Imperial College London

Centre for Low Emission Construction

Particle Size Distribution

Multi-gas combustion engine for the UK construction sector.

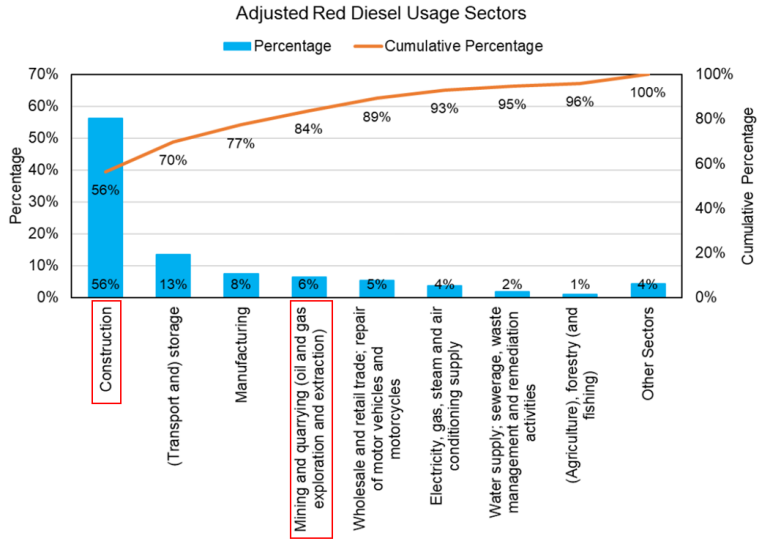
Dr. Carl Desouza, David Ek, Daniel Marsh, Dr. David Green

Imperial College London

Centre for Low Emission Construction

Why gas fuels?

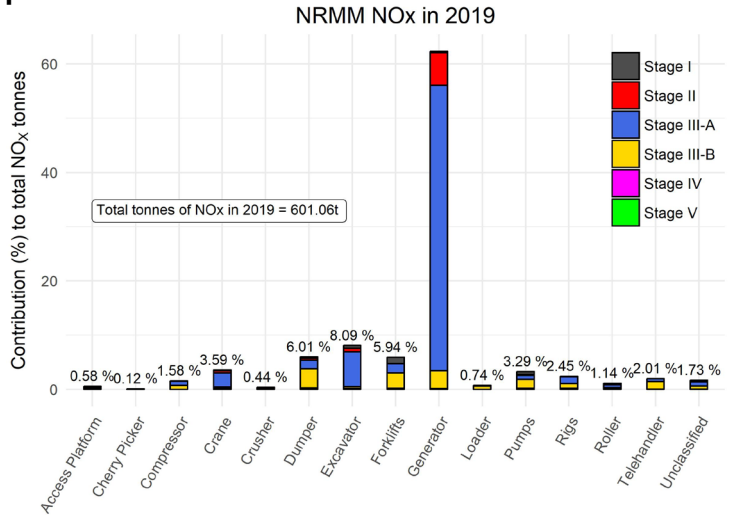
Diesel is the predominant fuel used on construction sites in the UK. [e]



[e] *UK Department for Business Energy Industrial Strategy 2023, Red Diesel Replacement Phase I Scheme.*

Why generators?

Generators are the highest emitters of air pollution on construction sites. [r]



[r] *Desouza et al. 2019, A spatial and fleet disaggregated approach to calculating the NO_X emissions inventory for non-road mobile machinery in London.*

Imperial Colleg
London

Engine Sp

- Engine manu
- Power rating
- Engine displ
- Exhaust afte
- Fuel types te

UN/SCETDG/63/INF.19

Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals

Sub-Committee of Experts on the Transport of Dangerous Goods **8 November 2023**

Sixty-third session
Geneva, 27 November-6 December 2023
Item 3 of the provisional agenda
Listing, classification and packing

Present and future products in the LPG industry – Addition of a new special provision to UN numbers UN 1075 and UN 1965 – Supporting information, research and testing

Submitted by the World LPG Association (WLPGA)

Executive summary:	The WLPGA has submitted informal document INF.18 requesting the addition of a new special provision (SP) to UN numbers UN 1075 and UN 1965 which will allow up to 12% by mass of Dimethyl Ether (UN 1033) to be added to LPG that is assigned to either of these UN numbers. This document provides the details of the supporting information, research and testing undertaken by the WLPGA.
Action to be taken	To be read in conjunction with informal document UN/SCETDG/63/INF.18 submitted by the WLPGA requesting the addition of a new SP to UN numbers UN 1075 and UN 1965.
Related documents:	UN/SCETDG/63/INF.18 – submitted by the WLPGA requesting the addition of a new special provision to UN numbers UN 1075 and UN 1965.

Liquefied Petroleum Gas; renewable Di-Methyl Ether

Imperial College London

Centre for Low Emission Construction

Test procedure

- ISO 8178 type G2 test procedure for constant speed SI engines
- 5 load points tested: 100%, 75%, 50%, 25%, 10%
- Idle emissions also tested; not part of the test procedure
- Engine rated at 12kW, test points: idle, 1.2kW, 3kW, 6kW, 9kW, 12kW

Imperial College London

Centre for Low Emission Construction

Emissions Measurement systems

Sensors Inc	High-speed exhaust mass flowmeter
3DATX Corp	Flex integrated portable emissions measurement system (iPEMS) CO, CO_2, HC, NO, NO_2, PM, PN
Indrio Technologies Inc	Zephyr ultra-low gas analyser NO, NO_2
Dekati Ltd	ELPI+ eDiluter particle measurement system PM, PN, PSD*

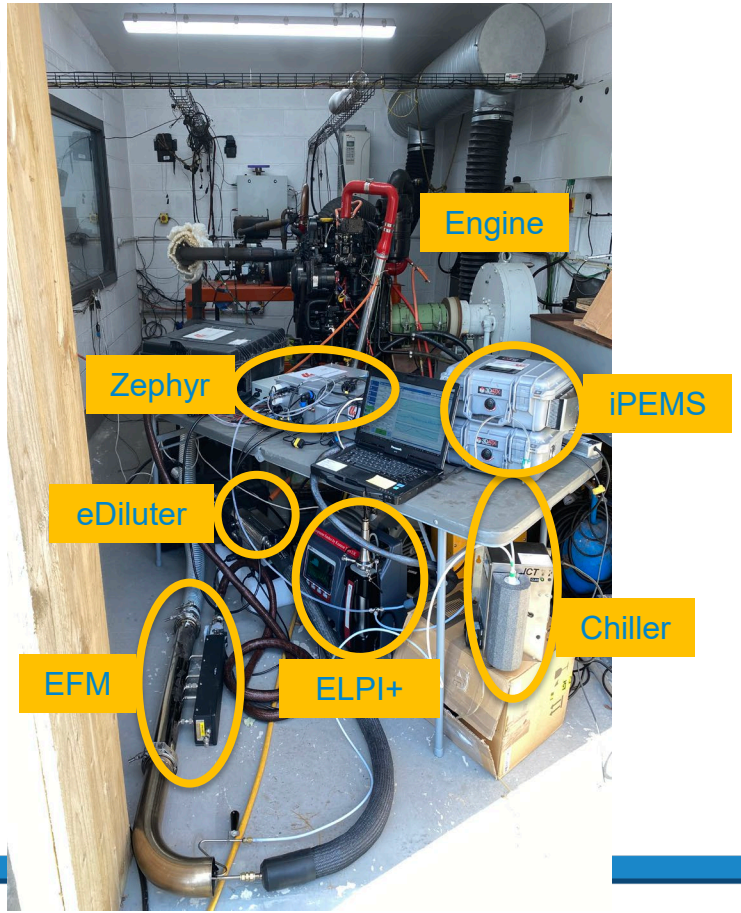
*Particle Size Distribution

Imperial College London

Centre for Low Emission Construction

Setup on engine dyno

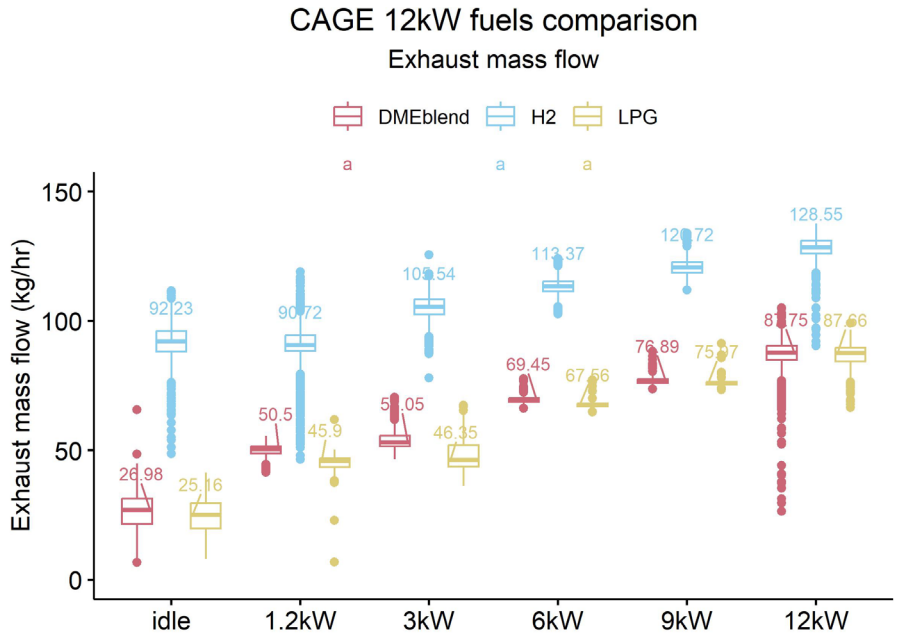
- Sensors Inc. – Exhaust-mass Flow-Meter
- JCT - Chiller condenser
- 3DATX - integrated Portable Emissions Measurement System
- Indrio - Zephyr ultra-low NOx analyser
- Dekati - eDiluter & Electrical Low-Pressure Impactor for particle number size distribution



Imperial College London

Centre for Low Emission Construction

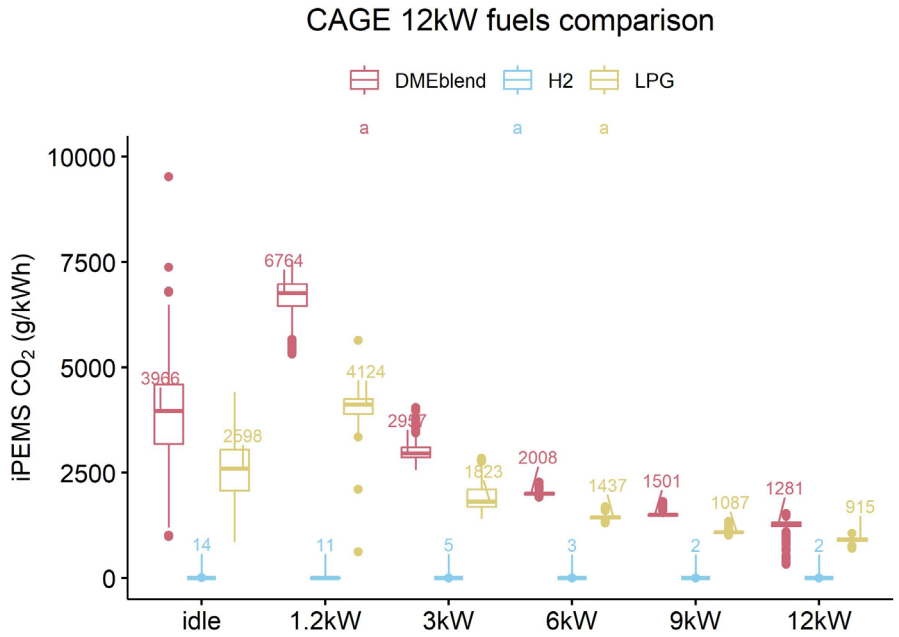
Exhaust mass flow



Imperial College London

Centre for Low Emission Construction

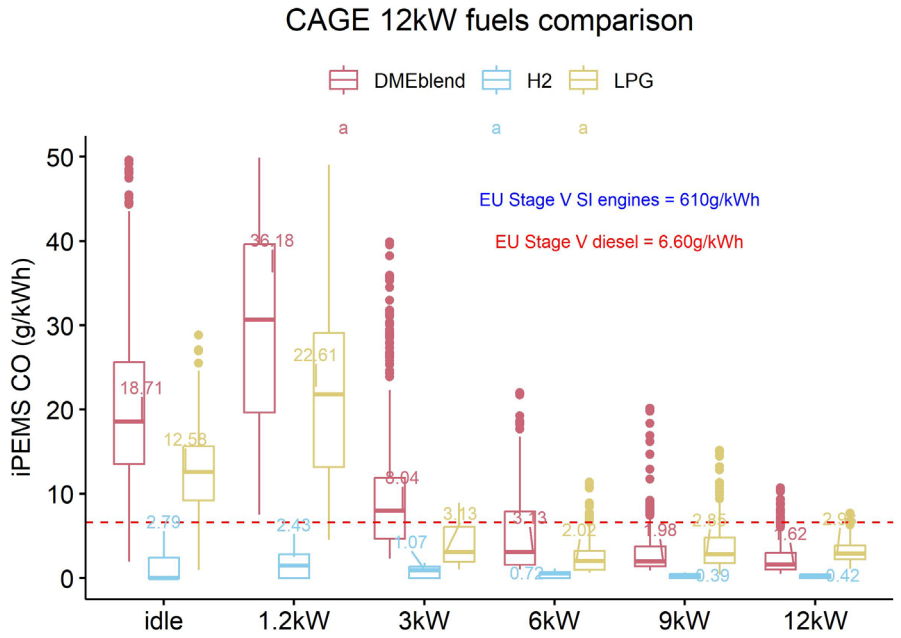
CO_2 emissions g/kWh



Imperial College London

Centre for Low Emission Construction

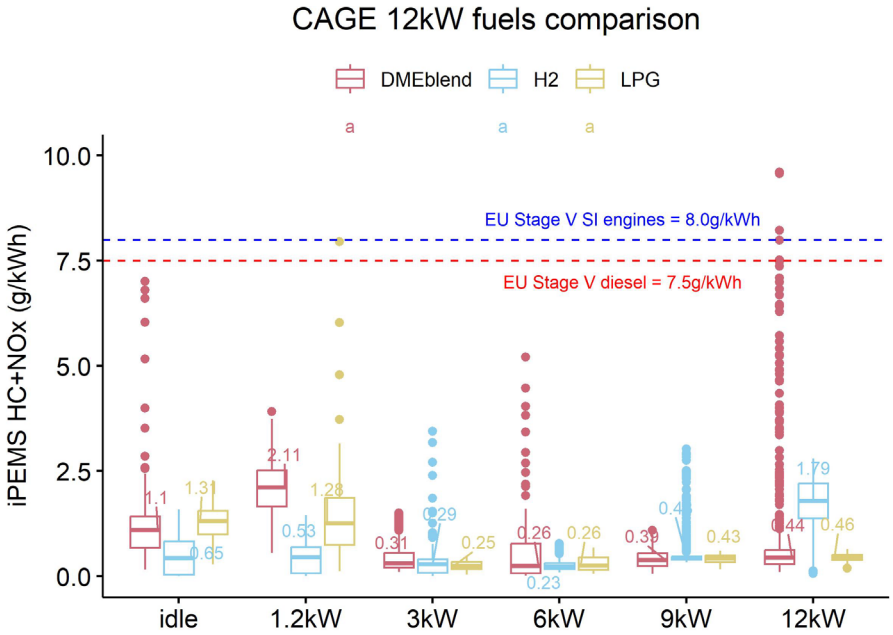
CO emissions g/kWh



Imperial College London

Centre for Low Emission Construction

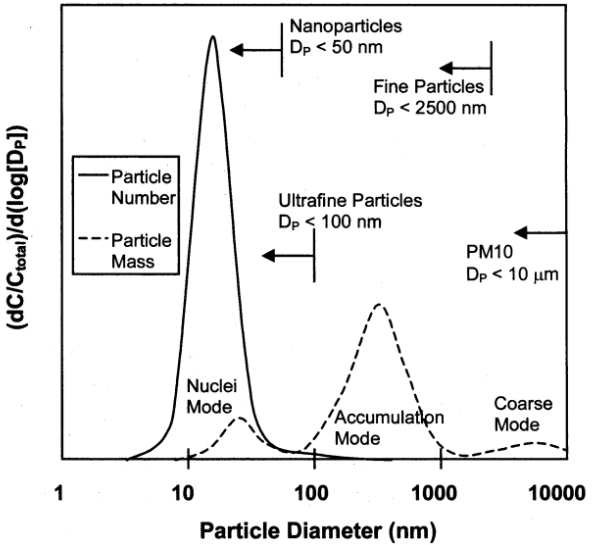
HC + NO_X emissions g/kWh



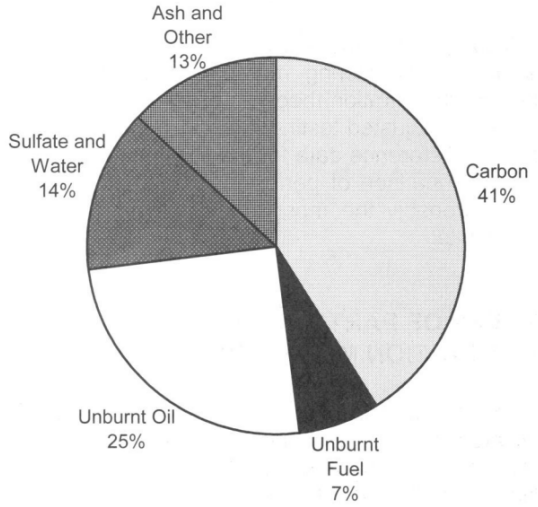
Imperial College London

Centre for Low Emission Construction

Theoretical particle distribution of diesel



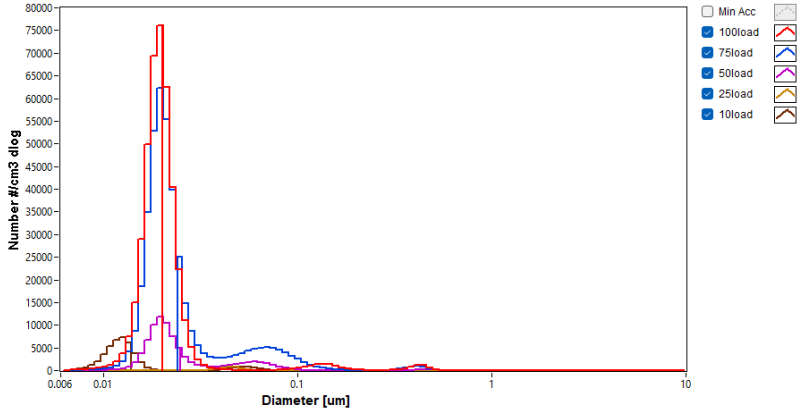
Typical diesel exhaust composition



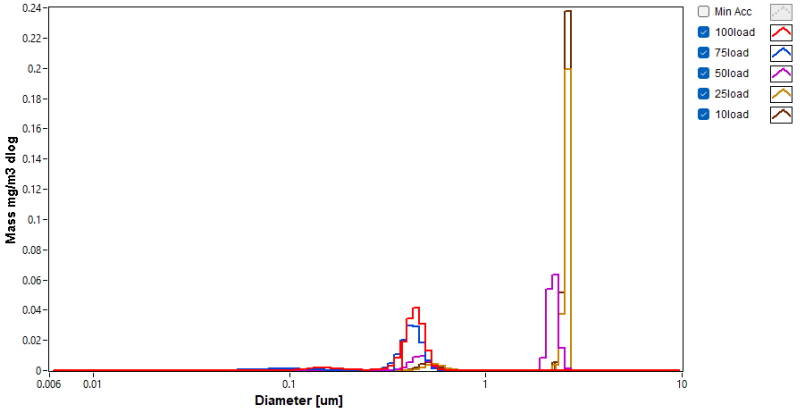
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, LPG



PN

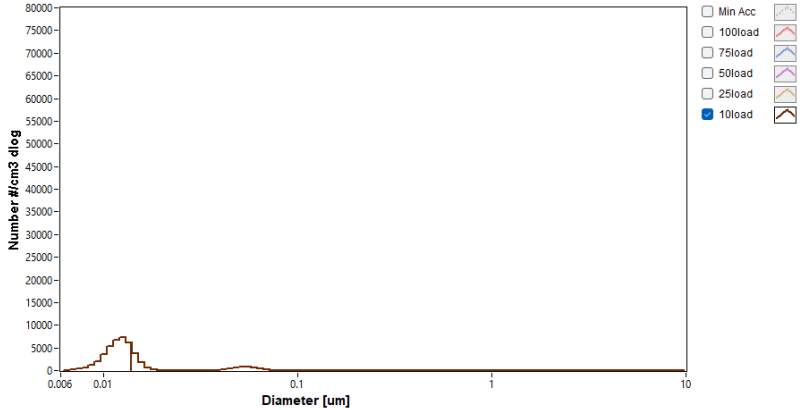


PM

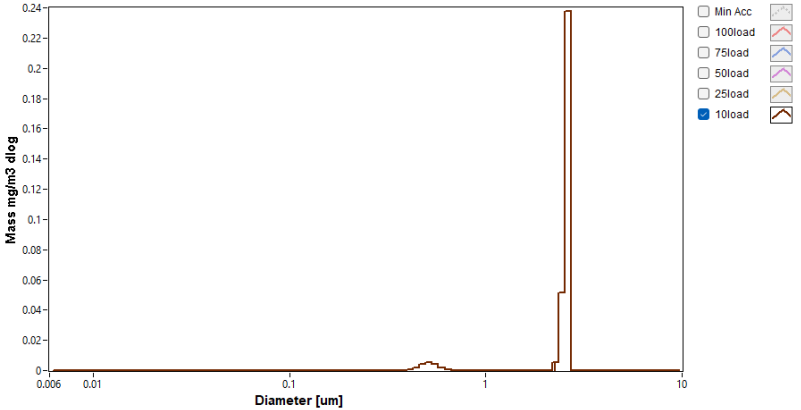
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, LPG 10%load



PN

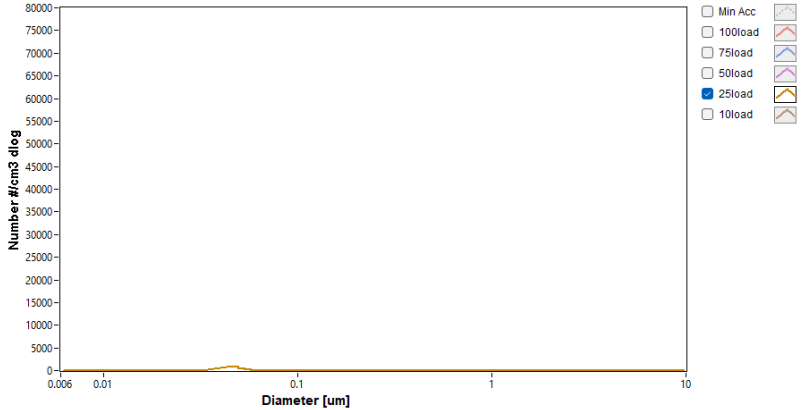


PM

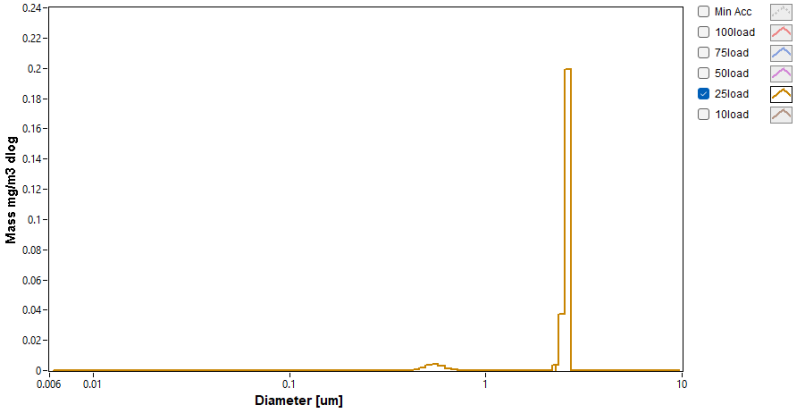
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, LPG 25%load



PN

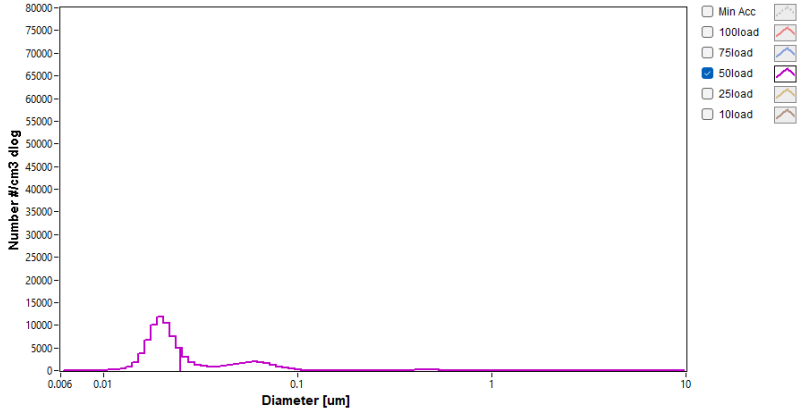


PM

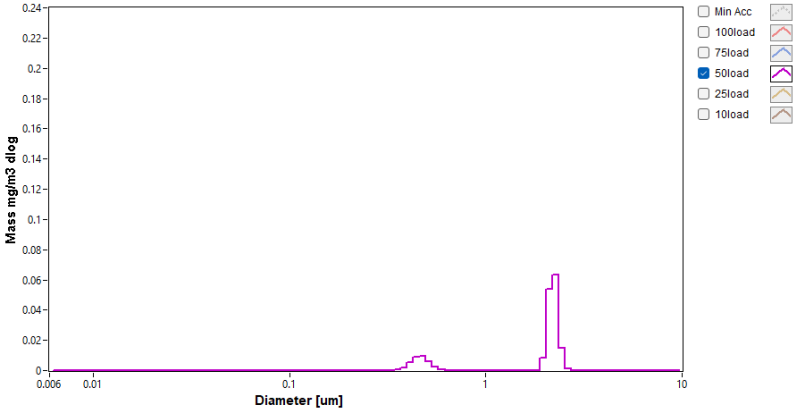
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, LPG 50%load



PN

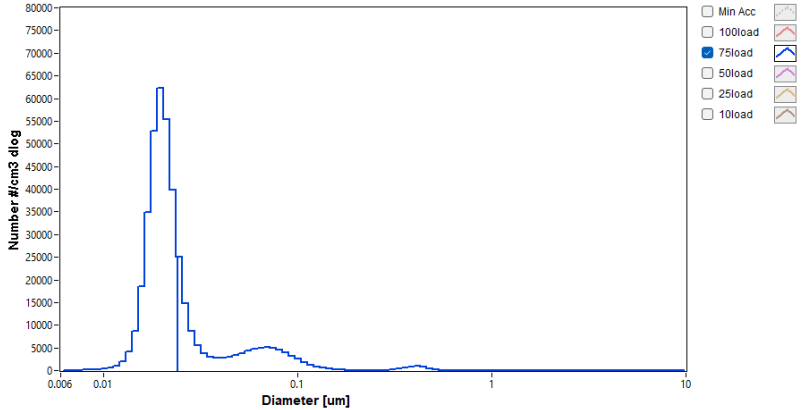


PM

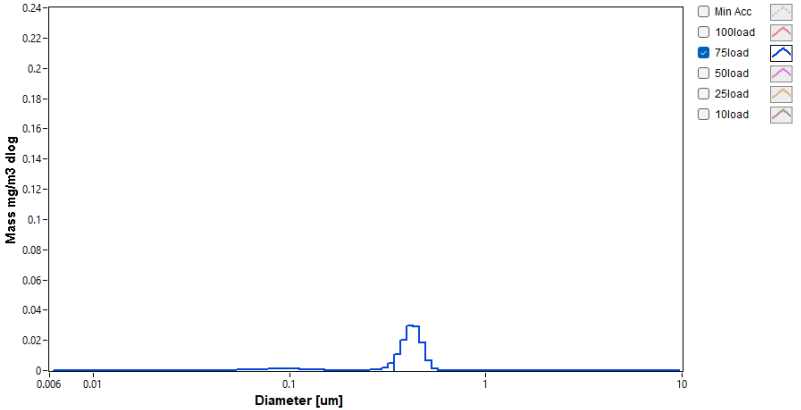
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, LPG 75%load



PN

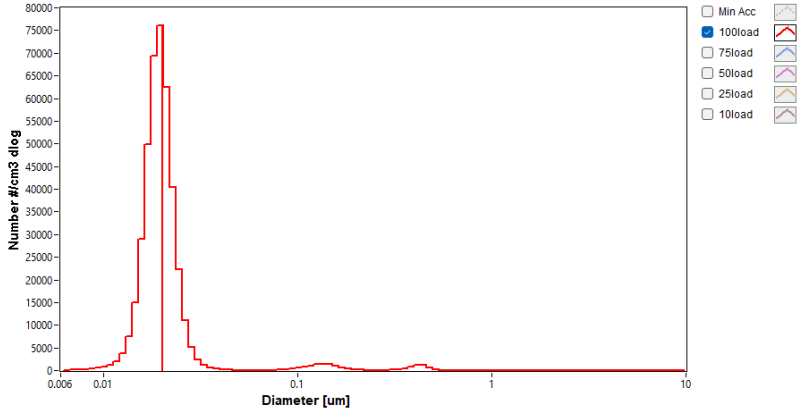


PM

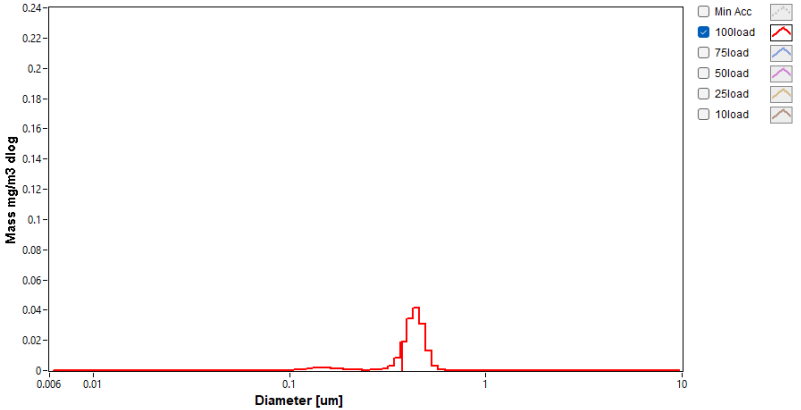
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, LPG 100%load



PN



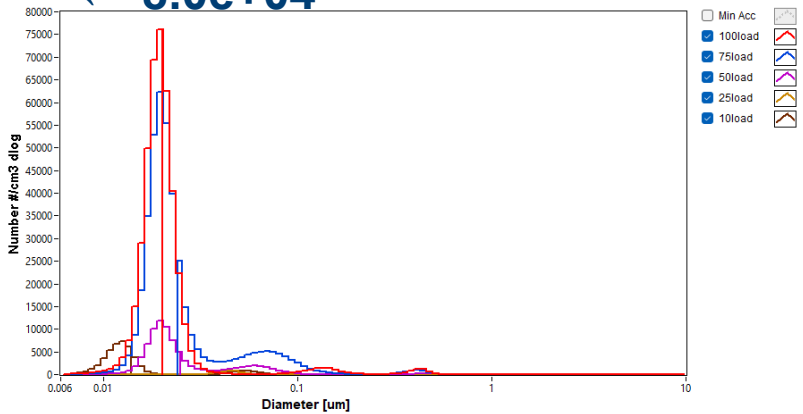
PM

Imperial College London

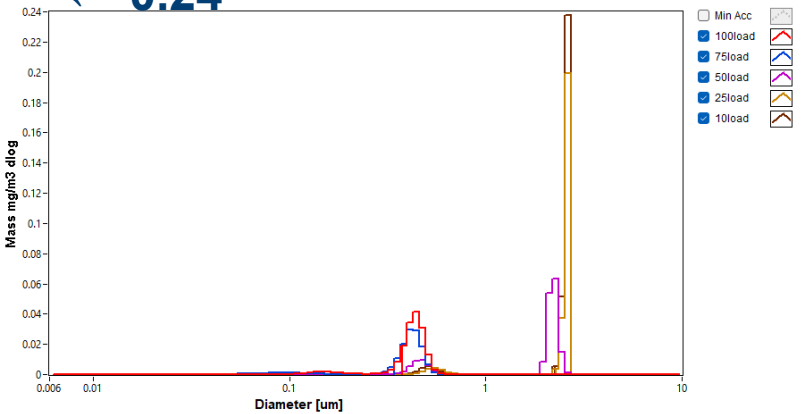
Centre for Low Emission Construction

Particle Size Distribution, LPG

← 8.0e+04



← 0.24



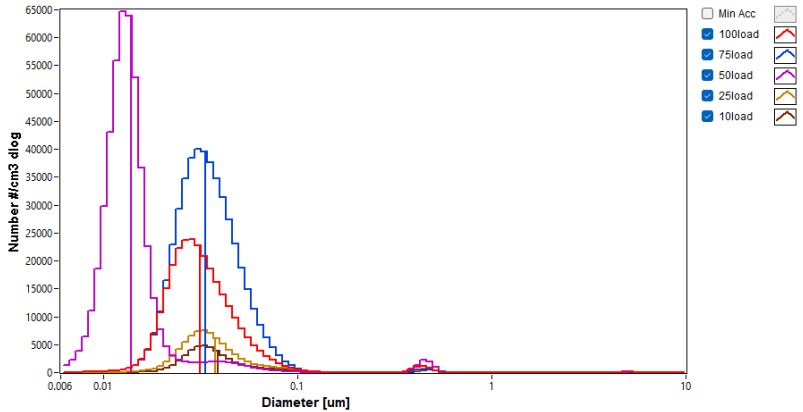
PN

PM

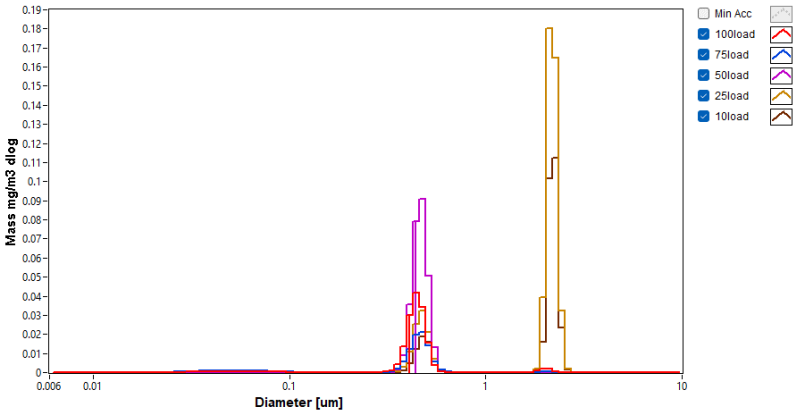
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, DME



PN

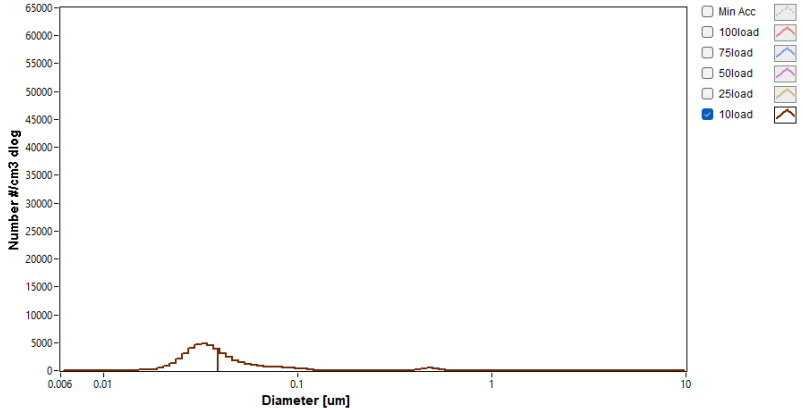


PM

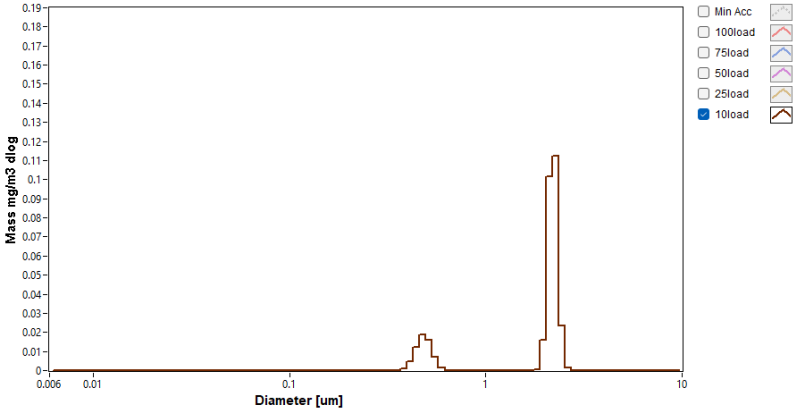
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, DME 10%load



PN

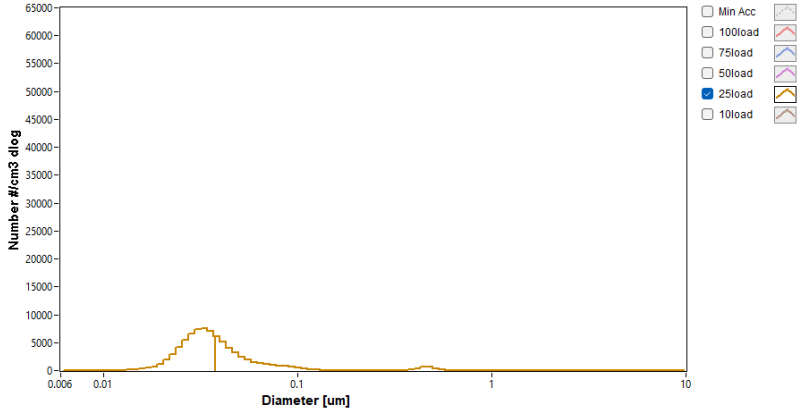


PM

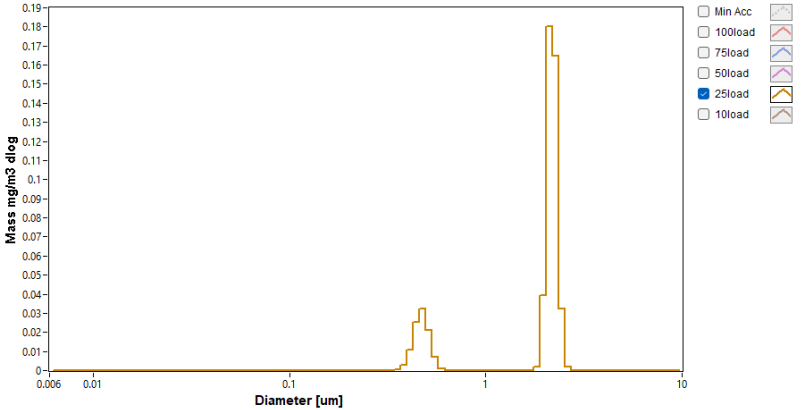
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, DME 25%load



PN

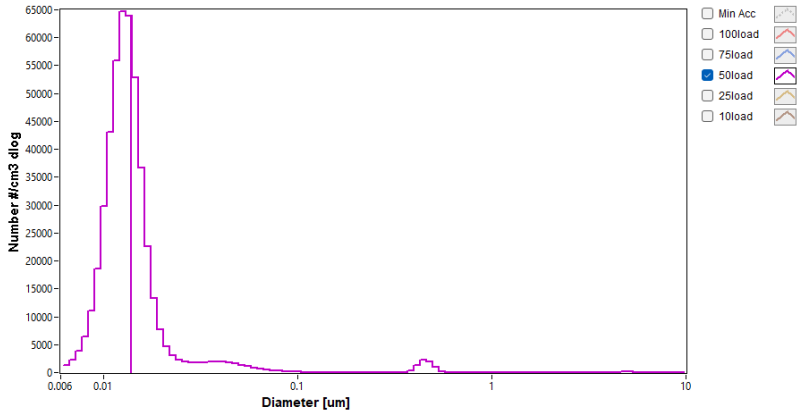


PM

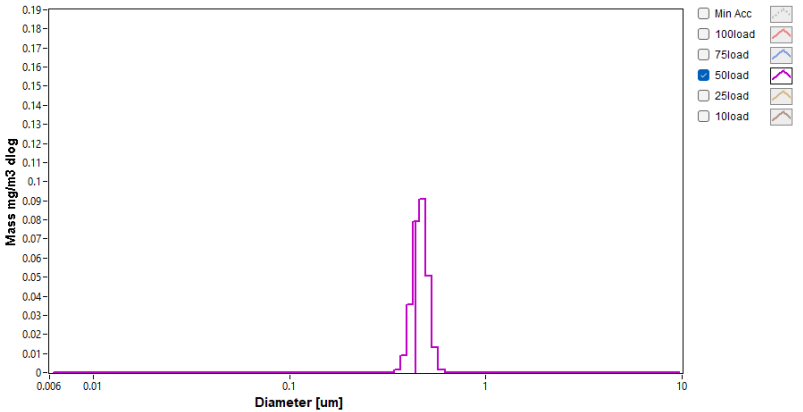
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, DME 50%load



PN

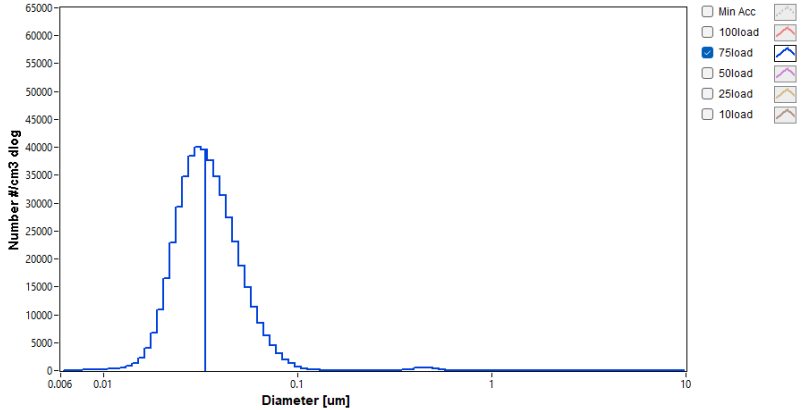


PM

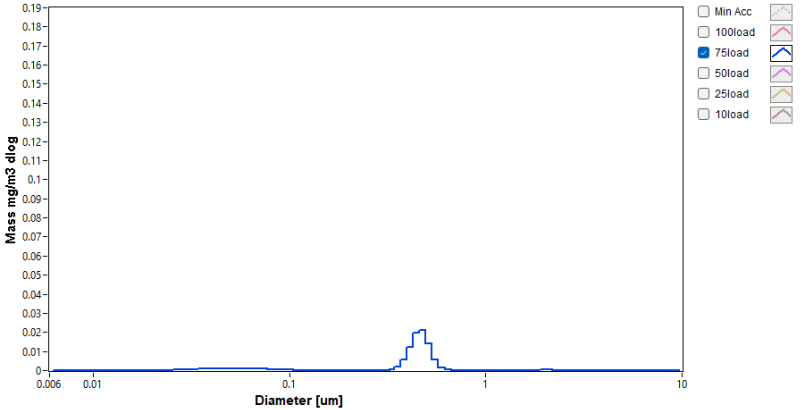
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, DME 75%load



PN

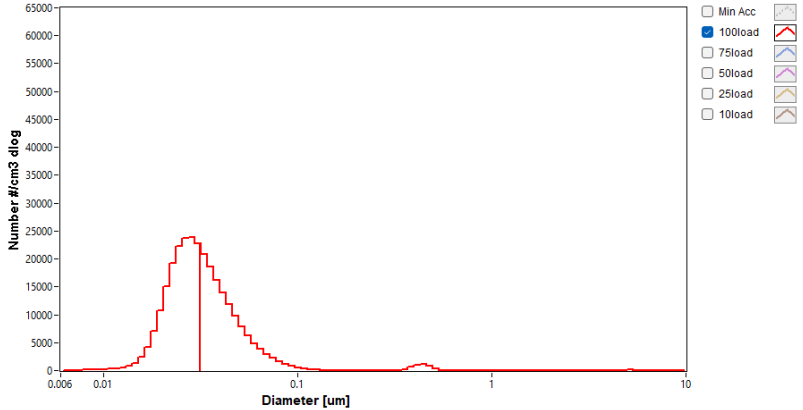


PM

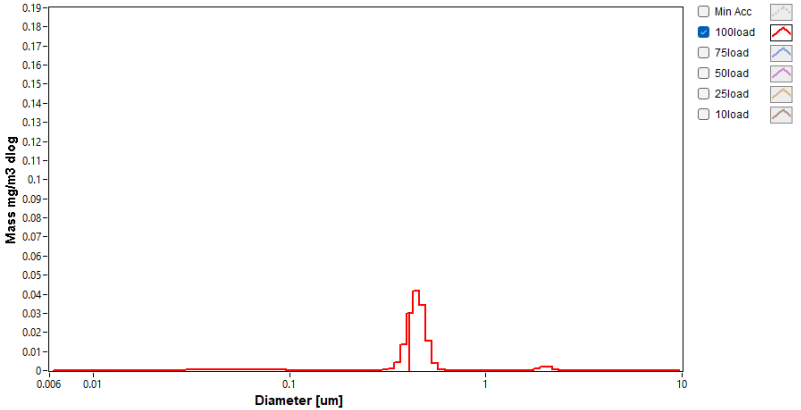
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, DME 100%load



PN



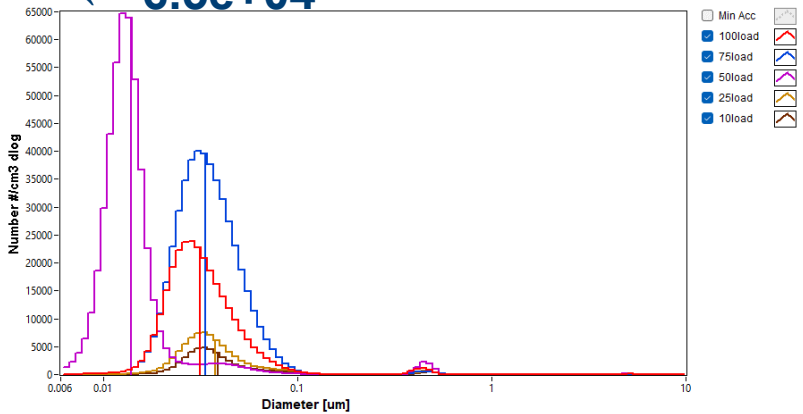
PM

Imperial College London

Centre for Low Emission Construction

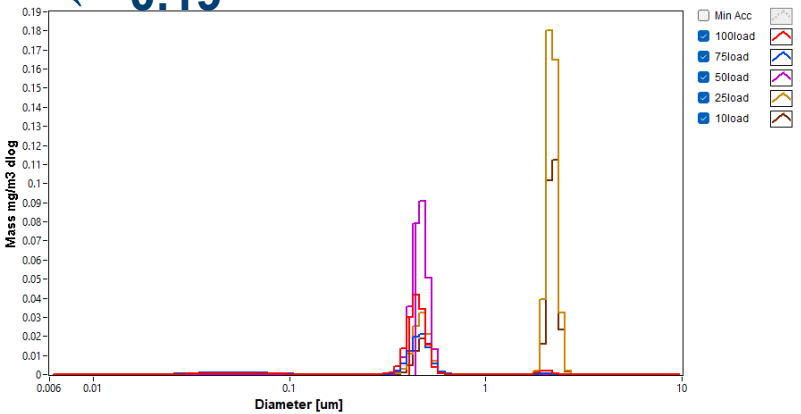
Particle Size Distribution, DME

← 6.5e+04



PN

← 0.19

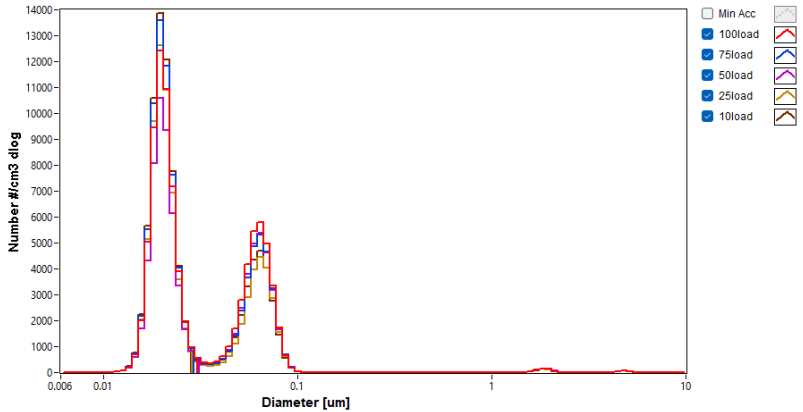


PM

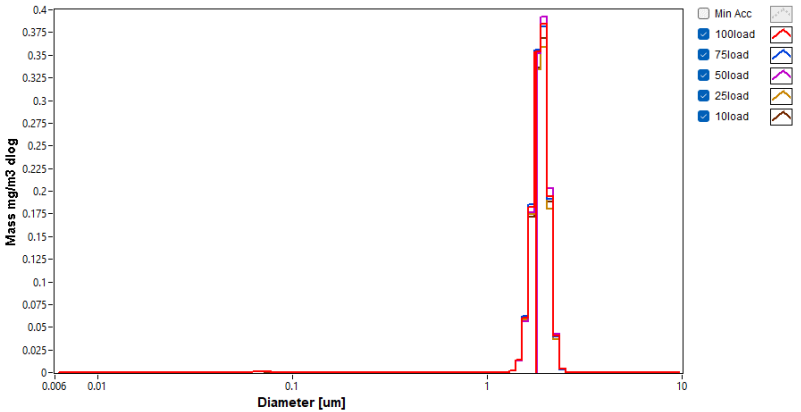
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, H_2



PN

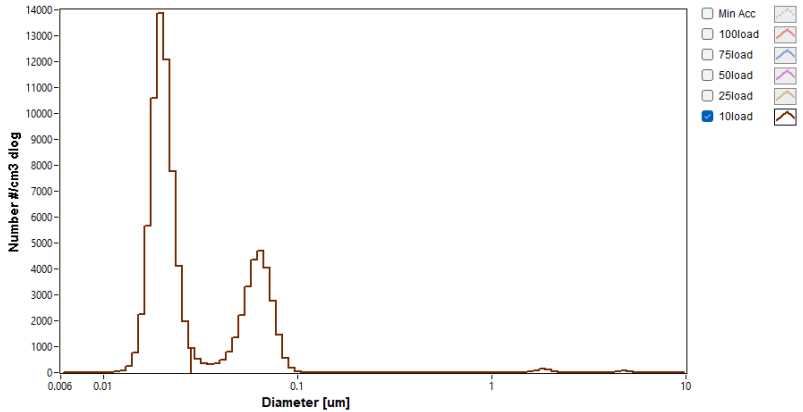


PM

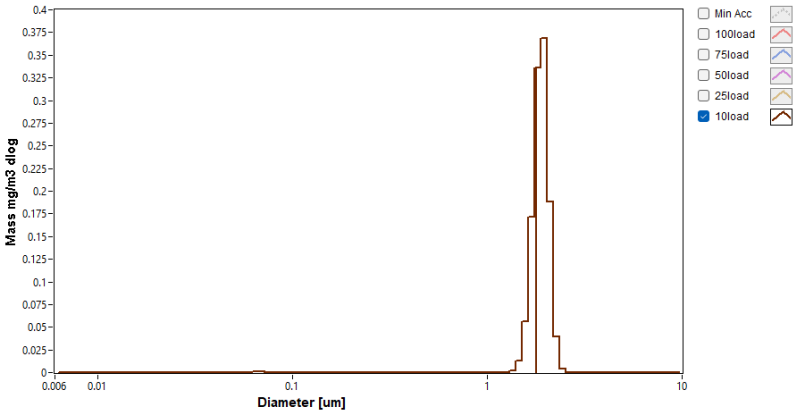
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, H_2 10%load



PN

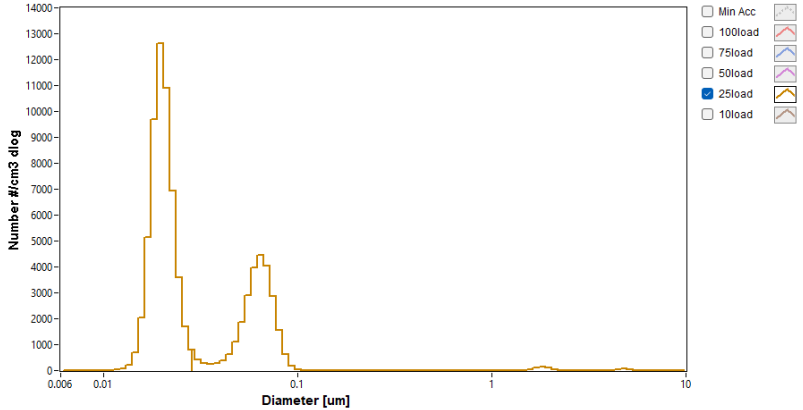


PM

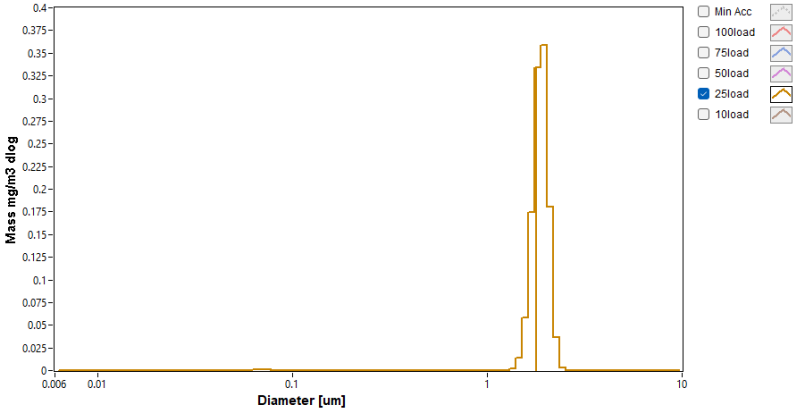
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, H_2 25%load



PN

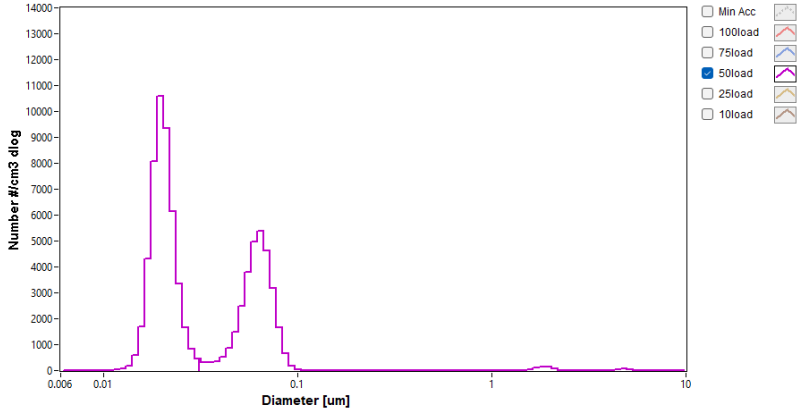


PM

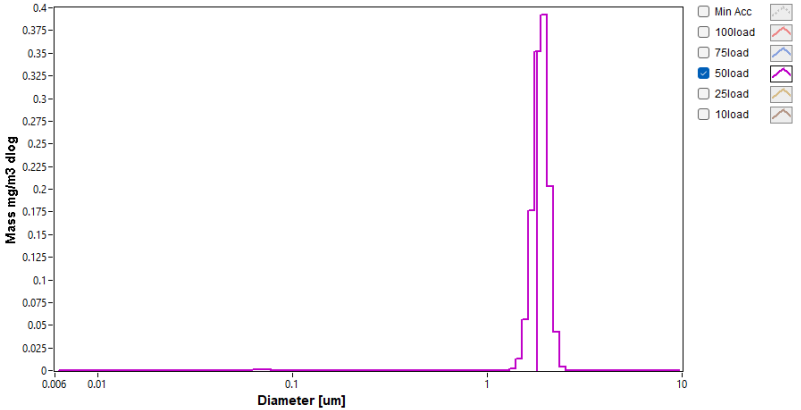
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, H_2 50%load



PN

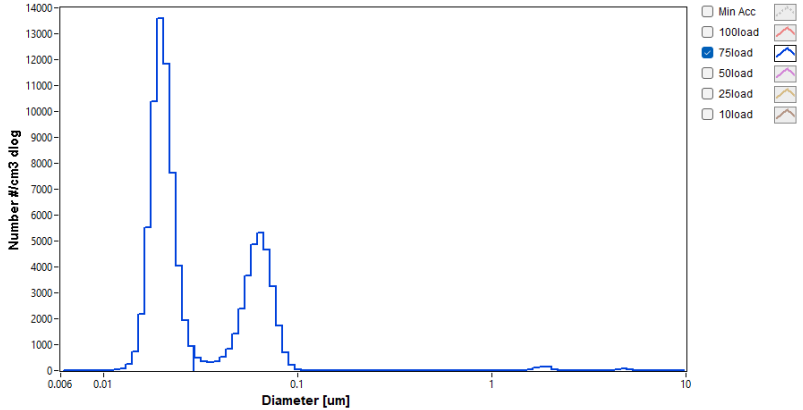


PM

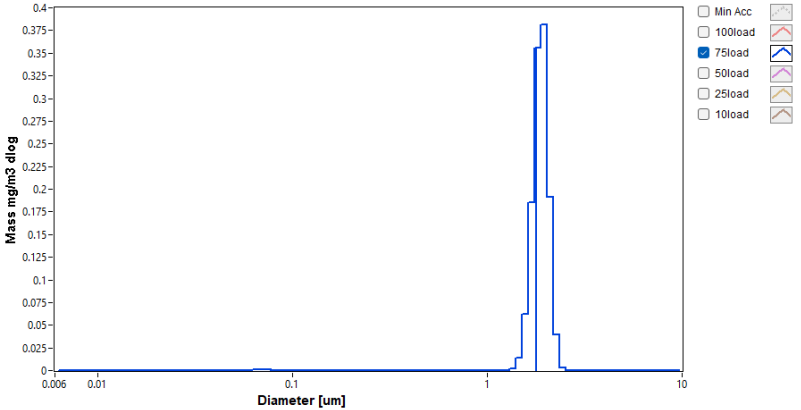
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, H_2 75%load



PN

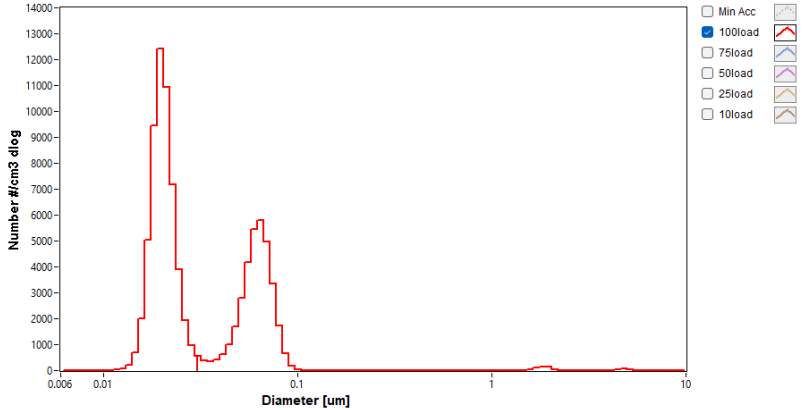


PM

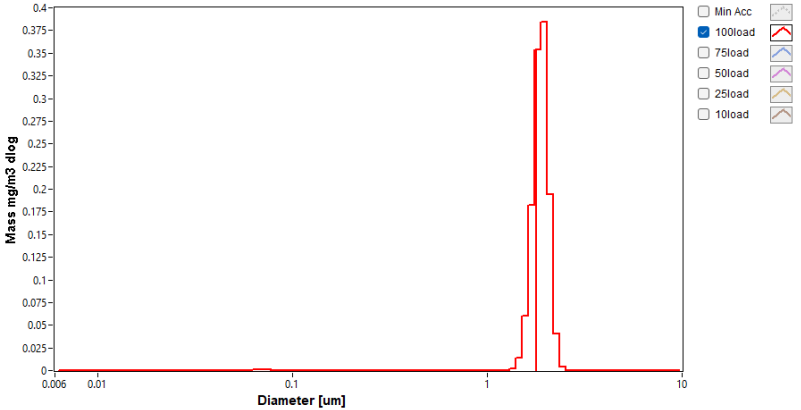
Imperial College London

Centre for Low Emission Construction

Particle Size Distribution, H_2 100%load



PN



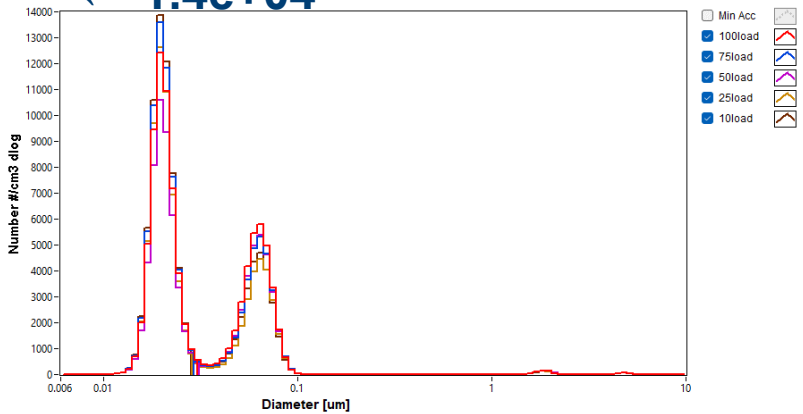
PM

Imperial College London

Centre for Low Emission Construction

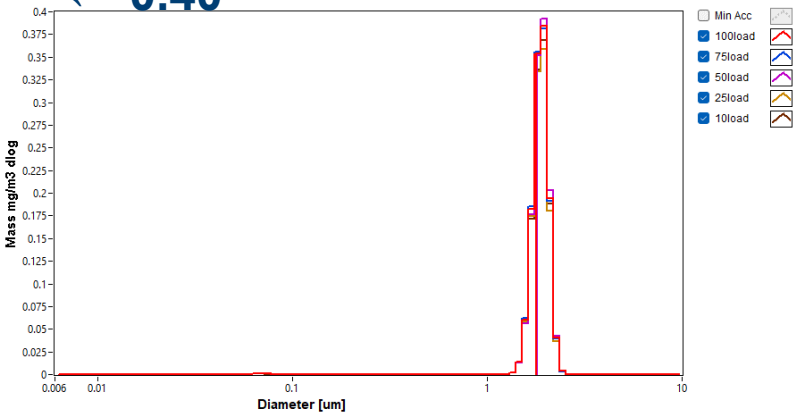
Particle Size Distribution, H_2

← 1.4e+04



PN

← 0.40



PM

Imperial College London

Centre for Low Emission Construction

Summary

- In a single engine, 3 different fuels used: LPG, H_2, DME-blended-LPG
- Gaseous pollutants (CO & HC+NO_X) were orders of magnitude below the EU Stage V emission limits for SI engines
- No particle emission limits for SI engines
- Different particle number size distribution noted for H_2 combustion (bi-modal)
- Do we need to get rid of EU 23nm regulation?
- Should future regulation (Stage VI / Tier 6) include particle emissions for SI?

Funded by United Kingdom Department for Energy Security and Net Zero – Red Diesel Replacement Phase II

Imperial College London

Centre for Low Emission Construction

Questions?

[Centre for Low Emission Construction]

[Environmental Research Group]

[www.clec.uk]

[carl.desouza@imperial.ac.uk]

Centre for
Low Emission Construction
IMPERIAL