with ID 656371. The test status is 'Accepted' with a 'Revert to Pending' button. A 'Fuel Economy Normalisation' section is visible with sub-links for 'Checking', 'Segments', and 'Results'. Below this are action buttons for 'Edit', 'Files', 'Duplicate', 'Cleaning Results', and 'Map and Speed Trace'. A table provides test metadata:

Location	Test Date	Test Equipment	Mapping ID	Custom Test	Client Name
United Kingdom	2017-01-17	DS, Pegasor m2		No	

Below the table, there are tabs for 'Vehicle Attributes', 'Tyres', 'Test Attributes', and 'Equipment Attributes'. The 'Vehicle Attributes' tab is active, showing a grid of vehicle specifications:

Model Year	Regulatory Stage	Vehicle Identification Number (VIN)	Vehicle Registration Mark (VRM)
2015	Euro 5	WVZZZ7HZFH132939	LG15 ULE
Vehicle Class	Vehicle Segment	Make	Model
Light Commercial	Passenger Van	Volkswagen	Transporter
Derivative	Driven Wheels	Drive Train	Power
T30SE TDI 9-Seat Shuttle	2	FWD	140 bhp
Engine Size	Battery Size	Fuel Type	Body Style
1968 cc		Diesel	Passenger Van
Doors	Transmission	Gears	Engine Location
5	Automatic	7	Front
Official Urban/City FE	Official Extra-urban/Highway FE	Official Combined FE	Official Kerb Weight
27.7 MPG (UK)	42.2 MPG (UK)	35.3 MPG (UK)	2237 kg

At the bottom of the vehicle attributes section, there is a note: 'NOx Control Technology'.

Figure 51: Screenshot from the workflow and sign-off software (2)

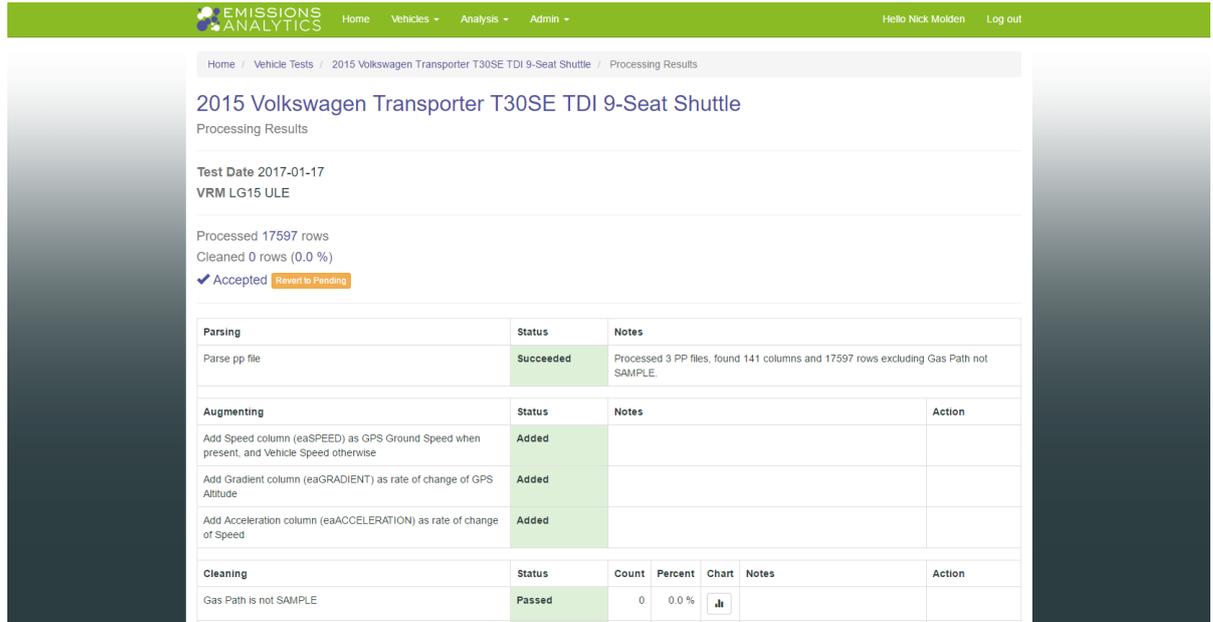
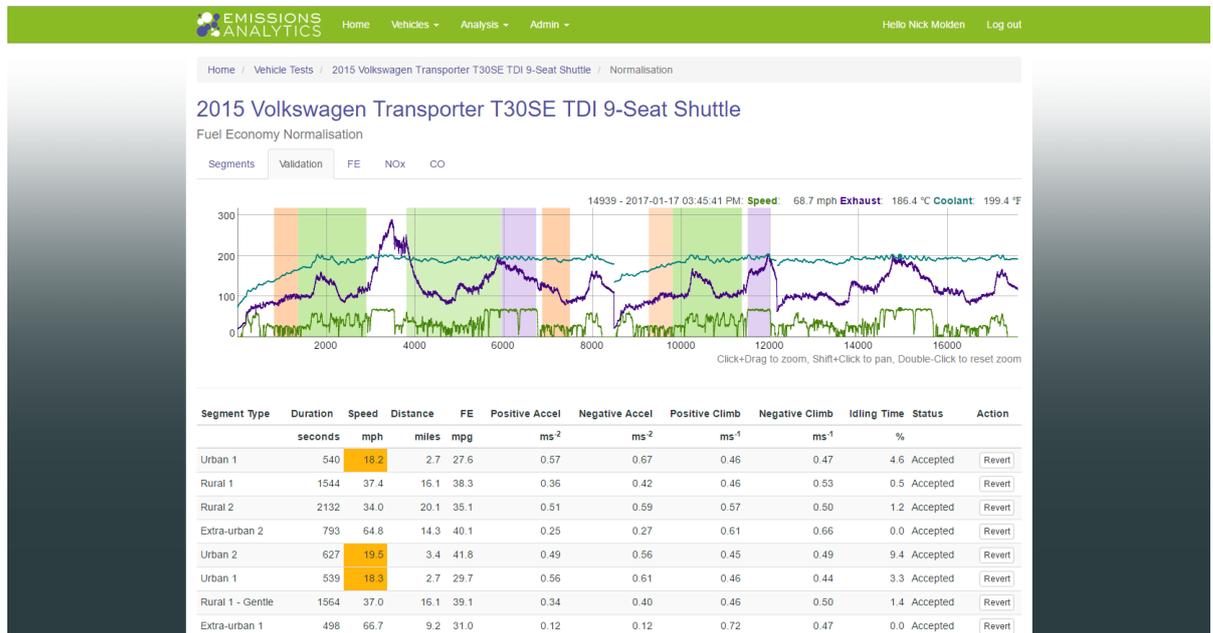


Figure 52: Screenshot from the workflow and sign-off software (3)



## Appendix E

### ABBA Test Results

Table 20: A1 vs A2 CO<sub>2</sub> emissions (g/km)

Model	A1				A2				Statistical Significance (A1 vs A2) (%)				Limit
	U	R	M	C	U	R	M	C	U	R	M	C	Values
<b>Focus Zetec/ Euro 5</b>	236.4	150.9	176.0	187.8	227.1	147.6	175.8	183.5	85.4	28.1	5.5	-	-
<b>Cooper S/ Euro 5</b>	214.5	127.8	149.7	164.0	210.3	131.4	147.0	162.9	87.4	63.0	67.9	-	-
<b>Astra Design/ Euro 5</b>	246.2	158.5	173.8	192.8	207.0	147.8	160.4	171.8	97.9	89.1	98.2	-	-
<b>Polo/ Euro 5</b>	159.2	125.3	141.7	142.1	158.8	128.1	148.0	145.0	13.1	74.8	94.9	-	-
<b>Qashqai Acenta Premium/Euro 5</b>	180.9	139.4	157.6	159.3	175.6	131.9	165.2	157.6	36.6	82.4	91.4	-	-
<b>308 Active/ Euro 5</b>	144.4	114.9	138.6	132.6	141.8	117.4	135.8	131.7	55.3	28.5	58.9	-	-
<b>Mondeo Titanium X Sport/ Euro 5</b>	193.6	153.5	188.6	178.6	191.2	150.5	172.1	171.3	32.9	27.9	91.8	-	-
<b>Passat GT Tech Estate/ Euro 5</b>	229.9	180.6	191.2	200.6	215.3	168.0	188.3	190.5	99.1	94.1	57.7	-	-
<b>Qashqai N-Connect/ Euro 6</b>	179.9	144.7	167.9	164.2	170.5	147.7	160.5	159.5	96.7	32.1	69.4	-	-
<b>Focus ST-Line/ Euro 6</b>	186.3	148.3	153.9	162.8	186.6	146.8	152.6	162.0	3.8	11.5	14.4	-	-
<b>Vivaro 2900 SWB/ Euro 4</b>	273.0	197.5	227.2	232.6	271.3	199.2	222.9	231.1	41.1	21.3	30.6	-	-
<b>Crafter CR35 MWBHigh Roof/E4</b>	377.3	253.2	311.2	313.9	381.2	247.0	297.5	308.6	37.4	76.8	62.6	-	-
<b>Berlingo Enterprise/ Euro 4</b>	207.4	155.8	188.5	183.9	198.7	138.9	178.3	172.0	81.0	92.7	89.7	-	-
<b>Transit 350EFLWBChassisCab/ E4</b>	265.4	295.1	372.0	310.9	*	273.6	353.0	*	0.0	33.2	91.1	-	-
<b>Transit Connect Trend/ Euro 5</b>	259.3	172.0	186.7	206.0	265.3	181.6	193.6	213.5	79.5	53.3	69.8	-	-
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	321.8	247.4	320.2	296.5	316.2	254.7	324.0	298.3	71.3	43.9	64.1	-	-
<b>Transit 280/ Euro 5</b>	262.2	203.6	218.4	228.0	246.3	205.4	231.9	227.9	98.1	12.9	95.9	-	-
<b>Partner 850 Professional/ Euro 5</b>	177.4	137.1	173.4	162.6	179.6	135.0	170.7	161.7	53.0	28.4	69.3	-	-
<b>Traffic SL27 Business + / Euro 5</b>	247.7	176.9	196.5	207.0	229.6	173.6	197.1	200.1	98.6	25.1	13.3	-	-
<b>Partner Professional 850/ Euro 6</b>	208.8	146.5	175.2	176.9	217.5	149.1	170.8	179.1	92.9	28.4	82.1	-	-
<b>Crafter CR35 Startline/ Euro 6</b>	273.0	254.4	269.2	265.5	271.4	240.6	258.4	256.8	14.8	85.6	77.3	-	-
<b>Transit 350 Luton L4/ Euro 6</b>	286.3	268.2	332.8	295.8	296.2	268.5	329.5	298.1	81.3	0.8	24.4	-	-

\*No data. All the A2 results were rejected during the data analysis phase as they failed QA. As there were sufficient A1 results, it was possible to calculate an overall result.

Table 21: B1 vs B2 CO<sub>2</sub> emissions (g/km)

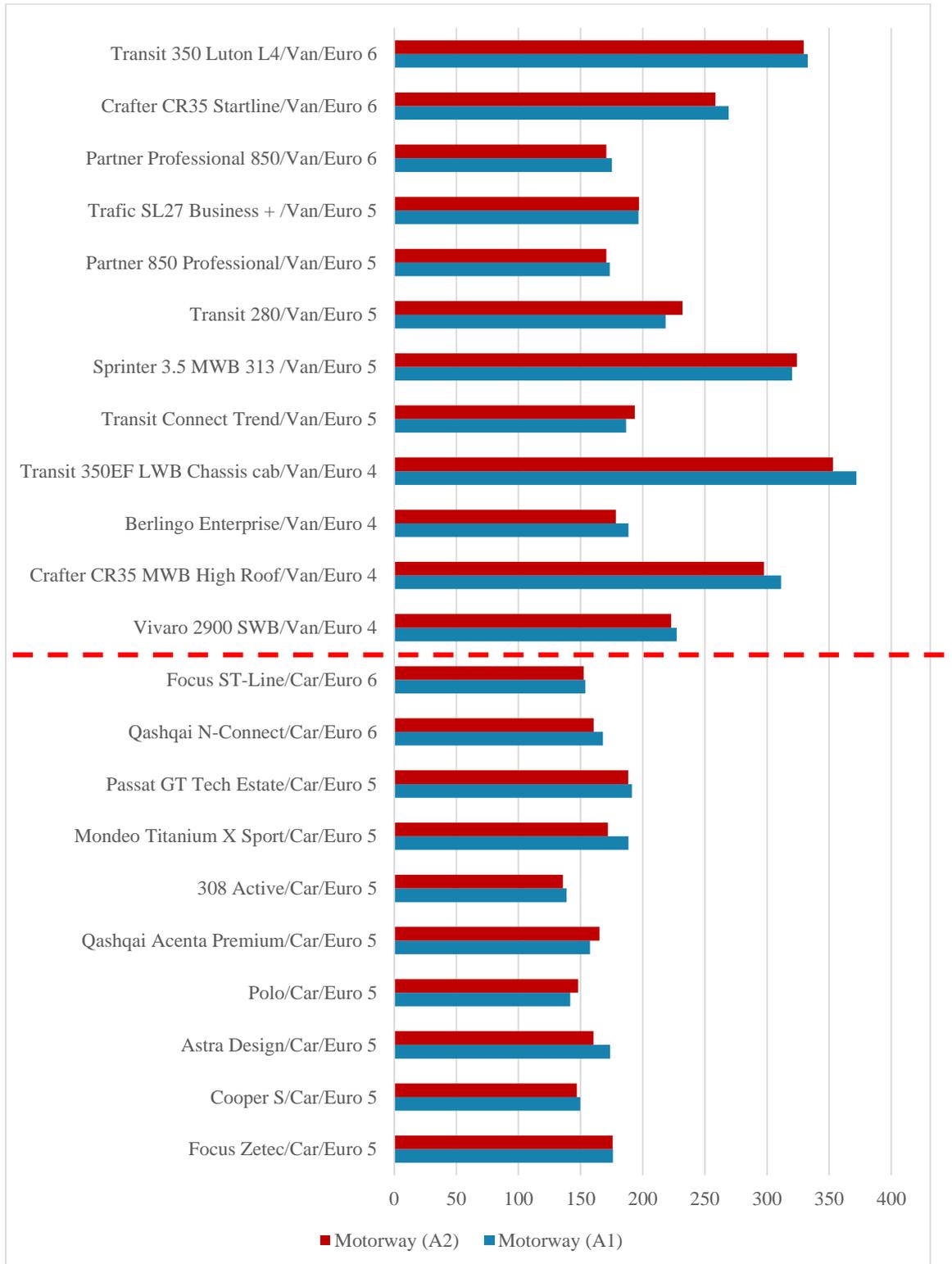
Model	B1				B2				Statistical Significance (B1 vs B2) (%)				Limit Values
	U	R	M	C	U	R	M	C	U	R	M	C	
<b>Focus Zetec/ Euro 5</b>	218.1	144.1	172.3	178.2	237.8	135.4	170.4	181.2	99.0	88.0	66.5	-	-
<b>Cooper S/ Euro 5</b>	189.8	128.0	147.7	155.2	194.2	120.7	139.9	151.6	78.6	92.6	94.9	-	-
<b>Astra Design/ Euro 5</b>	203.7	145.5	162.4	170.6	220.1	147.5	166.6	178.1	84.6	22.5	77.6	-	-
<b>Polo/ Euro 5</b>	148.1	116.7	137.2	134.0	155.4	121.1	140.6	139.0	93.1	56.3	81.8	-	-
<b>Qashqai Acenta Premium/Euro 5</b>	171.7	130.9	145.7	149.4	169.9	130.8	155.2	152.0	44.2	1.3	93.6	-	-
<b>308 Active/ Euro 5</b>	143.5	115.1	138.5	132.4	140.6	113.1	129.9	127.8	93.0	28.7	92.0	-	-
<b>Mondeo Titanium X Sport/ Euro 5</b>	185.7	141.1	172.1	166.3	184.4	138.5	166.8	163.2	19.2	50.0	81.1	-	-
<b>Passat GT Tech Estate/ Euro 5</b>	225.8	170.1	177.6	191.2	222.1	160.3	183.3	188.6	62.3	78.6	96.6	-	-
<b>Qashqai N-Connect/ Euro 6</b>	174.2	136.1	161.4	157.2	166.2	139.0	157.8	154.4	94.8	32.9	44.7	-	-
<b>Focus ST-Line/ Euro 6</b>	181.1	149.0	150.1	160.1	184.4	149.6	150.4	161.5	55.2	8.0	4.8	-	-
<b>Vivaro 2900 SWB/ Euro 4</b>	251.7	185.6	214.8	217.4	259.6	190.8	216.5	222.3	86.4	44.2	19.5	-	-
<b>Crafter CR35 MWBHigh Roof/E4</b>	374.3	232.2	294.4	300.3	371.9	231.4	283.0	295.4	44.5	9.9	99.0	-	-
<b>Berlingo Enterprise/ Euro 4</b>	191.4	144.0	189.1	174.8	191.4	135.3	177.2	168.0	0.5	72.6	99.2	-	-
<b>Transit 350EFLWBChassisCab/ E4</b>	246.1	267.8	347.1	287.0	269.1	260.4	345.9	291.8	94.8	36.2	14.1	-	-
<b>Transit Connect Trend/ Euro 5</b>	250.1	174.7	179.1	201.3	253.3	173.0	184.5	203.6	62.2	15.5	69.5	-	-
<b>Sprinter 3.5 MWB 313 / Euro 5</b>	317.2	226.8	288.4	277.5	310.8	228.8	297.2	279.0	78.8	18.3	81.7	-	-
<b>Transit 280/ Euro 5</b>	252.6	193.2	210.3	218.7	242.4	194.6	201.8	212.9	71.8	14.2	85.0	-	-
<b>Partner 850 Professional/ Euro 5</b>	165.0	125.5	169.8	153.4	163.1	128.1	172.0	154.4	56.7	45.8	41.6	-	-
<b>Traffic SL27 Business + / Euro 5</b>	230.6	176.4	192.0	199.7	244.2	183.1	193.3	206.9	94.6	92.3	37.7	-	-
<b>Partner Professional 850/ Euro 6</b>	212.7	141.2	169.9	174.6	208.2	143.4	168.8	173.5	87.9	46.2	39.7	-	-
<b>Crafter CR35 Startline/ Euro 6</b>	253.7	249.7	245.3	249.6	267.7	244.5	267.3	259.8	95.4	26.1	97.6	-	-
<b>Transit 350 Luton L4/ Euro 6</b>	275.9	252.1	314.3	280.8	289.4	264.4	342.2	298.7	90.3	85.0	98.8	-	-

Figure 32: A1 vs A2 CO<sub>2</sub> emissions (Urban) (g/km)



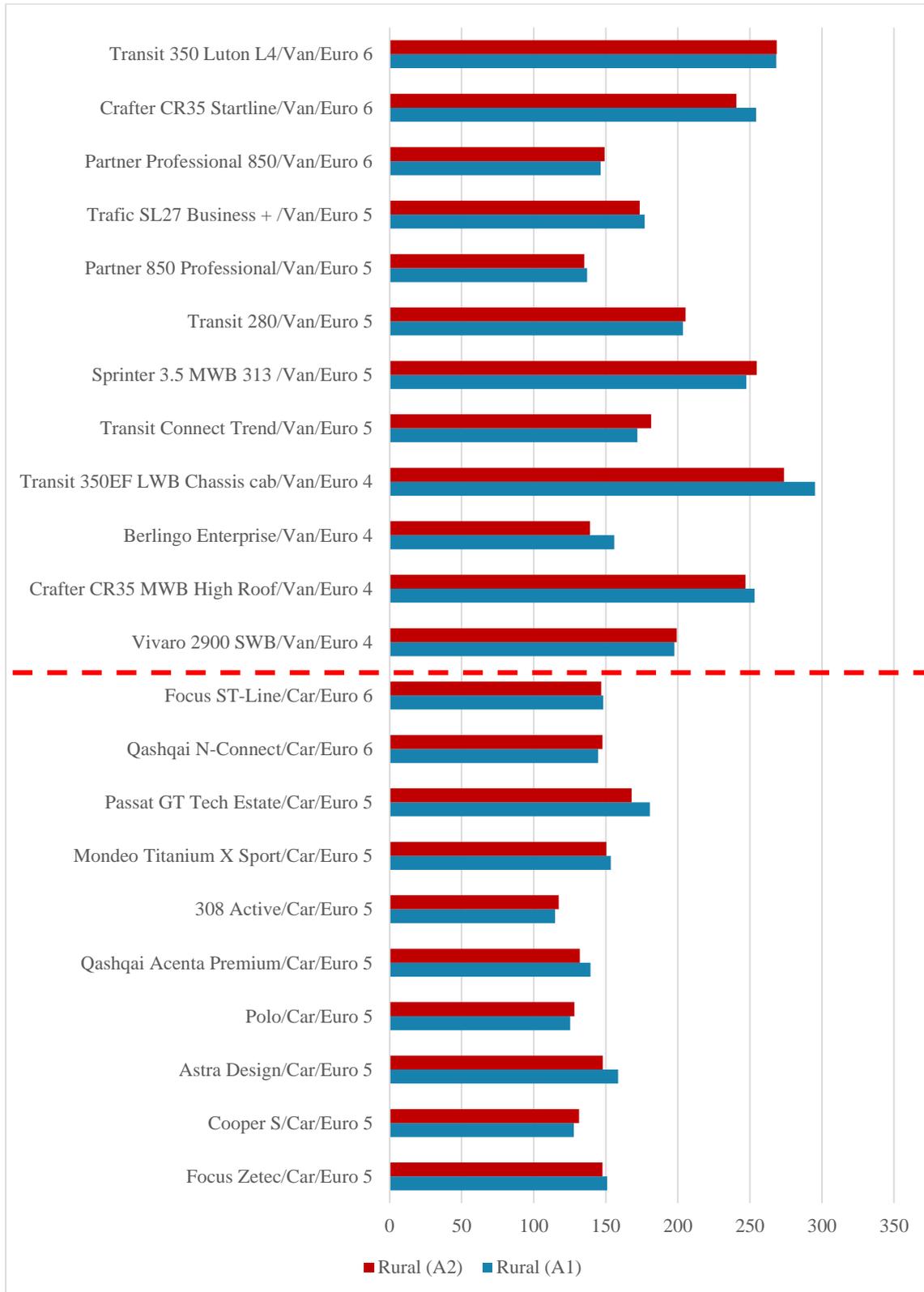
Note: Cars below the red dashed line, vans are above the line

Figure 33: A1 vs A2 CO<sub>2</sub> emissions (Motorway) (g/km)



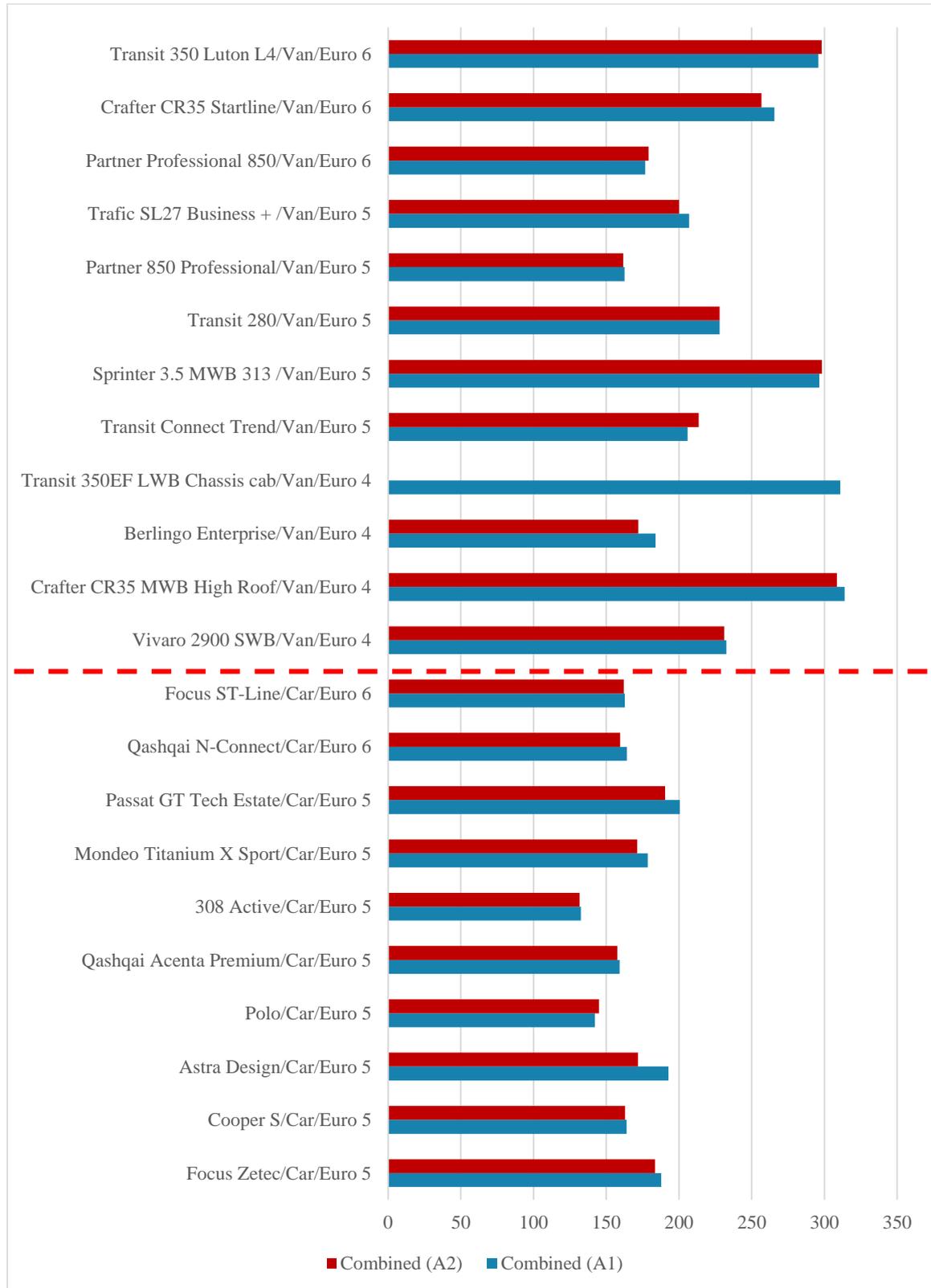
Note: Cars below the red dashed line, vans are above the line

Figure 34: A1 vs A2 CO<sub>2</sub> emissions (Rural) (g/km)



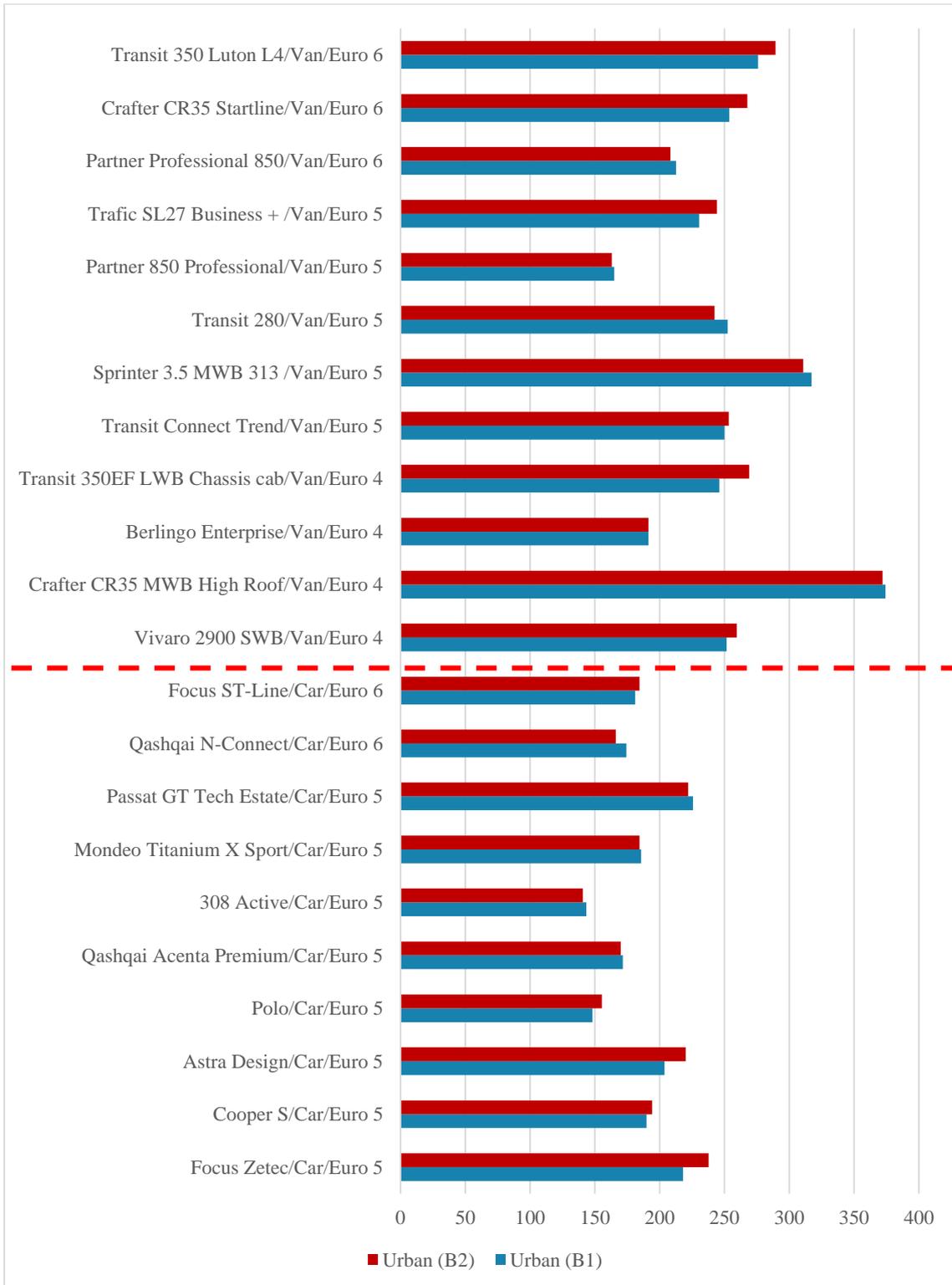
Note: Cars below the red dashed line, vans are above the line

Figure 35: A1 vs A2 CO<sub>2</sub> emissions (Combined) (g/km)



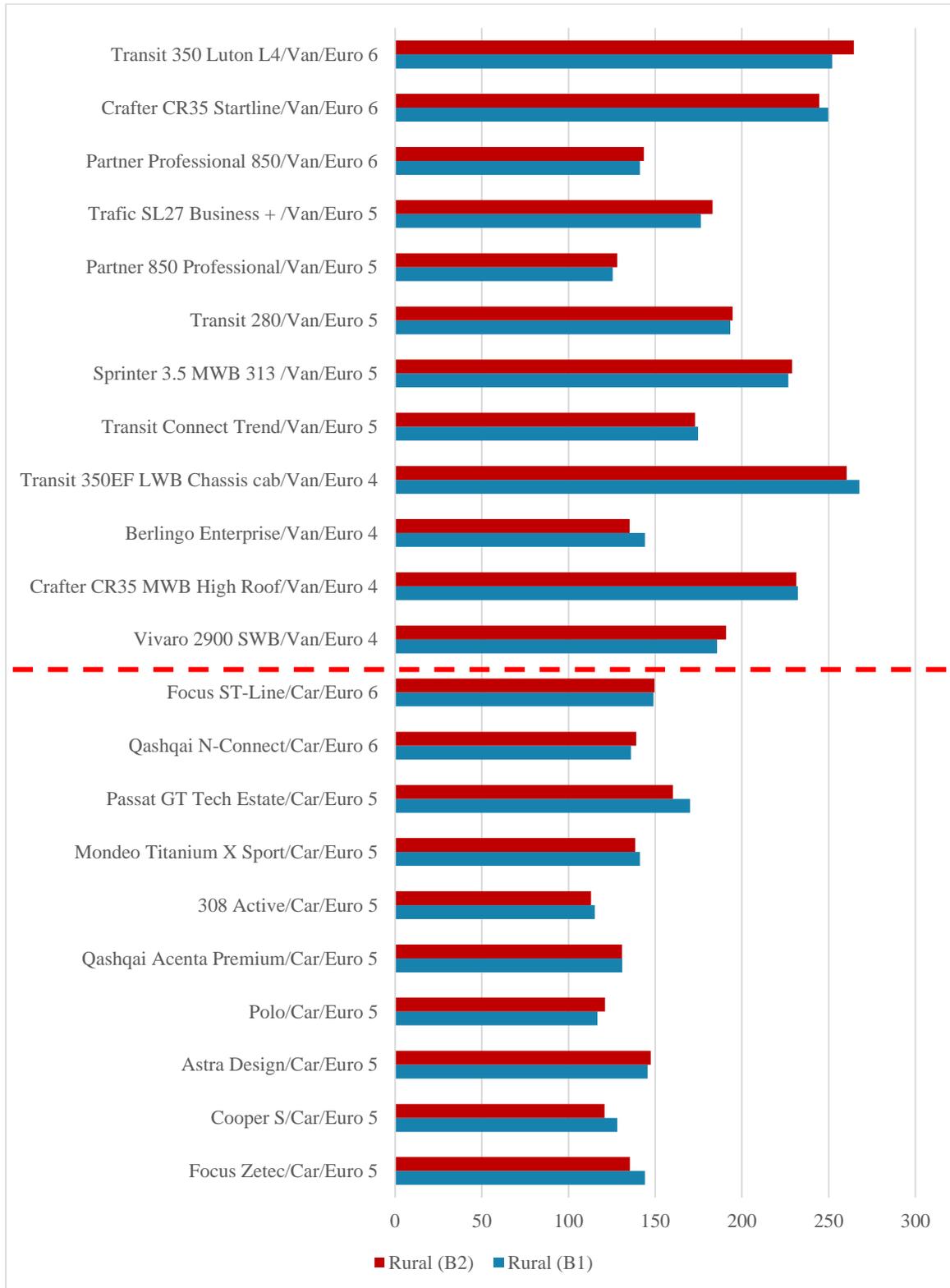
Note: Cars below the red dashed line, vans are above the line

Figure 36: B1 vs B2 CO<sub>2</sub> emissions (Urban) (g/km)



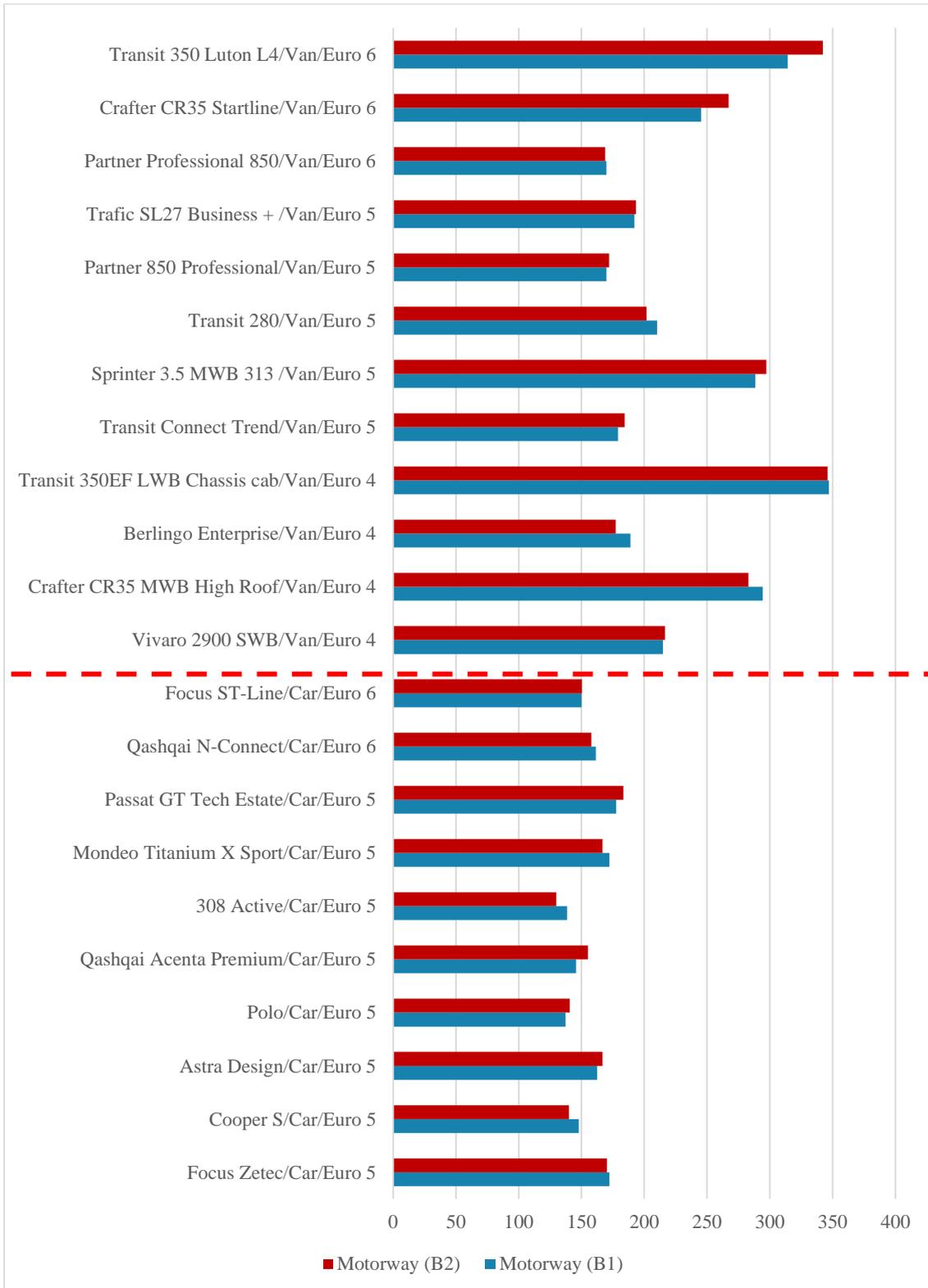
Note: Cars below the red dashed line, vans are above the line

Figure 37: B1 vs B2 CO<sub>2</sub> emissions (Rural) (g/km)



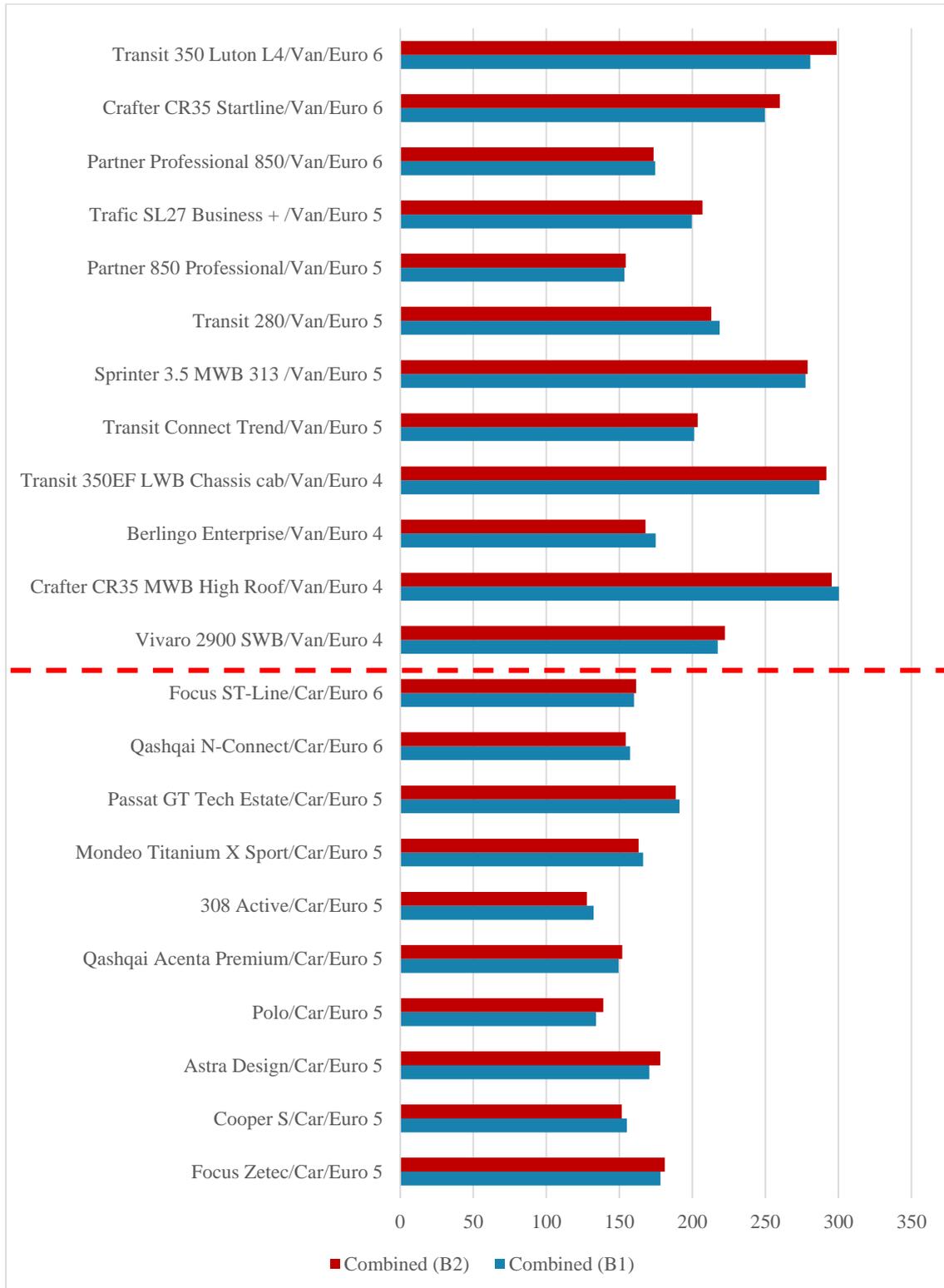
Note: Cars below the red dashed line, vans are above the line

Figure 38: B1 vs B2 CO<sub>2</sub> emissions (Motorway) (g/km)



Note: Cars below the red dashed line, vans are above the line

Figure 39: B1 vs B2 CO<sub>2</sub> emissions (Combined) (g/km)



Note: Cars below the red dashed line, vans are above the line

## Appendix F

### Comparison Against Emissions Analytics Database

Table 22: A vs EA CO<sub>2</sub> emissions (Urban, Rural and Combined) (g/km)

Model	A (diesel)			Emissions Analytics database (EA)			Difference, Combined (C) (A-EA)/A (%)
	U	M	C	U	M	C	
<b>Cooper S/ Car / Euro 5</b>	212.2	148.3	163.4	165.9	122.2	144.3	12%
<b>Astra Design/ Car / Euro 5</b>	228.1	168.1	183.1	175.7	140.4	157.8	14%
<b>Polo/ Car / Euro 5</b>	159.1	145.5	143.7	151.7	121.4	136.7	5%
<b>Qashqai Acenta Premium/ Car / Euro 5</b>	178.4	161.1	158.4	156.2	142.0	149.1	6%
<b>308 Active/ Car / Euro 5</b>	143.1	137.2	132.1	151.3	121.5	136.3	-3%
<b>Mondeo Titanium X Sport/ Car / Euro 5</b>	192.4	180.3	174.9	187.1	155.2	171.0	2%
<b>Passat GT Tech Estate/Car / Euro 5</b>	222.1	189.8	195.4	175.8	142.4	159.2	19%
<b>Qashqai N-Connect/ Car / Euro 6</b>	175.2	164.2	161.9	159.7	141.7	150.7	7%
<b>Focus ST-Line/ Car / Euro 6</b>	186.3	153.6	162.5	146.2	129.1	137.5	15%
<b>Transit Connect Trend/ Van / Euro 5</b>	262.3	189.9	209.6	194.1	179.3	186.7	11%
<b>Traffic SL27 Business + / Van / Euro 5</b>	238.7	196.8	203.7	200.3	181.6	191.1	6%

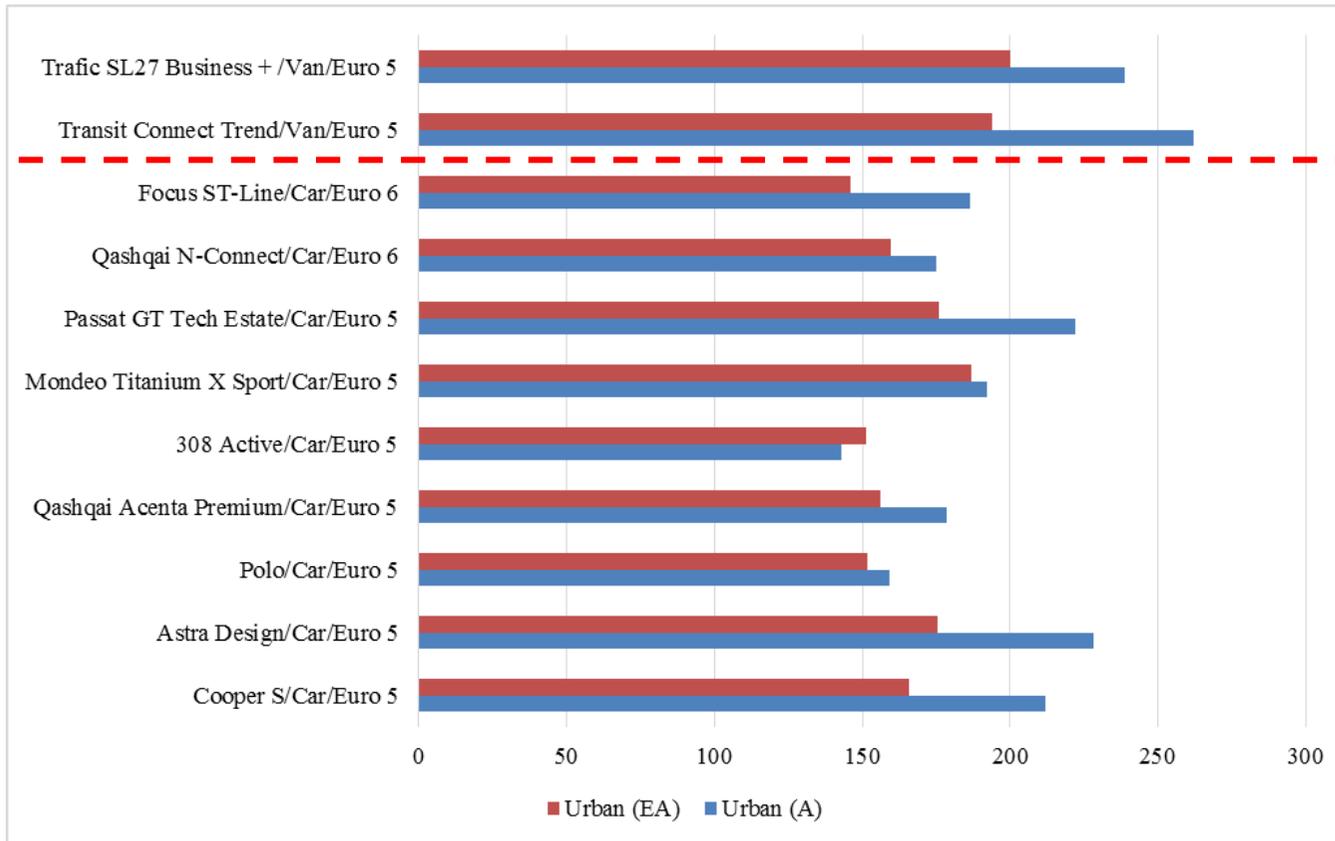
Table 23: A vs EA CO emissions (Combined) (g/km)

Model	A (diesel)	Emissions Analytics database (EA)	Difference (A-EA)/A (%)
<b>Cooper S/ Car / Euro 5</b>	0.019	0.188	-889
<b>Astra Design/ Car / Euro 5</b>	0.156	0.188	-21
<b>Polo/ Car / Euro 5</b>	0.025	0.063	-152
<b>Qashqai Acenta Premium/ Car / Euro 5</b>	0.454	0.188	59
<b>308 Active/ Car / Euro 5</b>	0.045	0.188	-318
<b>Mondeo Titanium X Sport/ Car / Euro 5</b>	0.051	0.188	-269
<b>Passat GT Tech Estate/Car / Euro 5</b>	0.069	0.188	-172
<b>Qashqai N-Connect/ Car / Euro 6</b>	0.239	0.188	21
<b>Focus ST-Line/ Car / Euro 6</b>	0.098	0.063	36
<b>Transit Connect Trend/ Van / Euro 5</b>	0.309	0.188	39
<b>Traffic SL27 Business + / Van / Euro 5</b>	0.213	0.188	12

Table 24: A vs EA NO<sub>x</sub> emissions (Combined) (g/km)

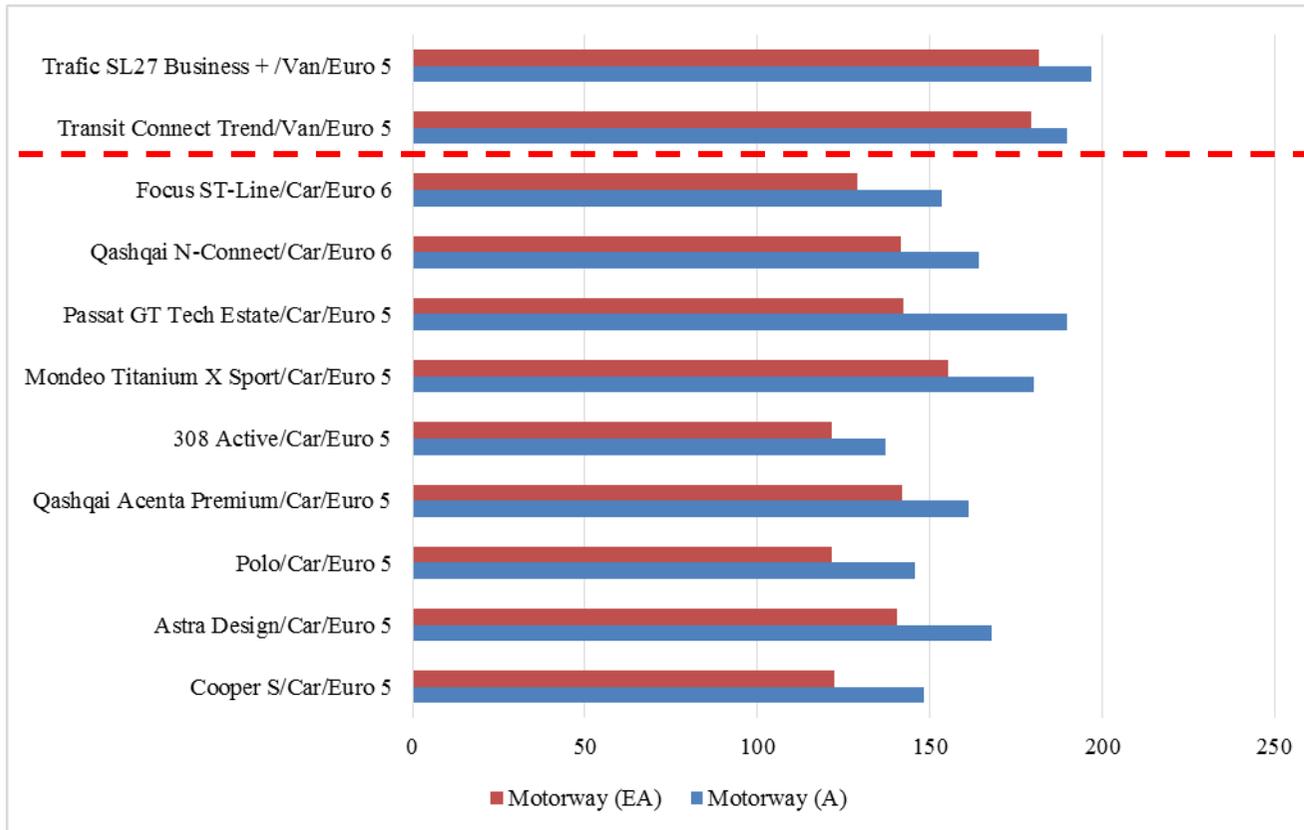
Model	A (diesel)	Emissions Analytics database (EA)	Difference (A-EA)/A (%)
Cooper S/ Car / Euro 5	0.786	0.375	52
Astra Design/ Car / Euro 5	1.438	1.130	21
Polo/ Car / Euro 5	0.700	0.375	46
Qashqai Acenta Premium/ Car / Euro 5	0.979	0.625	36
308 Active/ Car / Euro 5	0.534	0.625	-17
Mondeo Titanium X Sport/ Car / Euro 5	0.705	0.875	-24
Passat GT Tech Estate/Car / Euro 5	0.429	0.625	-46
Qashqai N-Connect/ Car / Euro 6	1.038	1.130	-9
Focus ST-Line/ Car / Euro 6	0.510	0.150	71
Transit Connect Trend/ Van / Euro 5	0.995	0.875	12
Traffic SL27 Business + / Van / Euro 5	1.126	0.375	67

Figure 40: A vs EA CO<sub>2</sub> emissions (Urban) (g/km)



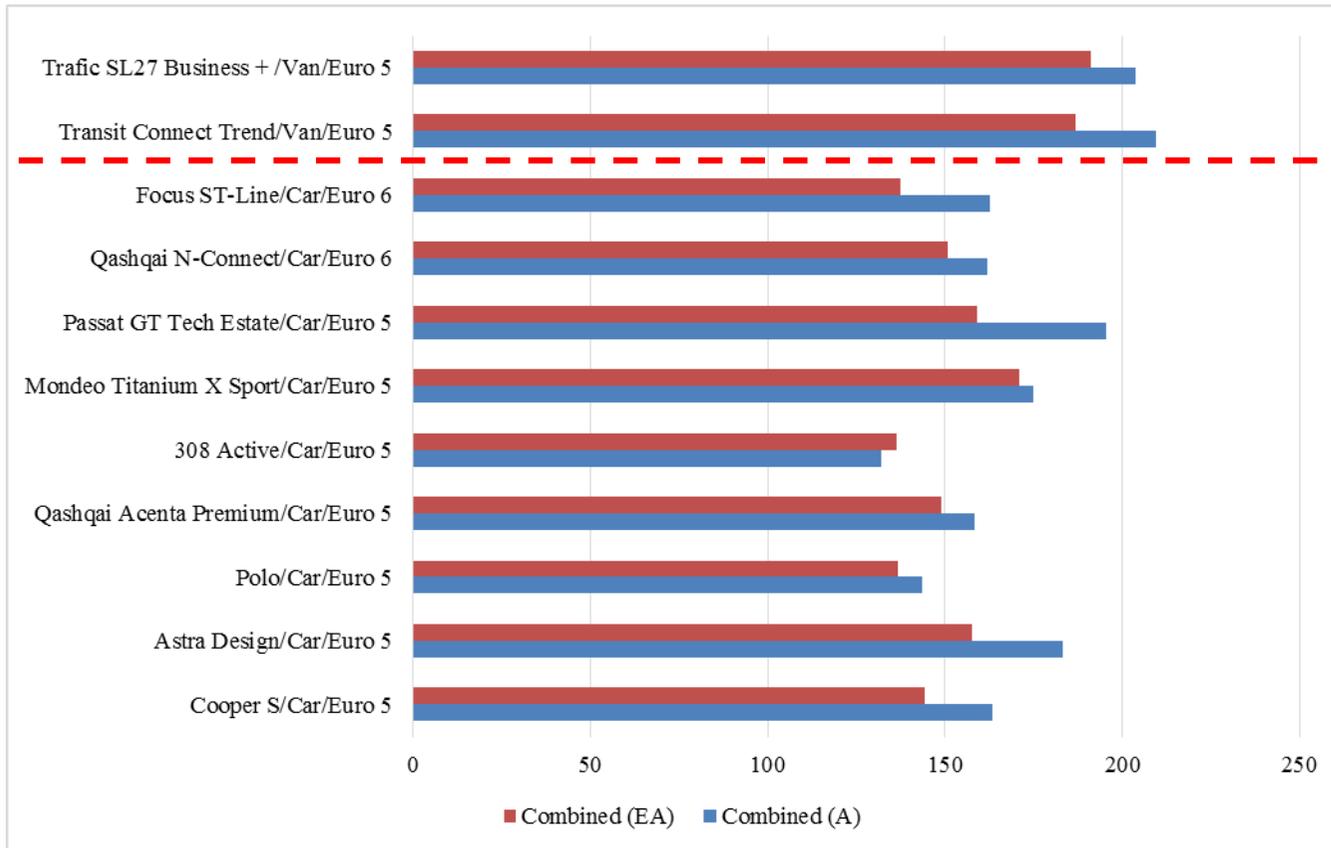
Note: Cars below the red dashed line, vans are above the line

Figure 41: A vs EA CO<sub>2</sub> emissions (Motorway) (g/km)



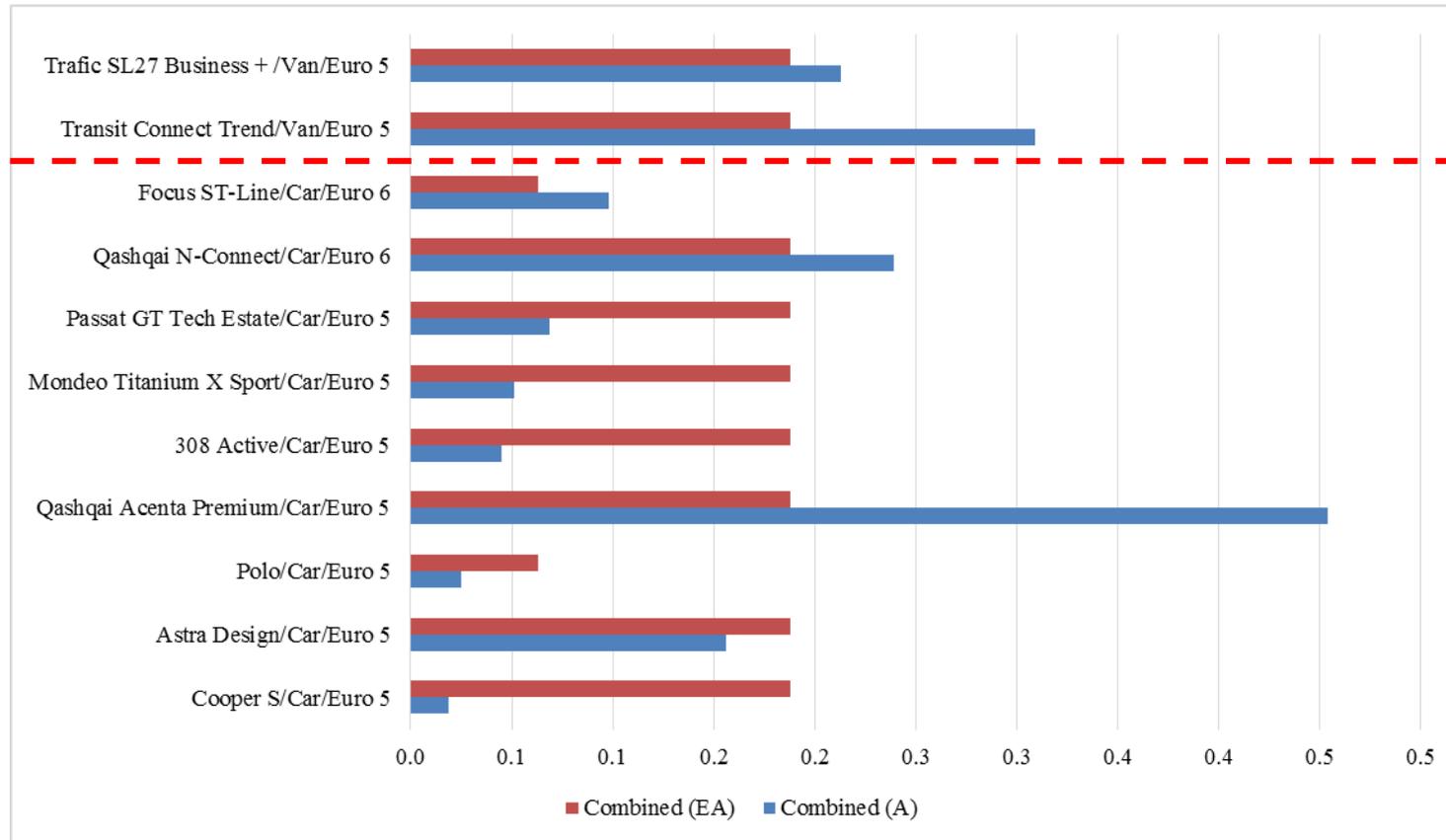
Note: Cars below the red dashed line, vans are above the line

Figure 42: A vs EA CO<sub>2</sub> emissions (Combined) (g/km)



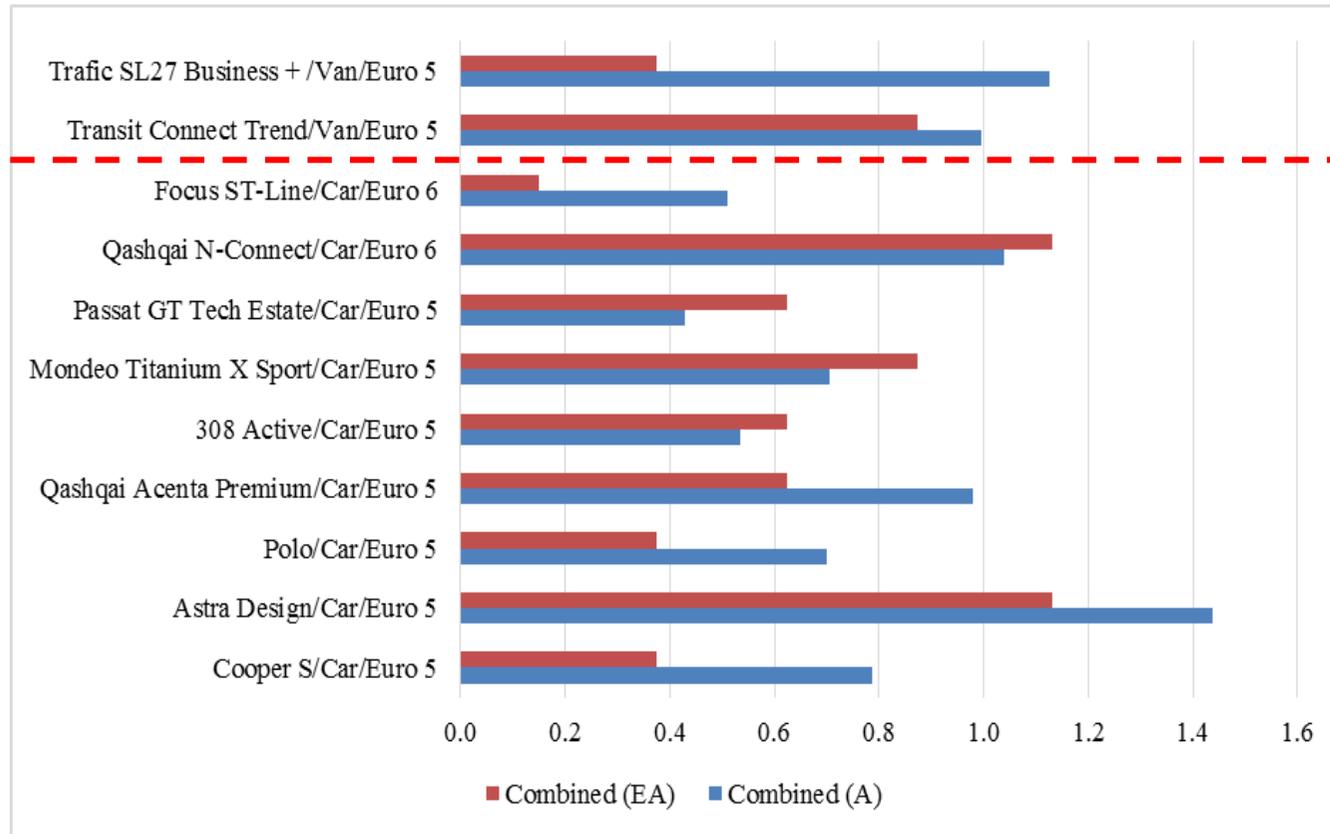
Note: Cars below the red dashed line, vans are above the line

Figure 43: A vs EA CO emissions (Combined) (g/km)



Note: Cars below the red dashed line, vans are above the line

Figure 44: A vs EA NO<sub>x</sub> emissions (Combined) (g/km)



Note: Cars below the red dashed line, vans are above the line