TRUE – The Real Urban Emissions Initiative London 2017-2018

Fieldwork and methodology report

Company	Opus Remote Sensing Europe S.L. (Opus RSE)
Client	International Council on Clean Transportation (ICCT)
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1 EXECUTIVE SUMMARY

The objective of this document is to report the fieldwork done by Opus RSE and Ricardo in London for the TRUE initiative (https://www.trueinitiative.org/), from November 6th 2017 to April 12th 2018.

The Remote Sensing Device (RSD) that was used in the project is the **Opus AccuScan™ RSD5000.** Project management and data analysis has been done by Opus RSE, who subcontracted Ricardo Energy and Environment, led by Dr. David Carslaw, to perform the roadside measurements.

The objective of the project has been successfully achieved (100 thousand valid records), as a database of 122,385 valid remote sensing measurements made with the RSD5000 has been delivered to the ICCT. Also, additional 41,959 measurements collected with the FEAT instrument have been provided. In this report, only data collected with the RSD5000 are considered.

Data analysis is reported in a separate document. This document only reports on the fieldwork and methodology used.

2 METHODOLOGY USED IN LONDON

The project has been completed in three phases:

- **Phase 1**: Sampling plan development and securement of permits and approvals
- **Phase 2**: Data collection
- **Phase 3**: Data processing and number plate matching

2.1 Phase 1 – Sampling plan

Prior to the field campaign, Opus RSE and Ricardo made a selection of potential sites in the urban area of London. The preliminary sites where chosen depending on their potential of providing good quality of data. Emissions are highly dependent on driving conditions (speed, acceleration, gradient of the road, time since the engine was started, traffic, etc.), so the selection of the sites was done very carefully, looking for different properties, while at the same time meeting certain conditions for the correct measurement of emissions.

The list was composed of 16 potential sites, which had the following characteristics:

1. Single lane roads, so that emissions of each vehicle can be measured without exhaust gases overlapping and therefore each record can be matched to a single vehicle without the problem of possible mixture of gases from the plumes.
2. Smooth traffic flow. Not too busy such that the road is frequently congested (measurements cannot be made in queuing traffic or jams) but where the RSD can measure thousands of vehicles per day.
3. Locations on a slight upward slope, and / or locations where vehicles are under acceleration e.g. on the exit from a roundabout. This type of locations maximizes the exhaust gas signal and data capture.
4. Some sort of street furniture in the middle e.g. a small traffic island, or a hatched area that can be coned off to protect the RSD equipment.
5. Preferably not close to residential areas where vehicles with cold engines may be measured.
6. Sites where there is a representative mix of different vehicle types.

The potential sites where reviewed with the ICCT and with the GLA (Greater London Authority), who assisted in the conversations with TFL (Transport for London) to obtain the permits.

From the list of potential sites, the RSD was finally deployed in 9 sites, which are shown in Table 2-1.

Table 2-1 Sites of the project

Site ID	Site Short Name	Latitude	Longitude	Slope (°)	Number of days
1	A10M25JUNC	51.682800	-0.051400	-0.1	7
2	DAWLEYHAYE	51.502102	-0.430602	-1.0	1*
3	EALING	51.519651	-0.354650	0.4	4
4	HESTONRD	51.489601	-0.371700	0.0	2
5	PUTHIL	51.455399	-0.219551	1.7	12
6	STOCKLEY R	51.513302	-0.450680	0.0	1*
7	TULSEHIL	51.441200	-0.112659	2.6	6
8	WESTENDHIL	51.568600	-0.422508	0.0	9
9	WOOLCIR	51.479698	0.060046	0.8	3
				Total:	**45**

* Some locations that seemed appropriate beforehand, were not good enough in practice. That is why, thanks to the ease of deployment of the RSD, the project was adapted as it progressed, to measure in more suitable locations.

The selected sites had different slopes, different traffic characteristics and some of them where very good locations in terms of valid measurements per hour. Figure 2-1 shows the nine locations in a map.

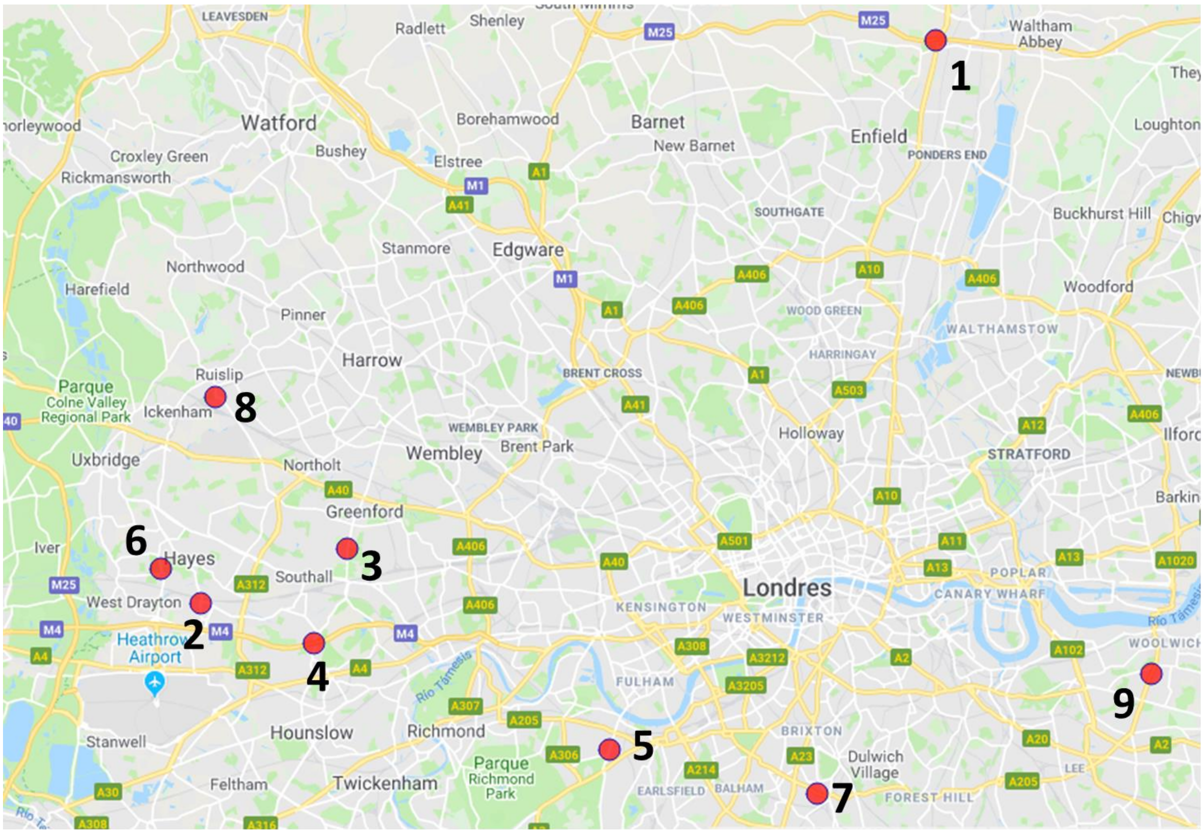


Figure 2-1 Map view of the sites

The specific days that have been measured at each of the sites is shown in Annex III.

Below is a description and a photograph of each location.

Site 1 – Juntion between A10 and M25:

Busy traffic flow with around 800 to 900 vehicles per hour. Site situated on a slightly decreasing gradient but acceleration of vehicles joining M25 counteracted this. Mixed fleet of vehicles including HDV's and passenger cars.

Figure 2-2 Site 1

Site 2 – Dawley road near to Waltha avenue:

Site situated after a roundabout on Dawley Road. The majority of vehicles were decelerating after the roundabout leading to slow moving traffic. Due to this, measurements were abandoned after the first day.

Figure 2-3 Site 2

Site 3 – Ealing, Greenford road:

Most vehicles were passenger cars with some HDV's and buses (site situated along bus route). Traffic became stationary intermittently and many cars are decelerating because of this.

Figure 2-4 Site 3

Site 4 – Heston road under the M4:

This site was used as a solution to measuring in the rain, situated under a bridge under the M4. Spray from vehicles still did inhibit measurements during prolonged episodes of precipitation, however as this got lighter and the road dried validity increased, obtaining ~700 vehicles per hour.

Figure 2-5 Site 4

Site 5 – Putney Hill:

Mostly passenger vehicles with some buses as the site is located on a bus route. The site is on a steady gradient leading to acceleration of vehicles and a high validity.

Figure 2-6 Site 5

Site 6 – Stockley road coming from Stockley Park:

The site was located on a slip road leading onto Stockley Road from Stockley Park. However, this led to low vehicle flows determined only by rush hour traffic exiting Stockley Park. Coupled with minimal acceleration and a flat gradient this lead to low validity, therefore measurements at this site were postponed.

Figure 2-7 Site 6

Site 7 – Christchurch road heading north west:

The site was situated on a positive gradient, however occasionally there was deceleration due to queuing vehicles further along the road and vehicles turning left at the next junction. There were predominantly passenger vehicles with some buses and HDV's.

Figure 2-8 Site 7

Site 8 – West End road heading north:

The site was located on West End Road heading towards Ruislip. The predominant vehicle type were passenger vehicles with some buses (as the site is located on a bus route). Acceleration was common as vehicles turned around a corner and then accelerated out of it.

Figure 2-9 Site 8

Site 9 – A205 South Circular:

The site was located on the A205 South Circular in Woolwich. A relatively flat gradient in a 30MPH speed zone led to many vehicles deccelerating when driving past our camera. This led to a lower than expected validity. Most were passenger vehicles with some buses (again on a bus route) and a small percentage of HDV's.

Figure 2-10 Site 9

2.2 Phase 2 – Data collection

The fieldwork consisted of 41 days of measurements, capturing data for 8 hours per day, from November 6th 2017 to February 15th 2018 in a total of 41 days of measurements. The field campaign was led by Dr. David Carslaw, from Ricardo (see Annex II).

The RSD is always first calibrated prior to each data collection session, in a process that only takes a few minutes. During the course of the session, the RSD is audited each 45 minutes, to verify the system is performing within specifications and does not need re-alignment and/or re-calibration.

The calibration procedure involves a two-stage process of calibrating then auditing the system. Firstly, the SDM alignment signals need to be above 10,000 for both IR and UV (ideally maximized where possible), then a calibration can be started. Calibrations involve the use of a cell calibration which contain known values of calibration gas. The cell is placed in the IR beam path and the SDM is calibrated to known gas values. This process can only occur when there is a break in the traffic. Following this, audits are undertaken whereby gas bottles of known quantities containing the measured pollutants are measured and referenced against the stated concentrations. This provides factors that can be applied to the data.

As data is collected, sophisticated Accuscan™ exhaust plume validation software (developed and improved over two decades) reviews each measurement in real-time to ensure it is of adequate strength, that the exhaust plume decayed in a manner consistent with warm loaded-mode vehicle operations, and that the prevailing background levels are stable and can be accurately determined. Each session's dataset is compiled every day and put together into a large database later on.

Table 2-2 shows the number of data captured and the data with a corresponding license plate and technical data available.

Table 2-2 Number of valid and matched records per site

Site ID	Site Short Name	Number of records	Number of valid records	Number of valid records with identified license plate	Number of valid records with identified license plate and technical data available
1	A10M25JUNC	31,391	23,296	20,559	19,810
2	DAWLEYHAYE	1,695	1,151	1,067	1,018
3	EALING	12,178	9,199	8,904	8,149
4	HESTONRD	1,999	1,431	1,380	1,319
5	PUTHIL	46,929	40,818	38,398	38,356
6	STOCKLEY R	1,166	1,021	975	928
7	TULSEHIL	18,893	16,182	15,440	14,790
8	WESTENDHIL	28,956	23,475	22,801	21,943
9	WOOLCIR	6,608	5,813	5,479	5,157
		149,815	**122,385**	**111,553**	**111,470**

Table 2-3 shows the number of measurements obtained per site and the valid records per hour.

Table 2-3 Number of records per site

Site ID	Site Short Name	Total time per site (hours)	Number of valid records per hour
1	A10M25JUNC	43,4	537
2	DAWLEYHAYE	3,2	359
3	EALING	29,7	309
4	HESTONRD	6,1	233
5	PUTHIL	67,6	604
6	STOCKLEY R	7,4	139
7	TULSEHIL	40,0	404
8	WESTENDHIL	64,5	364
9	WOOLCIR	13,3	438
		275,29	

149,815 records have been captured in total, **122,385** of them **valid**. Each one is composed by:

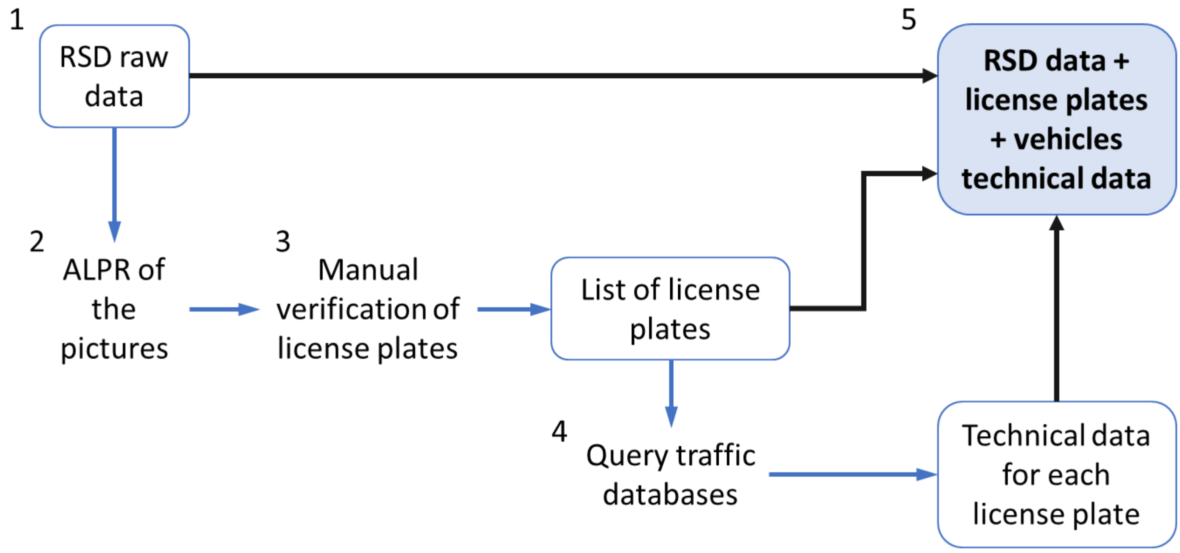
- Photograph of the license plate that allows to retrieve the technical data of each vehicle (type, fuel, euro standard...).
- Kinetic conditions, speed, acceleration and engine load (VSP)[1].
- Pollutants (CO, HC, NO, NO_2 and PM) measured in ratios that are later converted to other units.
- Environmental conditions (pressure, temperature and relative humidity).

The RSD measures the conditions of the gas in the air before passing a vehicle to establish a base condition. Then, it repeats the measurement to evaluate the gas after the vehicle has just passed. The difference between the two conditions represents the vehicle's emissions. The RSD measures the amounts of gas present for CO, CO_2, HC, NO and NO_2. The measured quantities of the gas are specifically the number of molecules along the path of the measurement beam. The light beam passes through the exhaust plume and is reflected by the CCM back to the detector, which records the changes in light intensity produced by the absorption of the different gases. From this absorption, concentrations can be calculated by applying Lambert-Beer's law. However, due to the remote nature of the equipment (we do not know the length of the optical path, l), it is not possible to report absolute concentrations, but the RSD provides emission concentrations (ratio of concentrations of each of the pollutants with respect to CO_2).

[1] Opus RSD measures the speed and acceleration of each vehicle. When it is installed, the slope of the road is also measured. With these 3 variables the system automatically calculates the VSP for each record.

2.3 Phase 3 – Data processing

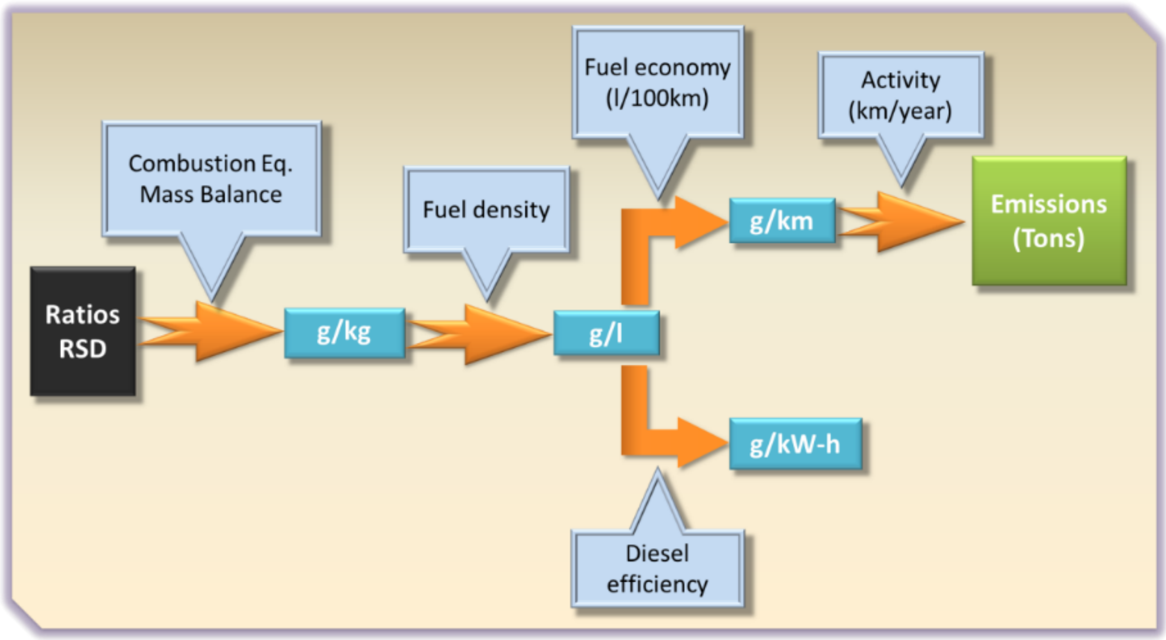
The data processing process is shown below.



1. The RSD compiles each session dataset, which is composed of:
    a. An access file with all the data registered by the RSD.
    b. All the pictures taken during the session.
2. The pictures taken by the RSD camera are processed by an ALPR software (Automatic License-Plate Reader) that recognizes the characters of the license plates of the vehicles and delivers a text-format result, to update the access file.
3. Because of different conditions on the sunlight, the camera distance, the vehicles speed and other factors, the ALPR software does not recognize all the license plates. Therefore, all records are checked manually.
4. The list of license plates is created, to retrieve the vehicle technical information of each vehicle from the traffic databases. Ricardo accessed number plate databases available in the UK to retrieve very valuable information on the vehicle characteristics: fuel type, vehicle model, VIN, Euro Standard, mileage from the most recent UK MOT test, etc.
5. The RSD data is matched to the license plates and the vehicles' technical information, to create a large database that provides complete information for each record.

As mentioned in previous chapter, RSD readings are ratios (or gas concentrations). Those are the emission values directly given by the RSD. Any other units must be calculated after step 5.

From the concentrations given by the RSD, assuming that they are constant throughout the exhaust plume, emissions can be calculated in meaningful units. The following table shows an outline of the different transformations that can be made:



To transform the ratios to emissions in grams of pollutant per kg of fuel, the fuel combustion equation must be used. A series of assumptions must be made, and mass balances must be applied. All these steps are explained in detail on the following website: http://www.feat.biochem.du.edu/whatsafeat.html

The fuel combustion equation is used, assuming CH_2 for diesel and gasoline and CH_4 for CNG:

$CH_2 + m(0.21O_2 + 0.79N_2) \rightarrow aCO + bH_2O + 2c(C_3H_6) + dCO_2 + eNO + fNO_2 + (0.79m - (e+f)/2)N_2$ (diesel, petrol)
$CH_4 + m(0.21O_2 + 0.79N_2) \rightarrow aCO + bH_2O + 2c(CH_4) + dCO_2 + eNO + (0.79m - \frac{e}{2})N_2$ (CNG)

Mass balances are applied for each element (carbon, hydrogen and oxygen) and the following equations are obtained:

$$CO\,(\frac{g}{kg}) = \frac{Q}{1 + Q + 0.0006xQ'} \text{x} \frac{1}{KgMC} \text{xM}_\text{w}$$

$$CO_2(\frac{g}{kg}) = \frac{1}{1 + Q + 0.0006xQ'} \text{x} \frac{1}{KgMC} \text{xM}_\text{w}$$

$$HC\,(\frac{g}{kg}) = \frac{0.0001xQ'}{1 + Q + 0.0006xQ'} \text{x} \frac{HCRF}{KgMC} \text{xM}_\text{w}$$

$$NO(\frac{g}{kg}) = \frac{0.0001xQ''}{1 + Q + 0.0006xQ'} \text{x} \frac{1}{KgMC} \text{xM}_\text{w}$$

$$\boldsymbol{NO_2\left(\frac{g}{kg}\right) = \frac{0.0001xQ'''}{1 + Q + 0.0006xQ'} \text{x} \frac{1}{KgMC} \text{x} M_w}$$

$$PM\left(\frac{g}{kg}\right) = [UV_{smoke}]x10$$

Q, Q', Q'' and Q''' are the ratios directly obtained from the RSD readings:

$$Q = \frac{CO\ (\%)}{CO_2(\%)}$$

$$Q' = \frac{HC\ (ppm\ propano)}{CO_2(\%)}$$

$$Q'' = \frac{NO\ (ppm)}{CO_2(\%)}$$

$$Q''' = \frac{NO_2(ppm)}{CO_2(\%)}$$

M_w: Molecular weight of each gas:

Gas	M_w (g/mol)
CO	28
HC (propane)	44
NO	30
NO_2	46
CO_2	44

KgMC is a parameter that represents the proportion of carbon in the fuel. Thus, depending on the fuel, this value will be different:

Fuel	Diesel	Petrol	CNG	LPG
KgMC	0,014	0,014	0,016	1

HCRF is a factor that corrects the hydrocarbon measurements:

Fuel	Diesel	Petrol	CNG	LPG
HCRF	1,63	2,2	3,33	1

To obtain emissions in g/l, it is sufficient to multiply the emissions in g/kg by the density of the corresponding fuel:

Fuel	Diesel	Petrol	CNG	LPG
Density (Kg/l)	0,81	0,73	0,46	0,46

From the emissions in g/l, the emissions in g/kW-h (only necessary for heavy duty vehicles) can be obtained by multiplying by a parameter known as 'diesel efficiency'. The value we use is 0.26l/kW-h, which is provided by Volvo.

From the emissions in g/l, the emissions in g/km can also be calculated by multiplying by the consumption (l/km).

ANNEX I - DESCRIPTION OF THE TECHNOLOGY

The AccuScan™ RSD5000 is a Remote Sensing Device (RSD) that remotely measures exhaust emissions from motor vehicles as they are driven past the remote sensing device on streets and highways. The emissions are measured spectroscopically by casting a narrow infrared (IR) and ultraviolet (UV) beam of light across the road and through the trailing exhaust of passing motor vehicles. A mirror then reflects the IR/UV light back to a series of detectors that measure the amount of transmitted light at characteristic wavelengths absorbed by the pollutants of interest. By subtracting any pre-vehicle background absorption from the amount of IR/UV light absorbed by the various tailpipe pollutants, the system can determine the pollutant levels in the vehicle's exhaust. As the emissions are measured, the video camera captures a digital image of the license plate and the speed/acceleration sensors record the speed and acceleration of the vehicle. The emissions, weather conditions, slope, speed and acceleration data as well as the license plate image are merged within less than a second to complete a measurement record which is then stored in a computer database for future analysis and reporting.

The system measures hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO2), nitrogen monoxide and dioxide (NO and NO2 separately, combined as NOx) and particulate matter (PM) [2]. By taking the ratios of the various pollutants to CO2 and applying stoichiometric rules and other conversion factors (the combustion equation), one can calculate the emission values in meaningful units (i.e. g/kg fuel burned), which can then be converted to g/km and g/kwh with appropriate assumptions [3].

A typical mobile installation of the various RSD components is shown below (Figure 0-1).

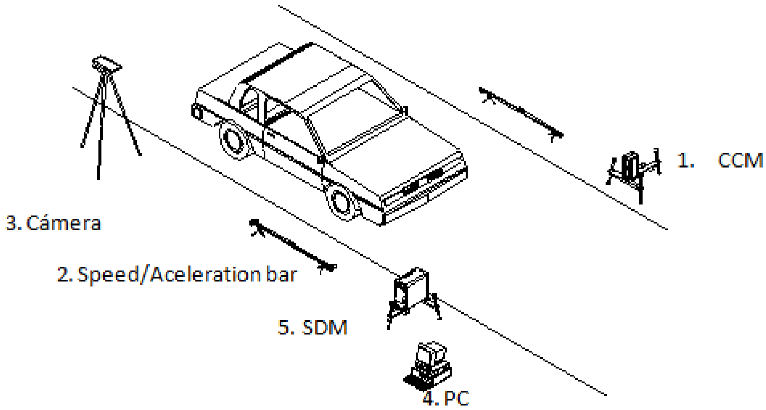


Figure 0-1 RSD components

[2] PM is measured as a fuel-specific opacity using ultraviolet light which is more sensitive to fine particulate and less affected by NO_2 than traditional green light opacimeters. Opacity measurements in IR wavelengths of 230 nm are also used to help characterize the type of smoke opacity being observed. Studies have demonstrated our collective opacity measurements can be used as an on-road screen for high $PM_{2.5}$ emissions.

[3] Bishop G.A., Stedman D.H.; Acc. Chem. Res., 1996, 29, 489-495.

The main components of an RSD5000 system are described below:

Gas Analyzer / Source Detector Module (SDM)

The RSD has an enclosed Source Detector Module. Using Sapphire windows, the SDM is sealed against the environment to better protect the optics and electronics inside. These windows are impervious to scratching and are easily cleaned. Along with an enclosed SDM, the RSD can have an automated gas calibration cell that eliminates the need for using gas calibration bottles and will calibrate during normal traffic movement (Figure 0-2).

Figure 0-2 Gas Analyzer / Source Detector Module

The Corner Cube Mirror (CCM)

The Corner Cube Mirror (CCM) is a simple reflector of the Source light beams. It returns the beams back to the Detector side of the SDM. The CCM consists of three stationary mirrors positioned at a 90° angle with respect to one another, like the corner of a room (Figure 0-3).

Figure 0-3 The Corner Cube Mirror

Speed/Acceleration System (Detector/Emitter Bars)

This system provides valuable information to the operator about the driving conditions of the vehicles at the time of the measurement. Poor test sites can be immediately identified by test results showing too many cars undergoing hard accelerations or decelerations. The Emitter and Detector Bars of the S/A system along with other parts of the RSD work in tandem to help the operator determine if a test site is favorable to capturing accurate emission readings (Figure 0-4).

Figure 0-4 Speed/Acceleration System

Video Camera for License Plate Capture

This high-speed video camera captures a digitized picture of the rear of the vehicle. It does this at the same instant the speed/acceleration values of a vehicle are calculated as the car passes through the exit beam of the S/A detector bar. Camera is software controlled from console. The software allows for control of pan, tilt and zoom, light control offset that automatically compensates for the lighting conditions throughout the day (Figure 0-5).

Figure 0-5 Video Camera for License Plate Capture

System Control Unit

The System Control Unit (SCU) utilizes Windows based XP, an Intel P4-3.0GHz or greater processor, a built-in 802.11g WiFi communication to the remote GUI Laptop and a built-in GPS module. The SCU gathers and integrates the emission readings, speed and acceleration values and video picture of the license plate. It also archives all information including the digitized vehicle license plate picture for future reference. The SCU also mediates electronic connections between the computer, monitor, CPU and other modules. The SCU provides the connection for all the peripherals to the computer and serves as a central power supply for the system (Figure 0-6).

Figure 0-6 System Control Unit

Weather Station

The Weather Station monitors external temperature and barometric pressure. The station includes an external temperature sensor. The console includes a power adapter with battery backup, backlit display for easy viewing, and a serial interface to a computer (Figure 0-7).


Figure 0-7 Weather Station

Emissions concentration values and other related data are stored in a computer and can also be monitored remotely by an operator stationed in a mobile unit parked safely along the roadside.

Opus RSD5000 measures the following emissions of each individual vehicle:

1. Carbon dioxide (CO_2)
2. Carbon monoxide (CO)
3. Nitric monoxide (NO)
4. Nitrogen dioxide (NO_2)
5. Hydrocarbons (HC)
6. Opacity and/or particulate matter (PM)

The RSD measures CO, HC, CO_2 and opacity via non-dispersive infrared spectroscopy (for the carbon species) and NO_x as well as also opacity via dispersive ultraviolet spectroscopy over 0.5 seconds in the trailing exhaust of vehicles as they pass roadside RSD installations. RSD software determines the ratios of CO/CO_2, HC/CO_2, NO/CO_2 and NO_2/CO_2 in the diluted and dispersed exhaust plumes and applies the mathematics of chemical mass balance of internal combustion to calculate tailpipe concentrations that are corrected for water and excess air.

Chemical mass balance states that carbons introduced as fuel (-CH_2-) must be emitted as hydrocarbons, partially oxidized CO, or fully oxidized CO_2.

The entire equipment can be deployed, aligned, calibrated, and commissioned within 20 minutes by a single operator. In contrast to competing units which can take hours to set-up and require reflectors to be embedded into roadways, the RSD5000 deployment is a) fast and easy, b) entirely stand-alone (no poles or roadway infrastructure required), and c) places nothing on the traveled road surface; making permitting that much easier.

ANNEX II – THE TEAM OF THE PROJECT

The team that was involved in the project is shown in this chapter.

Name: Josefina de la Fuente	Company: Opus RSE	Role: CEO
For the past 12 years she has been dedicated exclusively to the remote sensing technology and its various applications in Europe. Since 2013, she has been the Director of Opus RSE.		

Name: Javier Buhigas	Company: Opus RSE	Role: Project manager
Javier has 8 years of experience in consulting, project management and data analysis. He played a key role in the comprehensive analysis of the data from the 2017 Remote Sensing project in Barcelona (100,000 valid records of remote sensing measurements).		

Name: José Montero	Company: Opus RSE	Role: Technical leader
José has 10 years of experience both in national and international projects, 5 years working in Opus RSE, being laboratory responsible. Currently he is CTO of the company and he has been responsible of the analysis of the data compiled in the ICCT London project.		

Name: David Carslaw	Company: Ricardo E&E	Role: Technical leader
David holds a joint position between Ricardo Energy & Environment, where he is Knowledge Leader for Air Pollution Science, and the University of York, where he is a Reader in Air Pollution Science within the Department of Chemistry. David has over 20 years' experience as an air quality scientist with expertise in urban air pollution. Recent work has included the comprehensive measurement of vehicle emissions using remote sensing techniques, which has yielded many new insights into urban vehicle emissions.		

Name: Ben Fowler	Company: Ricardo E&E	Role: Project manager
Ben has 3 years' experience as air quality consultant in Ricardo Energy & Environment. He has played a key role in the management of Ricardo Energy & Environment's deployment of equipment in this project. Furthermore, Ben was part of the field team that deployed the AccuScan equipment over the 2017/18 winter.		

Name: Les Phelps	Company: Ricardo E&E	Role: Team Member
Les joined Ricardo Energy and Environment in 2017 and has been a field team member for the entirety of this project, becoming experienced in deployment and operation of the equipment.		

Name: Tom Green	Company: Ricardo E&E	Role: Team Member
Tom joined Ricardo Energy and Environment in 2017 and has been a field team member for the entirety of this project, becoming experienced in deployment and operation of the equipment		

Name: Rebecca Rose	Company: Ricardo E&E	Role: Senior Consultant
Rebecca has a PhD in spectroscopy and led the data analysis and management of the ICCT project and helped coordinate collaboration with the University of York.		

ANNEX III – SAMPLING PLAN CALENDAR

Next table shows the specific days that have been measured at each of the sites:

Day	Site ID	Comments
06 November 2017	EALING	Problems calibrating the S/A bar due to laser alignment. Mostly vehicles are passenger cars. Some HDV's and buses (site situated along bus route). Traffic does become stationary intermittently and many cars are deaccelerating. Dry day.
07 November 2017	EALING	Problems calibrating the S/A bar due to laser alignment. Mostly vehicles are passenger cars. Some HDV's and buses (site situated along bus route). Traffic does become stationary intermittently and many cars are deaccelerating. Intermittent rain showers throughout day.
08 November 2017	EALING	Problems calibrating the S/A bar due to laser alignment. Mostly vehicles are passenger cars. Some HDV's and buses (site situated along bus route). Traffic does become stationary intermittently and many cars are deaccelerating. Dry day
09 November 2017	EALING	Problems calibrating the S/A bar due to laser alignment - new S/A bar arrived ready to use for next week. Mostly vehicles are passenger cars. Some HDV's and buses (site situated along bus route). Traffic does become stationary intermittently and many cars are deaccelerating. Dry day.
15 November 2017	DAWLEYHAYE	New S/A bar - all ok. Problems with deacceleration and slow-moving traffic. Decided to abandon measurements at site.
16 November 2017	WESTENDHIL	Good site, positive acceleration and good valid gas measurements.
17 November 2017	WESTENDHIL	Good site, positive acceleration and good valid gas measurements.
20 November 2017	WESTENDHIL	Good site, positive acceleration and good valid gas measurements, 2 instances of rain showers during day
21 November 2017	WESTENDHIL	Good site, positive acceleration and good valid gas measurements. Dry day. On last audit of day SDM was failing to audit and gas could be heard from valve into SDM.
22 November 2017	WESTENDHIL	Good site, positive acceleration and OK valid gas measurements. Dry, windy day. Arrived at site late after checking problem with SDM audit. This looks to be fixed as audits are now successful.
23 November 2017	WESTENDHIL	Good site, positive acceleration and good valid gas measurements. Dry, sunny day.

Day	Site ID	Comments
27 November 2017	STOCKLEY R	Average site - low traffic, cars not accelerating - no gradient - intermittent rain.
28 November 2017	WESTENDHIL	Condensation on mirrors and rain first thing. Measured from 09:30 until 16:00.
29 November 2017	WESTENDHIL	Traffic at a standstill during peak periods.
30 November 2017	WESTENDHIL	Traffic from 07:45-09:15 made measurements very difficult.
04 December 2017	A10M25JUNC	Busy traffic flow, around 800-900 cars per hour. Reliant on M25 running smoothly. Lots of HDVs.
05 December 2017	A10M25JUNC	Lots of HDVs and articulated lorries made setting up at rush hour difficult. Regardless, connectivity issues particularly when carrying out the second cylinder. Estimate we lost around 2000 vehicles because of that difficulty.
06 December 2017	A10M25JUNC	Started a bit later when safer to cross road. Connectivity issues throughout day, probably lost around 1000 vehicles as a result. Valid gas during last hour of measuring was over 80%.
07 December 2017	HESTONRD	Tried this wet weather site under the M4. Spray from vehicles still inhibited measurements during first half of the day. However, once road dried up, getting 700 vehicles per hour with valid gas at 70%.
11 December 2017	HESTONRD	Wet day - Spray from vehicles inhibiting measurements.
12 December 2017	WOOLCIR	Flat gradient meaning many vehicles are deaccelerating. Last hour saw around 1000 vehicles per hour.
13 December 2017	WOOLCIR	Wet day - Spray from vehicles inhibiting measurements. Obtained 300-400 measurements in the morning without rain but from around 10am continuous rain and spray inhibiting measurements. Packed away by 12:00 due to this.
14 December 2017	WOOLCIR	Nothing to remark.
02 January 2018	TULSEHIL	Wet day - started measurements around 1pm with intermittent rain. Good site with incline although some vehicles deaccelerating due to many turning left down Hillside Road.
03 January 2018	TULSEHIL	Dry windy day, valid gas around 45% due to vehicles turning left and occasional build-up of traffic. High flows of around 650/hour is good though.

Day	Site ID	Comments
04 January 2018	TULSEHIL	Wet morning, couldn't start measuring until around 10:30 due to rain then spray from HDVs causing splash onto mirrors. Dry since 11am. Around 43% validity.
08 January 3018	A10M25JUNC	Good site but very busy when trying to audit. Intermittent connectivity issues during day.
09 January 2018	A10M25JUNC	Good site but very busy when trying to audit. Intermittent connectivity issues during day. Light rain during last few hours of testing
10 January 2018	A10M25JUNC	Good site but slow to set up due to busy road and having to repeat audits.
11 January 2018	A10M25JUNC	Good site but slow to set up due to busy road. Light intermittent rain throughout day requiring some recalibrations.
18 January 2018	PUTHIL	Replacement S/A bar delivered Wednesday 17/01. Good site, high valid gas as on steady inclining gradient. A small rain shower around 3:30.
19 January 2018	PUTHIL	Dry sunny day. Valid gas at ~70%
21 January 2018	TULSEHIL	Ok site, some queuing vehicles caused by traffic lights and vehicles turning left at the junction up the road. Some vehicles deaccelerating
22 January 2018	TULSEHIL	Ok site, some queuing vehicles caused by traffic lights and vehicles turning left at the junction up the road. Some vehicles decelerating. Late set up due to busy road making calibration and audits difficult.
23 January 2018	TULSEHIL	Intermittent light rain from start of day and spray from vehicles produces challenging conditions. Packed up earlier due to too much surface water.
29 January 2018	PUTHIL	Measured from 13:30 - 17:00 - intermittent rain showers stopped measurements half way through but brightened up from 15:30
30 January 2018	PUTHIL	Dry, clear, sunny day.
31 January 2018	PUTHIL	Rain in the morning, heavy rain between 10:30 - 12:00. Dry and sunny in the afternoon
01 February 2018	PUTHIL	Dry for most of day with very short spell of light rain around middle of day.
14 February 2018	PUTHIL	3 hours of measurements made before rain stopped play.
15 February 2018	PUTHIL	Dry for the most part.
16 February 2018	PUTHIL	Measuring 08:00-12:55

Day	Site ID	Comments
09 April 2018	PUTHIL	Rain delayed setting up until 12:00. York kit was broke so measuring stopped.
10 April 2018	PUTHIL	Cloudy but dry day. York kit was also broken today so measuring stopped early.
11 April 2018	PUTHIL	Cloudy but dry day.
12 April 2018	PUTHIL	Light rain shower at around 11am, rest of day dry

ANNEX IV – DESCRIPTION OF THE DATABASE

The following table shows a description of each field in the delivered database of emissions and vehicles' technical data.

Field	Description
search_term	License plate
keeper_start_date	Date current keeper took ownership of the vehicle.
keeper_previous_acquire	Date previous keeper took ownership of the vehicle.
keeper_previous_dispose	Date previous keeper disposed of the vehicle.
keeper_previous_keepers	Number of previous keepers.
keeper_v5c_date	Issue date of latest V5C form (from June 2004).
keeper_vic_date	Date Vehicle Identification Check has been Issued.
keeper_vic_result	Pass or Fail result for the Vehicle Identification Check
vehicle_make	The full make of a vehicle. For example, RENAULT.
vehicle_model	The full model of a vehicle. For example, CLIO RN.
vehicle_cherished_transfer	A marker to show that the vehicle has undergone a cherished transfer (plate change) at some point in its life.
vehicle_manufactured_date	Vehicle date of manufacture (if only the year is known, this will display 31-12-YYYY). On other occasions no date of manufacture was provided therefore the date of first registration may be shown instead.
vehicle_registration_date	The Date a Vehicle was First Registered and Made Known to the DVLA.
vehicle_v5c_date	Issue date of latest V5C form (from June 2004)
vehicle_prior_use	Indicates that a vehicle had been used prior to its initial registration with the DVLA.
vehicle_vin_full	The Vehicle Identification Number as Allocated to the Vehicle by the Original Vehicle Manufacturer (VIN).
vehicle_vin_ending	Last 4 characters of vehicle VIN.
vehicle_colour	Generic Vehicle Colour e.g. Blue, Red, White, Black. Vehicles can also be coded as two distinct colours in which case these will be separated by a slash: 'BLUE/GREEN'. Other vehicles may be coded as 'MULTI-COLOUR'.
vehicle_country_of_origin	Manufacturer Country of Origin (final plant assembly).
vehicle_exported	Shows if the vehicle is recorded as being permanently exported a Flag of "1" will return in the XML.
vehicle_export_date	The data the vehicle was exported from the UK as advised to the DVLA.

Field	Description
vehicle_imported_uk	Populated only where a vehicle was directly imported from outside the UK.
vehicle_imported_ni	Identifies that a vehicle has been imported into Great Britain from Northern Ireland.
vehicle_import_date	The date the vehicle was imported into the UK and advised to the DVLA.
vehicle_scrapped	0 = Vehicle has not been recorded scrapped 1 = The vehicle has been scrapped 2 = A certificate of destruction has been issued.
vehicle_scrapped_date	The date the vehicle was scrapped as advised to the DVLA.
vehicle_unscrapped	Indicates that the vehicle is no longer deemed to be scrapped and is on the road.
vehicle_body	Vehicle body style description.
vehicle_body_class	Vehicle body class style description.
vehicle_seat_count	Seat Count (driver included).
vehicle_wheelplan	Vehicle Wheelbase Length in mm.
vehicle_co2	DVLA Carbon Dioxide emission levels (2001 vehicles onwards).
vehicle_noise_engine	The total output (dB) from the vehicle with the engine running at a higher speed.
vehicle_noise_drive_by	The total output (dB) from the vehicle as it travels along the road.
vehicle_cc	Engine displacement in cubic centimetres (cc).
vehicle_engine_number	The vehicle's engine number. Typically stamped onto the engine or on a rating plate. Checking the value recorded here with the engine in the car can identify whether the engine has been swapped.
vehicle_fuel_type	Fuel description e.g Petrol, Diesel etc.
vehicle_max_power	The maximum net power of the engine (including cooling systems).
vehicle_max_tech_mass	The maximum weight permissible including payload.
vehicle_power_to_weight	Maximum net power divided by mass (Motorcycles Only).
vehicle_trailer_braked	The maximum total weight of a braked trailer incl. payload.
vehicle_trailer_unbraked	The maximum total weight of an unbraked trailer incl. payload.
vehicle_gross_weight	The maximum weight of a vehicle including payload
vehicle_fuel_code	
vehicle_cdl_id	
mvris_vrm	MVRIS Vehicle Registration Mark (VRM) - This should be the same as the DVLA/DVA VRM.

Field	Description
mvris_first_reg_date	MVRIS Vehicle Registration Date (this date should be the same as the Date of First Registration).
mvris_engine_size	Manufacturer Engine Size in Litres.
mvris_cc	Manufacturer Exact Cubic Capacity.
mvris_bhp_count	Manufacturer Brake Horse Power (BHP).
mvris_door_count	Manufacturer number of doors.
mvris_body_desc	Manufacturer Body Description.
mvris_cab_type	Cab Type generally relates to commercial vehicles.
mvris_transmission	Gearbox Type.
mvris_axle_count	Number of axles.
mvris_mvris_code	
mvris_vehicle_series	Manufacturer Advised Vehicle Succession.
mvris_vehicle_origin	Manufacturer Country of Origin (final plant assembly).
mvris_vehicle_desc	Manufacturer Vehicle Description.
mvris_gears_count	Number of forward gears.
mvris_drive_type	Drive type e.g. FWD, 4WD RWD etc.
mvris_visibility_date	Date vehicle was first visible within the MVRIS data.
mvris_setup_date	Date vehicle was officially introduced to the UK market as advised by the vehicle manufacturers.
mvris_body_shape_roof_height	Commercial vehicle roof shape and height configuration.
mvris_drive_axle	The number and position of the given wheels.
mvris_gross_combined_weight	Gross combined weight of a vehicle including payload - generally applies to heavy commercial vehicles only.
mvris_vehicle_gross_weight	Maximum gross vehicle weight - generally applies to heavy commercial vehicles only.
mvris_vehicle_height	Vehicle height in millimeters.
mvris_kerb_weight	Vehicle weight when loaded with all fluids (including full tank of fuel) and the driver.

Field	Description
mvris_vehicle_length	Vehicle length in millimeters.
mvris_seat_count	Number of seats.
mvris_power_delivery	Method of power delivery to engine combustion chamber.
mvris_rigid_artic	Bodystyle relating to heavy commercial vehicles only.
mvris_type_approval_category	Vehicle Type Approval Category.
mvris_unladen_weight	Vehicle weight without payload or passengers - commercial vehicles only.
mvris_wheelbase_length	Length of the wheelbase in millimeters.
mvris_vehicle_width	Width of vehicle in millimeters (may or may not include wing mirrors).
mvris_primary_fuel	Primary Fuel Flag. Returns 'Y' when providing data for vehicle's primary fuel source (in case of more than 1 source fitted to vehicle).
mvris_power_kw	Maximum power output of the engine.
mvris_rpm_power	The engine RPM at which maximum power output occurs.
mvris_torque_lb	The maximum amount of torque generated by the engine (in Pound/Foot).
mvris_torque_nm	The maximum amount of torque generated by the engine (in Newton/Metres).
mvris_rpm_torque	The engine RPM at which maximum torque is produced.
mvris_co2	Vehicle Manufacturer derived Carbon Dioxide Emission value.
mvris_urban_cold_mpg	Value of the fuel used on urban roads as tested by the vehicle manufacturer at a cold start in miles per gallon.
mvris_extra_urban_mpg	Value of the fuel used on non-urban routes as tested by the vehicle manufacturer using a pre-warmed engine in miles per gallon.
mvris_combined_mpg	Average value of the fuel used on urban/non-urban roads as test by the vehicle manufacture in miles per gallon.
mvris_urban_cold_lkm	Value of the fuel used on urban roads as test by the vehicle manufacturer at a cold start. Figure given in litres/100Km.
mvris_extra_urban_lkm	Value of the fuel used on non-urban routes as tested by the vehicle manufacturer using a pre-warmed engine. Figure given in litres/100Km.
mvris_combined_lkm	Average value of fuel the vehicles uses on urban/non-urban routes. Figure given in litres/100Km.
mvris_max_speed_mph	Maximum speed in miles per hour.
mvris_max_speed_kph	Maximum speed in kilometers per hour.
mvris_acceleration_mph	Acceleration Time 0-62mph (s).

Field	Description
mvris_acceleration_kph	Acceleration Time 0-100kmh (s).
mvris_engine_description	Manufacturer engine description.
mvris_engine_location	Engine location within the vehicles body.
mvris_engine_make	Manufacturer engine make NB: This may differ to the vehicle manufacturer in the case of LCV's. Motorcaravans and HGV's.
mvris_bore	Cylinder Bore Diameter (mm).
mvris_stroke	Piston Stroke Length (mm).
mvris_fuel_delivery	Fuel delivery e.g. direct or indirect injection.
mvris_cylinder_arrangement	Cylinder arrangement.
mvris_cylinder_count	Number of cyclinders.
mvris_valve_count	Number of valves per cyclinder.
mvris_valve_gear	Arrangement and operation of the valves in relation to the camshaft.
mvris_make	Manufacturer Make Description.
mvris_model	Manufacturer Model Description.
mvris_body	Manufacturer Body Description.
mvris_fuel_type	Fuel description e.g Petrol, Diesel etc.
mileage_mileage_record_value	Mileage Reading.
mileage_mileage_record_date	Date the mileage is recorded.
mileage_mileage_record_source	Mileage Data Source.
mot_results_mot_test_odometer_value	Mileage of a vehicle at its last technical inspection.
mot_results_mot_test_odometer_unit	Unit for the mileage.
NORMA EURO	Applicable Euro Standard. 0 = pre-Euro
SITE_AREA ID	Code for location of the measurements
SITE NAME	Name of the site of the measurements
COUNTRY	Country of the site of the measurements
CITY	City of the site of the measurements
Slope	Slope of the road in degrees

Field	Description
SessionDate_dd/mm/yyyy	Date of the measurements
Start_SessionTime_hh:mm:ss	Start time of the session
End_SessionTime_hh:mm:ss	End time of the session
EmissionTime_hh:mm:ss	Time of the measurement
Speed Km/h	Vehicle's speed (Km/h)
Acceleration Km/hs	Vehicle's acceleration (Km/hs)
Temperature_ºC	Ambient temperature (ºC)
Humidity	Ambient relative humidity (%)
Pressure	Ambient pressure
Longitude_Decimal	Coordinates of the site (longitude)
Latitude_Decimal	Coordinates of the site (latitude)
VSP	Vehicle Specific Power (kW/Metric Ton)
Plume_Size	Size of the plume (%cm)
COCO2	Concentration of CO
HCCO2	Concentration of HC
NOCO2	Concentration of NO
NO2CO2	Concentration of NO2
NH3CO2	Concentration of NH3
uvSmoke	Opacity
CO_gpl	CO (g/l)
CO2_gpl	CO2 (g/l)
HC_gpl	HC (g/l)
NO_gpl	NO (g/l)
NO2_gpl	NO2 (g/l)
NOx_gpl	NOx (g/l)
NH3_gpl	NH3 (g/l)
PM_uvSmoke_gpl	Particulate matter, PM (g/l)
CO_gpKm	CO (g/km)
CO2_gpKm	CO2 (g/km)
HC_gpKm	HC (g/km)
NO_gpKm	NO (g/km)
NO2_gpKm	NO2 (g/km)
NOx_gpKm	NOx (g/km)
NH3_gpKm	NH3 (g/km)
PM_uvSmoke_gpKm	Particulate matter, PM (g/km)

Field	Description
CO_gpkWhr	CO (g/kW-h)
CO2_gpkWhr	CO2 (g/kW-h)
HC_gpkWhr	HC (g/kW-h)
NO_gpkWhr	NO (g/kW-h)
NO2_gpkWhr	NO2 (g/kW-h)
NOx_gpkWhr	NOx (g/kW-h)
NH3_gpkWhr	NH3 (g/kW-h)
PM_uvSmoke_gpkWhr	Particulate matter, PM (g/kW-h)
CO_gKg	CO (g/kg)
CO2_gKg	CO2 (g/kg)
HC_gKg	HC (g/kg)
NO_gKg	NO (g/kg)
NO2_gKg	NO2 (g/kg)
NOx_gKg	NOx (g/kg)
NH3_gKg	NH3 (g/kg)
PM_uvSmoke_gKg	Particulate matter, PM (g/kg)
EM_SCORE_gKg	Emission score (g/kg)
FUEL_SCORE_gKg	Fuel score (g/kg)
Valid	Valid record