Ultra-Low Emission Bus Scheme: Test Guidance for Certification

This document sets out the guidance notes for testing over the **UK Bus Cycle** (UKBC) for certification under the **Ultra-Low Emission Bus (ULEB) Scheme**. Achieving ULEB certification is a requirement of the Ultra-Low Emission Bus Scheme for winning operators and local authorities to receive grant funding from Department for Transport (DfT).

"*An Ultra-Low Emission Bus is defined as saving 30% well-to-wheel greenhouse gas emissions compared to the average performance of a Euro VI diesel of equivalent passenger capacity over the UK Bus Cycle as well as having a Euro VI certified engine or equivalent emissions*"

All manufactures are encouraged to test to the UKBC and any current requirement for the Bus Service Operators Grant (BSOG) Low Carbon Emission Bus (LCEB) incentive can be extracted from the test.

BSOG is expected to be reviewed in 2018/19 and LowCVP are aiming to help shape the incentive to reward vehicles based on the greenhouse gas saving to encourage fuel efficiency and encourage the shift to lower carbon technologies.

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Contents

Introduction

The new Ultra Low Emission Bus Scheme, which runs from 2018/19-2020/21, will see £48m distributed to operators and public authorities to assist in the purchase of Ultra Low Emission Buses and supporting infrastructure.

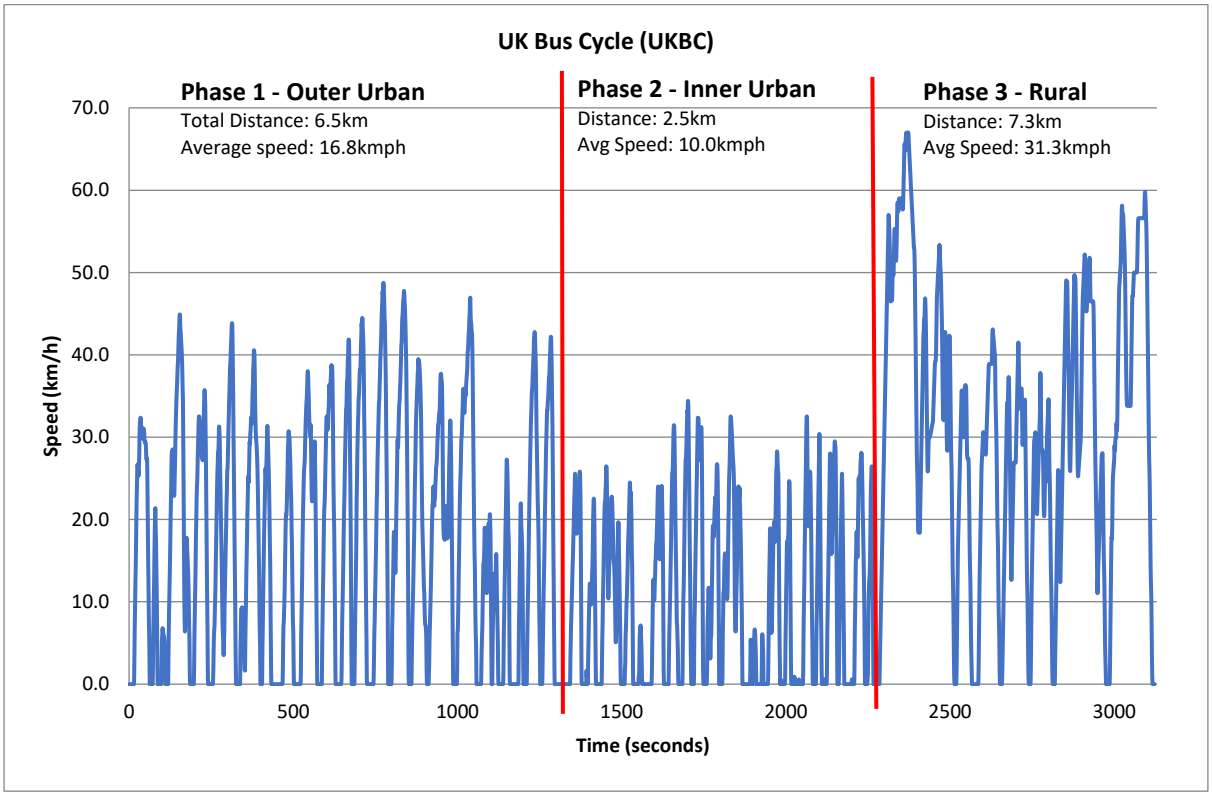
To access the ULEB scheme bidding guidance and other related documents, please visit the DfT website here.

As part of the Bus Working Group work programme for 2018/19, LowCVP undertook a review and refresh of the Low Emission Bus Scheme (2015-2017), with the objective of updating the scheme to meet the latest emission standards in line with requests from the European Commission.

The subsequent test development, in line with changes being made to the MLTB test used by TfL, has resulted in the new UK Bus Cycle (UKBC) over which manufacturers must test their vehicle in order to be eligible for funding under the ULEB Scheme.

From LEB to ULEB: Summary of Changes

The following list summarises the changes made for the ULEB UKBC test cycle:



- Warm up phase: Outer Urban only – previously Rural.
- Rural cycle moved to the end of test cycle – previously performed first.
- Test cell temperature set to 10°C – previously 18°C.
- Doors will open at designated bus stops, 20 in total.
- Heating switched on at beginning of warm up phase. Internal saloon temperature set to 17°C with a tolerance of +/- 2°C, monitored by thermocouples evenly distributed throughout the saloon. Doors closed during warm up.
- Internal and external lights are switched on. Head lights set to dim.
- Driver's cab demisters turned on to full.

- 50% of windows are opened, evenly distributed between each side of vehicle and upper/lower deck for double decks.
- 24V battery monitored by the test house to ensure ancillary loads power is not being drawn from the battery.
- All vehicles will use grid average *emission conversion factors for greenhouse gas company reporting* sourced from the UK Government's national publication for the UK.
- Where fitted and active during the test, auxiliary diesel heater emissions factor will be added to total vehicle emissions. This emission factor is an additional +170 g CO_2e/km.
- The UKBC requires that test results used for certification may only be taken from emission tests conducted consecutively, at least 3 tests in a row.

Refreshing the Low Emission Bus Scheme

The Low Emission Bus Scheme saw £41m awarded by Office for Low Emission Vehicles (OLEV) to support the purchase of over 400 Low Emission Buses and supporting infrastructure from 2015-2017 across England. The LEB Scheme built on 20 years of bus testing and lessons learnt from the Green Bus Fund and Low Carbon Emission Bus definition.

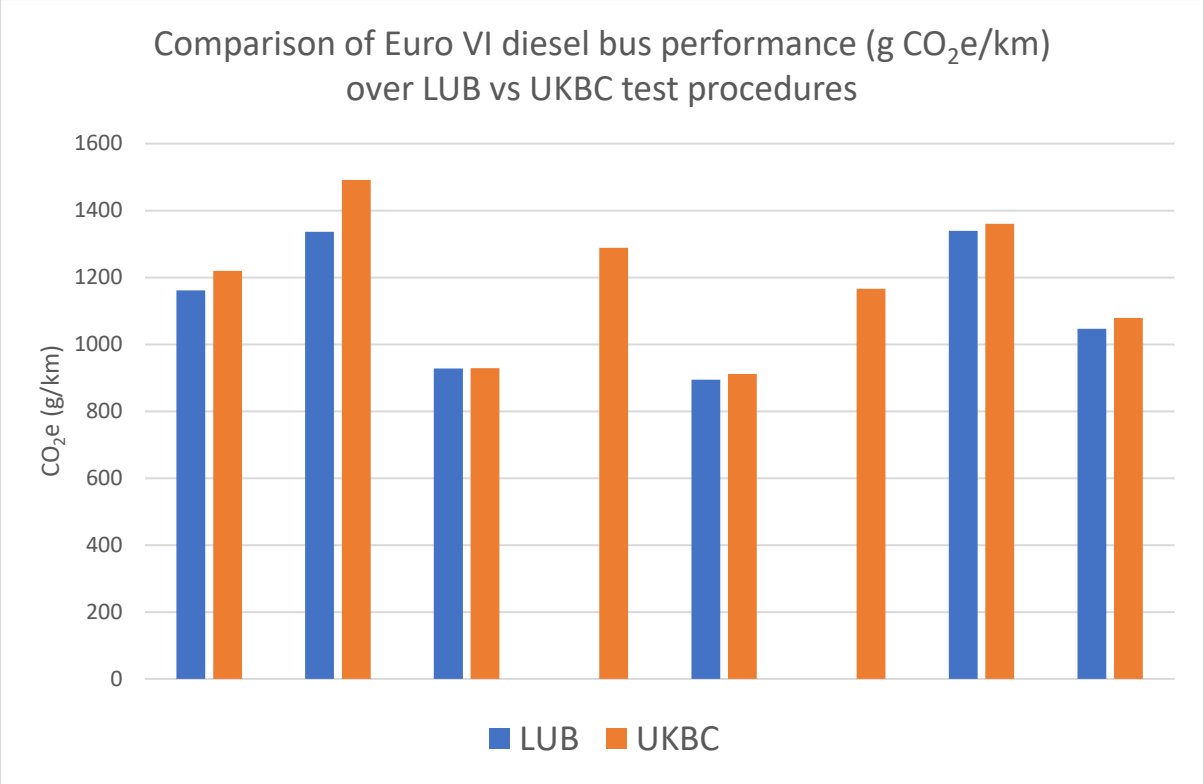
"A Low Emission Bus is defined as a bus that saves 15% well-to-wheel greenhouse gas emissions compared with a Euro V diesel bus with equivalent passenger capacity and has a Euro VI certified engine or equivalent emissions."

The Department for Transport subsequently commissioned LowCVP to establish the baseline energy consumption performance and associated emissions of conventional Euro VI diesels to ensure bus testing was relevant to the most recent emissions standards.

Working in partnership with bus manufactures and TfL, LowCVP tested 8 Euro VI diesels to establish a greenhouse gas emissions baseline performance from which an Ultra-Low Emission Bus could be defined.

As part of the vehicle test programme, vehicles were tested over the LowCVP UK Bus Cycle (LUB) used for LEB certification and a revised version of the cycle, now the UK Bus Cycle (UKBC), which aimed to include elements to make the test cycle more representative of real world operations. Key changes to the test were the reduction in test cell temperature, the inclusion of the ancillary loads such as lighting, heating and demisters as well as reducing the intensity of the vehicle warm up phase.

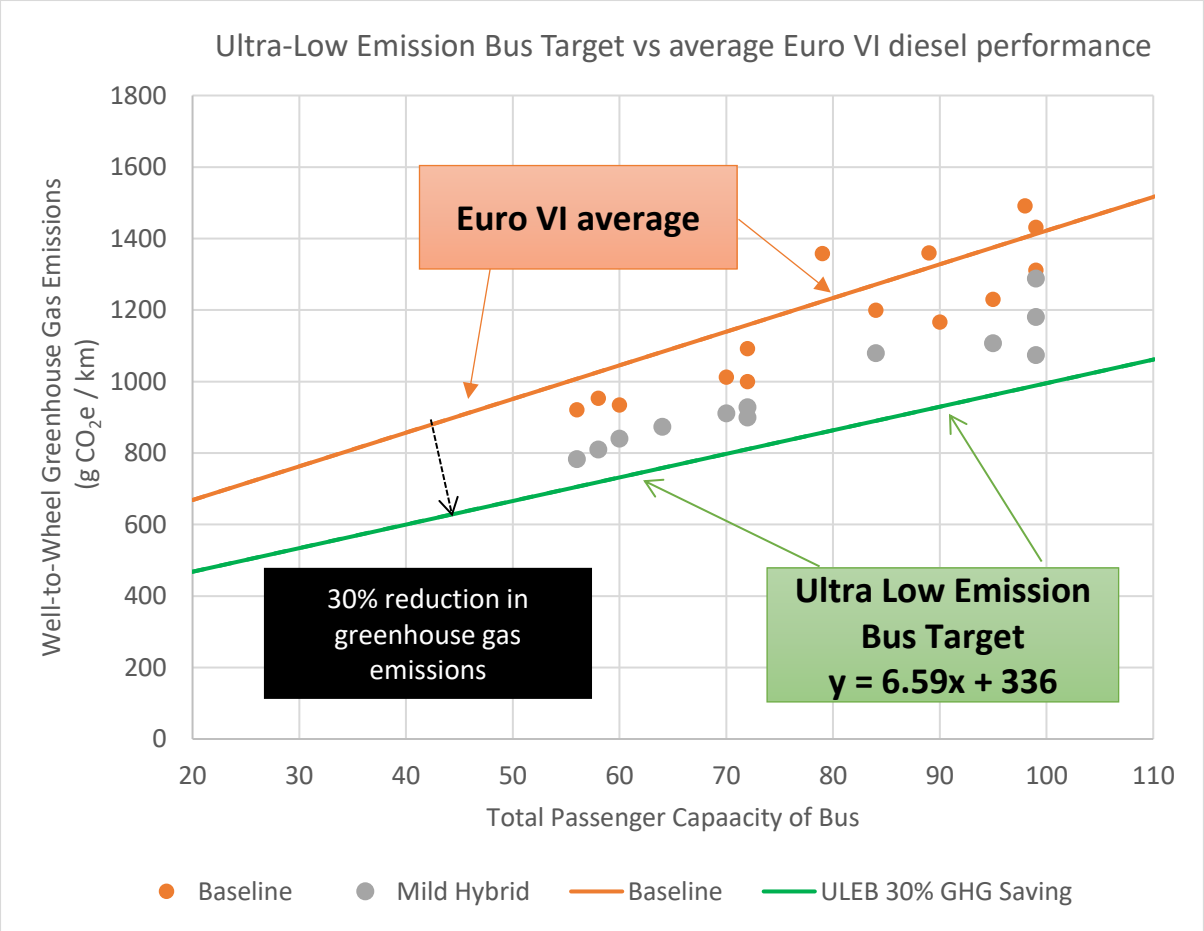
As a result, the new more robust UKBC resulted in an average of a 4% rise in CO_2e compared with the LUB test used under the LEB scheme.



There was a small improvement in well-to-wheel CO_2e emissions from Euro V to Euro VI when comparing like for like test results over the LUB cycle, despite the increased production of N_2O from the conversion of NO_x in the aftertreatment system. This demonstrates that manufacturers are continuing to improve diesel vehicle efficiency through improved driveline and new energy management systems alongside light weighting strategies.

Setting the Euro VI baseline

To create the Euro VI baseline, LowCVP use a formula which describes the average CO_2e performance of a bus as a function of its total passenger capacity. Plotting the test results of the diesel test programme, a line of best fit is drawn to create a baseline of average performance for greenhouse Euro VI diesel buses, this enables operators and policy makers to quickly estimate the greenhouse gas impact of a diesel bus without having to test the vehicle at a test house and to compare against low carbon technologies.



The greenhouse gas performance of the Euro VI diesel bus over the UKBC did not differ greatly from the previous Euro V diesel baseline over the LUB cycle. As such, LowCVP has set the average Euro VI performance baseline at the same level as the Euro V.

The average performance of a Euro VI diesel is described by the following formula:

Well-to-Wheel Greenhouse Gas Emissions (g CO_2e /km) = 9.42 x [Total Passenger Capacity] + 480

The use of the existing Euro V baseline enables the continued use of the Low Emission Bus definition (15% better than Euro V) and the ability for manufacturers to certify LEBs and ULEBs over the same test cycle. i.e. if the bus does not make the 30% ULEB target, it could still qualify as an LEB without having to perform a separate test.

Setting the ULEB target: 30% better than Euro VI

Using test data from Low Emission Bus technologies and assessing the performance of Euro VI diesels, LowCVP have set the target for the Ultra-Low Emission Bus Definition at 30% better than the Euro VI baseline.

This formula for calculating the target for greenhouse gas performance per kilometre for ULEB certification over the UKBC is described as:

Well-to-Wheel Greenhouse Gas Emissions (g CO_2e /km) =6.59 x [Total Passenger Capacity] + 336.

ULEB target calculation example

A manufacturer wishes to test a Euro VI hybrid bus with a passenger capacity of 84 passengers to achieve ULEB accreditation.

The Euro VI diesel baseline for a bus with 84 passengers is:

$$9.42 \times [84] + 480 = 1271.28 \text{ g } CO_2e/km$$

Therefore, the target for a ULEB is 30% better than 1271.268 g CO_2e/km:

$$6.59 \times [84] + 336 = 889.56 \text{ g } CO_2e \text{ /km}$$

The hybrid bus must achieve an average of 889.56 g CO_2e /km over the UKBC in order to achieve Ultra Low Emission Bus Status.

The test results of vehicles achieving Ultra Low Emission Bus Status will be published in the form of certificates on LowCVP's Low Emission Bus Hub and will include the target calculations and emissions performance of the bus.

Ultra Low Emission Bus Certificate Summary		
GHG Well-to-Wheel	*841.5*	g CO_2e / km
Euro VI Average Diesel Equivalent	*1299.5*	g CO_2e / km
WTW GHG saving (compared with Euro VI diesel equivalent)	*458.0*	g CO_2e / km
% WTW GHG saving (compared with Euro VI diesel equivalent)	*35%*	g CO_2e / km
Zero Emission operating range (km)	*N/A*	km
WTW CO_2 per passenger km (@ Max Pass Capacity)	*9.7*	g CO_2e/pass km
Approved as Ultra Low Emission Bus? (30% saving or more)	*YES*	

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ULEB Test Guidance

In support of the new DfT/OLEV Ultra Low Emission Bus Scheme, LowCVP has produced guidance notes for testing the range of technologies expected.

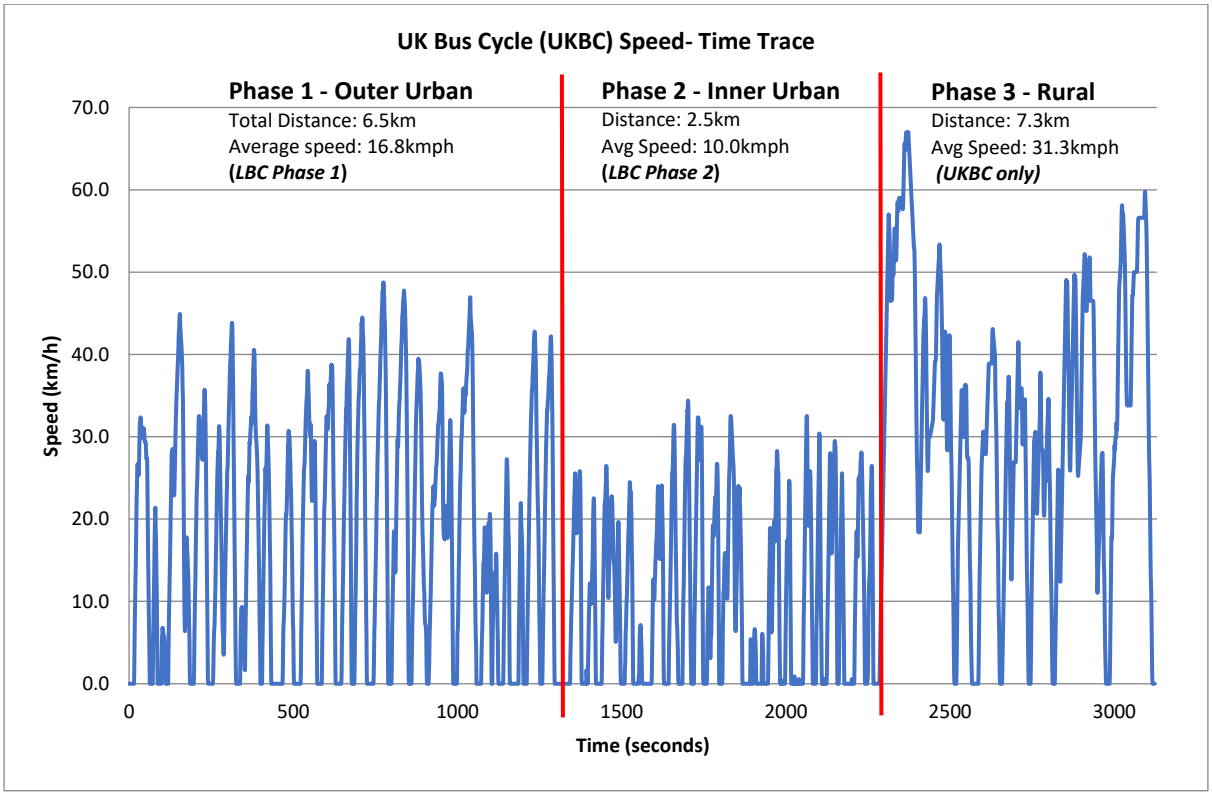
For vehicle manufacturers, these notes should be read in conjunction with the detailed testing requirements available at the end of this document in Annex A.

UK Bus Cycle

The UK Bus Cycle is the new test cycle for accrediting buses as Ultra Low Emission Buses. The test can also be used to achieve Low Emission Bus status for qualification for the BSOG LCEB incentive.

The UKBC consists of a warm up phase and 3 measured test phases; Outer Urban, Inner Urban and Rural.

Phase	Distance (km)	Time (seconds)	Average Speed (km/h)	No. of Bus Stops
Warm up	*6.5*	*1380*	*16.9*	***0***
Outer Urban	6.5	1380	16.9	10
Inner Urban	2.5	899	10.0	8
Rural	7.3	844	31.6	2
UKBC	**16.3**	**3123**	**18.8**	**20**



A key objective in the formation of the UKBC was to ensure the test processes align with those undertaken by Transport for London (TfL). As a result, TfL's new **London Bus Cycle** (LBC), previously the MLTB cycle (route 159), can be extracted directly from the UKBC by the test house, for all propulsion types.

The LBC consists of the Outer and Inner Urban phases only, previously the MLTB or '159 route' used for LCEB accreditation under the Green Bus Fund.

For more information on the LBC, follow this [Link].

Warm up phase – Combustion Engines

For buses with combustion engines, the warm up phase will be an Outer Urban phase, with the doors and windows closed throughout.

Warm Up Phase – Zero Emission Vehicles

The warm up phase for the UKBC for zero emission (ZE) vehicles is at the discretion of the test house and the vehicle manufacturer. The requirements for ending & exhaust stabilisation is not necessary for a zero-emission vehicle and so a warm up phase is not required. However, if a warm up is performed, energy consumption MUST be measured for the duration of the warm up to ensure the correct allocation of energy use to the measured test.

Cell Temperature – 10 ^{o}C

The test cell chamber temperature has been set at 10^{o}C, previously 18^{o}C, in order to better simulate the average annual operating temperatures in the UK.

Ancillary Loads/Devices Turned On

To better reflect the energy consumption of real world operations, a number of ancillary loads will be turned on during the test, including:

- All internal and external lights turned on.
- Headlights turned on, set to dipped beam.
- Driver's cab demisters turned on to full.
- Doors will open at designated bus stops, 20 in total.

50% Windows Opened

Half of the windows on the bus will be opened. The test house should distribute the open windows evenly on either side of the bus and on the upper deck if applicable.

Saloon Heating set to 17^{o}C

The internal saloon heating is set to 17^{o}C. Heating should be switched on at beginning of warm up phase. Internal saloon temperature set to 17^{o}C with a tolerance of +/- 2^{o}C, monitored by thermocouples evenly distributed throughout the saloon. Doors closed during warm up.

24V Battery Monitored

The onboard 24V/48V battery voltage will be monitored by the test house and any usage trends will be analysed and reported. This is to ensure that the ancillary loads power is not being drawn from the 24 V battery throughout the test. Batteries that run flat will result in a failed test.

Test Weights – 50% of seated or 25% of total passenger capacity

The test weight for the vehicle is determined by using the unladen kerb weight (which must be declared and will be confirmed by the test facility) plus 50% of the seated passenger capacity using a nominal 68kg per passenger. This was selected as consistent with bus regulations and TfL approach.

The weight of a crew member to represent the driver at 75kg will also be added.

Should seating capacity be less than 50% of total passenger capacity, the test weight shall be 25% of the total passenger capacity, using the nominal load of 68kg per passenger, plus 75kg for the driver.

Test Weight Example 1

Double deck bus. Total Passenger Capacity: 99, Seating Capacity: 67.

Seating Capacity is above 50% of total passenger capacity, therefore test weight is 50% of seated capacity:

50% of 67 = 33.5 Test weight = 33.5 x 68 kg = 2,278kg +75 kg = **2,350 kg**

Test Weight Example 2

Single Deck Bus. Total Passenger Capacity: 90 Seating Capacity: 20.

Seating Capacity is below 50% of total passenger capacity, therefore test weight is 25% of total passenger capacity:

25% of 90 = 22.5 Test Weight = 22.5 x 68 kg = 1,580 kg +75 kg = **1,655kg**

To allow some scope for specification variation, it is proposed that a vehicle can be tested at a specified seating configuration and that this test will cover variation of +/- 5 seats either way; i.e. a bus with alternative seating from 40 to 50 seats would be tested at a single figure of 45 seats.

This scope for variation totals 340kg in test weight. As such variations in vehicle design which affects the weight of the vehicle by +/- 340 kg e.g. changes in seating or flooring, will not result in a need to re-test the vehicle. However, the change in weight will have to be registered with LowCVP and the certifying test house to enable an adjustment to be made.

Dynamometer Setting: – Coastdown test required

Chassis dynamometers should be set using road load data from coastdown testing. Coastdowns are conducted to understand the deceleration rate of the vehicle from 70 km/h – 0km/h, with the sped-time data fed into the chassis dynamometer to simulate vehicle characteristics in the test chamber. LowCVP recommends that all ULEB vehicles undergo new coastdowns if one has not been conducted in the last 2 years.

Test fuel: – Assume grid or conventional fuel used for test

Vehicles should be tested on market available fuel unless specifically requested to use a bespoke fuel, in which case a sample of fuel will be taken and stored by the test facility.

Gas powered vehicles should declare the specification of gas being used for test and the recent fill locations.

The specification of fuel used for test (and for calculating fuel consumption figures) will be stated by the test facility.

Well-to-Tank Factors

An Ultra-Low Emission Bus's greenhouse gas performance will be assessed on a Well-to-Wheel basis. This includes tailpipe emissions from the engine or ancillary combustion engines and the upstream emissions (well-to-tank) associated with the extraction, production and delivery of a fuel.

LowCVP uses the annual national UK *'Government emission conversion factors for greenhouse gas company reporting'* spreadsheet produced by the UK government. LowCVP publishes the factors used on the Low Emission Bus Hub website and will update them annually.

All vehicles testing for ULEB certification will use the national average figure for grid gas, grid electricity or pump diesel. The factors for 2018 are shown below:

Fuel / Energy Source	**g CO_2e/Litre (Net CV)**	**g CO_2e/ MJ (Net CV)**
Pump Diesel (average biofuel blend)	618.46	17.23
Gaseous Fuels	**g CO_2e/ kg (Net CV)**	**g CO_2e/ MJ (Net CV)**
CNG	551.8	11.41
Other	**g CO_2e/ kWh (Net CV)**	**g CO_2e / MJ (Net CV)**
UK Grid Electricity	352.76	97.99

WTT factors from *Government emission conversion factors for greenhouse gas company reporting 2018*

Manufacturers will be able to state the likely performance of their vehicles over the UKBC and indicate whether they will pass based on previous LEB performance and the above factors.

Gas buses

Buses powered by gas or biomethane should be tested over the complete ULEB cycle assuming they are run on grid-sourced CNG. Biomethane discounts will not be applied as they were in the LEB scheme as the scheme is aimed at promoting the use of efficient vehicles, rather than supporting the benefits of renewable fuels.

If manufacturers are using the UKBC to achieve Low Emission Bus status, then biomethane discounts will be applied as stated in the Low Emission Bus Test Guidance Notes.

Electric buses

Buses powered by electricity only, should be tested over the complete ULEB cycle assuming they are run on grid-sourced electricity. The total energy used should be measured and a full charge completed with grid energy measured to establish the charging efficiency.

Electric Range should also be measured by the test facility. The manufacturer must declare the maximum usable energy in the battery to estimate the theoretical maximum range of the electric bus for use on the ULEB certificate.

Zero emission range

To determine the ZE range of a ZEC bus, the vehicle will be tested over the UKBC cycle (or phases thereof) from a fully charged condition until either 4 UKBC cycles have been travelled or the battery is depleted, and the conventional engine starts.

The vehicle must be fully charged prior to any warm up being performed

Battery SOC and energy flow will be measured on all ZE buses and may be used to determine ZE range if beyond 25km.

Advanced ZEC hybrid buses (non-plug-in)

Vehicles with advanced ZE capabilities which operate as hybrids (no off board charging) may be controlled to operate in ZE mode for a specific portion of the cycle. If required, multiple tests should be run with energy measurement and correction for zero net energy change.

Diesel Heater Emissions Factor

ZE heating can use up to 35% of the energy of a battery electric bus and as such manufacturers and operators in the UK have historically opted to have used diesel heaters to heat the vehicle saloon. LowCVP is now encouraging manufacturers to adopt ZE heating solutions as battery capacity improves and range becomes less of an issue.

An electric or hybrid bus using a diesel heater is permitted to qualify as an ULEB but shall have an emissions factor added to the final WTW Greenhouse gas emissions figure.

LowCVP conducted a desktop estimation of greenhouse gas from a 12kW diesel powered water heater used on a number of electric buses in service in Nottingham.

- Assumed diesel consumption of 1 litre / hour continuous to meet 17 ^{o}C saloon temp
- UKBC test is 52 mins long, therefore a 0.87L diesel consumption
- UKBC test is 16.3 km in length, therefore 0.05 litre / km consumption
- **Diesel Heater emissions factor: 170.5 g CO_2e / km WTW emissions** (including WTT emissions).

Diesel Heater Emission Factor Example:

Electric bus with passenger capacity of 70 achieves a 70% saving or an average of 341.82 g CO_2e/km over the UKBC, with an auxiliary diesel heater providing the energy needed to heat the saloon.

The final greenhouse gas emissions performance for this electric bus will be:

Well-to-wheel greenhouse gas emissions over UKBC: 341.82 g CO_2e/km

Diesel heater emissions factor: 170.5 g CO_2e/km

Total well-to-wheel greenhouse gas performance for ULEB certification: 341.82 + 170.5 = 512.32 g CO_2e/km or a 55% GHG saving.

LowCVP also worked with Millbrook Proving Ground to test the emissions and energy consumption of 23kW diesel heater. The test differed slightly from the UKBC conditions and demonstrates a worse case impact of the emissions heater assuming it was on full power for the entire UKBC test to give emissions of 404 g CO_2e/km.

Further details on the Millbrook diesel heater test are available here for LowCVP members, titled "Diesel Heater Emissions Test by Millbrook Proving Ground" on the LowCVP website.

Note: Detailed emissions testing of diesel heaters has not been extensively conducted in relation to emissions contribution in transport operations and LowCVP reserve the right to update the diesel emissions factor as more data is collated.

Note: The UKBC requires the heating system to maintain a saloon temperature of 17^{o}C +/- 2 ^{o}C in a chamber of 10^{o}C and represents a worst-case scenario where the bus heating is on constantly. In real world operations a diesel heater will not be on all year round and may not be set to 17^{o}C, therefore the energy consumption and emissions will likely be less than this when averaged across a year.

Plug-in hybrid buses

A bus which has a zero-emission operating mode and can complete the full Inner Urban phase of the test (2.5km) in this mode without additional charging can be defined as ZE capable. *If the ZE mode is*

a limited operation (i.e. speed limited) the full cycle should be run, and modal emissions and energy data recorded for subsequent analysis.

Energy to recharge any battery should be determined as for a pure EV bus.

The standard journey (distance between charges) used to calculate GHG performance, will be assumed to be 4 LUB cycles (66km). If this is not appropriate, manufacturers should provide evidence of specific operating and charging regimes for DfT/LowCVP consideration.

Manufacturers should discuss the operating characteristics for their plug-in vehicles with the test house and / or LowCVP to ensure the optimum test process is adopted.

Determination of WTW GHG and energy for plug-in hybrid vehicles

Plug-in vehicles will be tested in two modes.

1. Engine mode (depleted battery); 2. ZE mode (from full battery). If the ZE mode is a limited operation (i.e. speed limited) the full cycle should be run, and modal emission and energy data recorded for subsequent analysis.

The ZE mode will be run over a maximum of 4 repeated LUB cycles. If the vehicle is able to complete this in ZE mode, without charging, it will be assumed to operate as a fully ZE bus.

Hydrogen Buses

Test house to test hydrogen buses in line with light duty regulations, monitoring the weight of the hydrogen fuel tanks to measure fuel consumption.

There is no UK grid/pump greenhouse gas conversion factor produced for hydrogen, so any hydrogen buses projects must be assessed on a case by case basis. Based on previous calculations, 100% renewable electricity is needed to produce hydrogen gas with a low enough carbon intensity to meet the ULEB target.

Please contact LowCVP directly if you have a technology not considered here or wish to gain further clarity on the test process detail: secreariatl@lowcvp.org.uk , 0207 304 6880