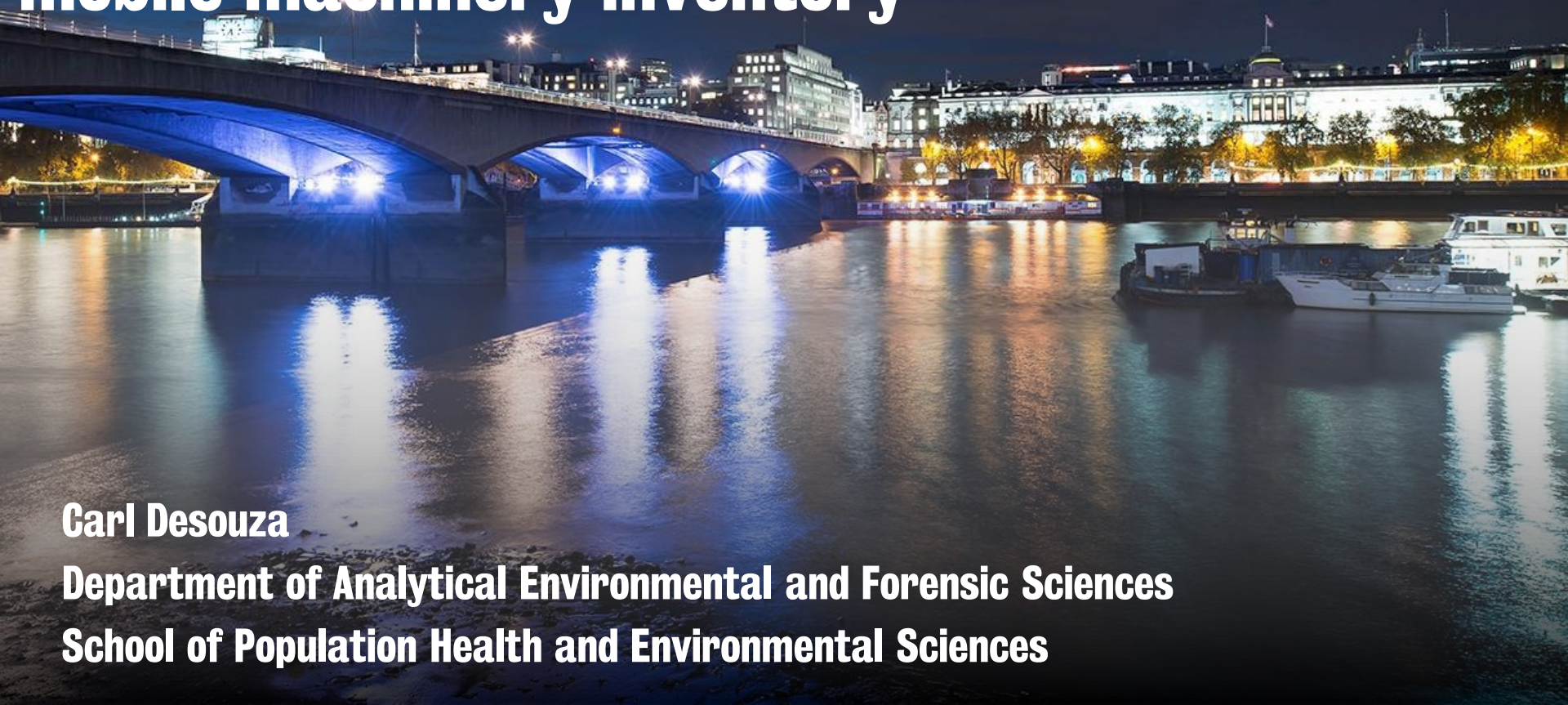
LONDON LOW EMISSION
CONSTRUCTION PARTNERSHIP

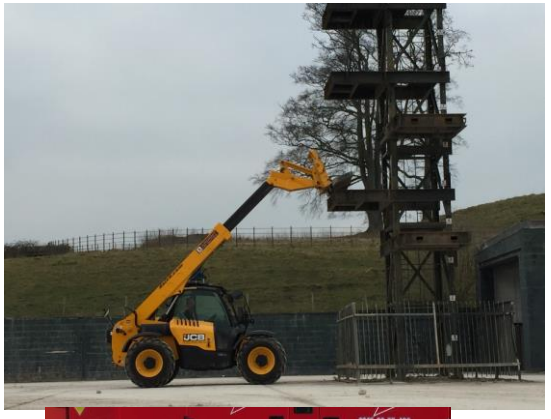
KING'S College LONDON

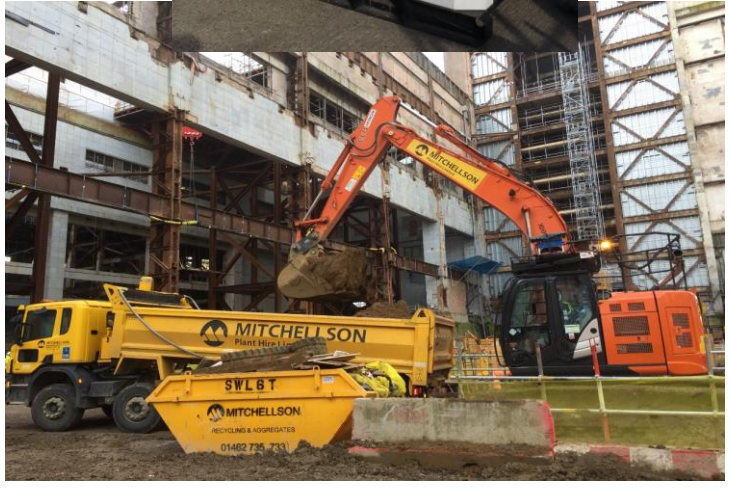
Developing a new approach to the non-road mobile machinery inventory



Carl Desouza
Department of Analytical Environmental and Forensic Sciences
School of Population Health and Environmental Sciences

What is non-road mobile machinery?

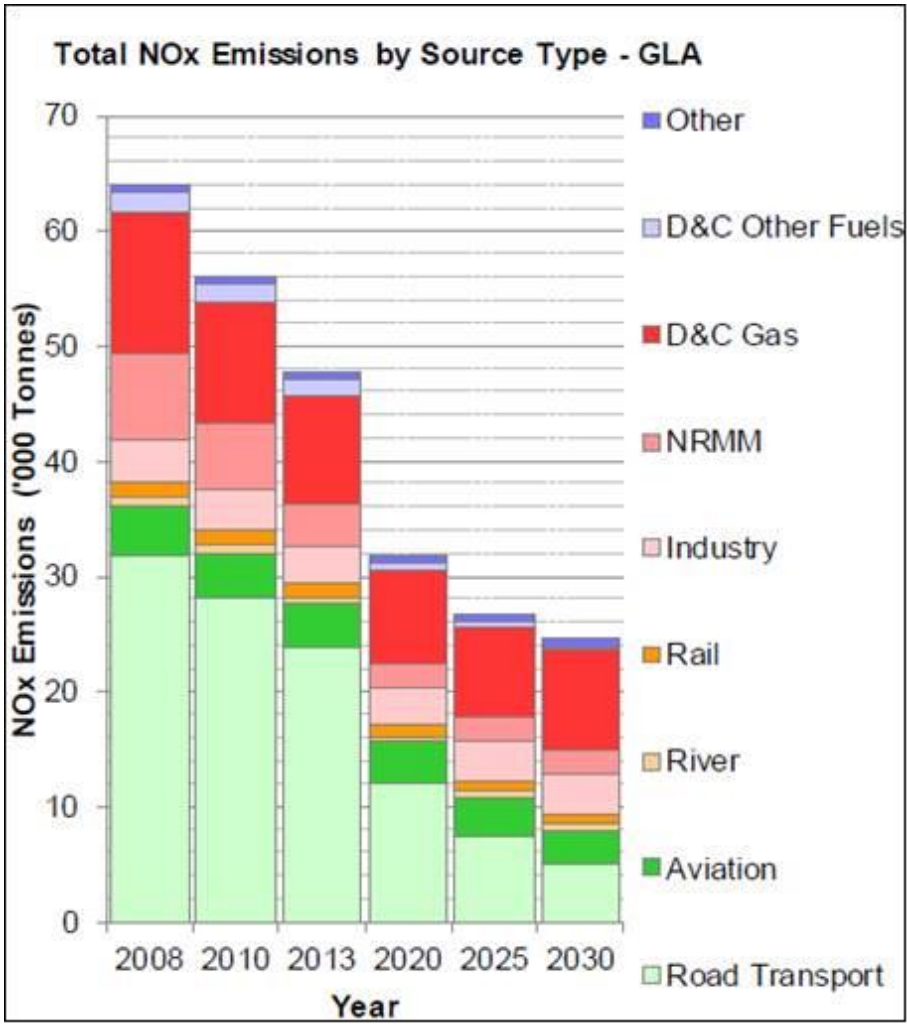




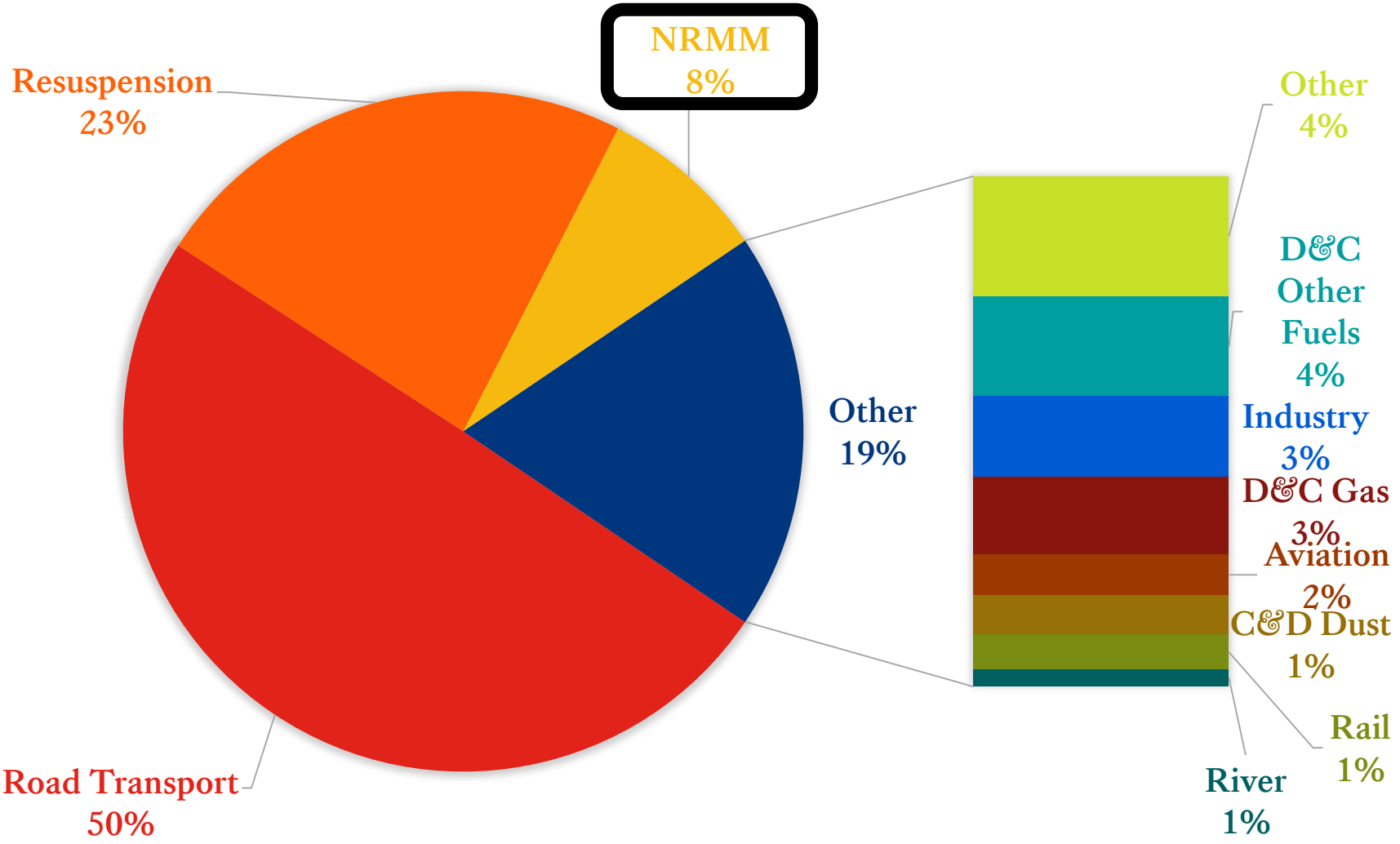
Why is an emissions inventory important?

- Helps accurately quantify the contribution from current sources of emissions.
- Enables testing of future policies and scenarios.
- Information on pollutants and trends.

- Future implications:
  - road transport is expected to decrease
  - other sources may increase – relative to road transport
  - new sources (e.g. wood burning) may be considered for future inventories

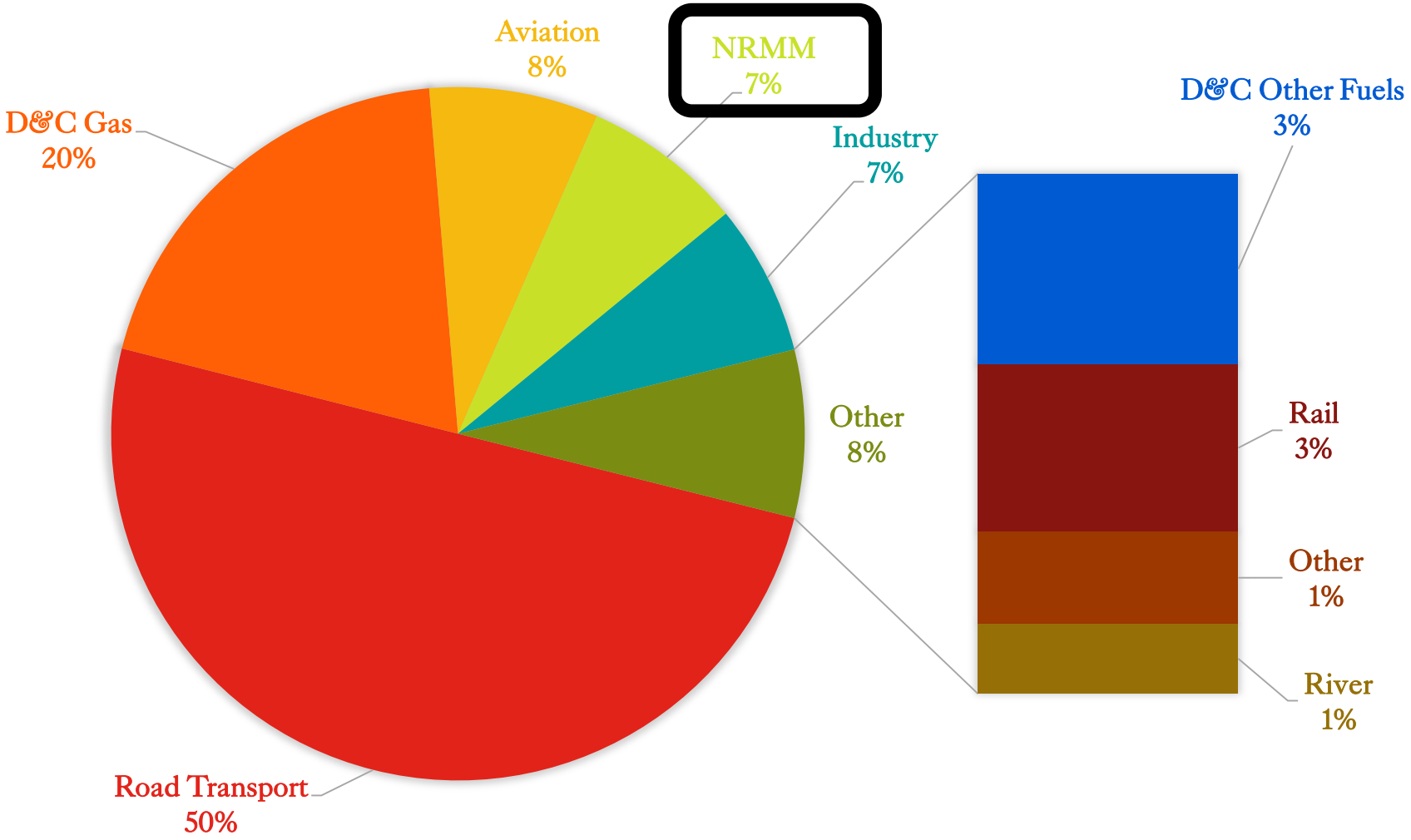


PM_{10} Emissions Inventory



London Atmospheric Emissions Inventory (LAEI) 2013

NO_x Emissions Inventory



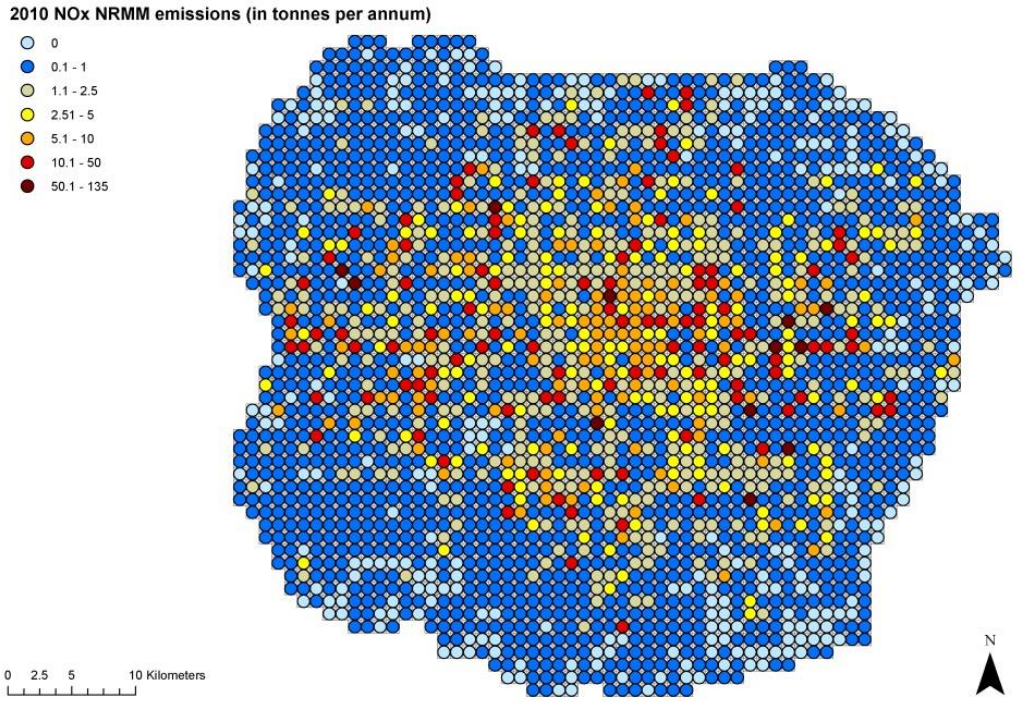
London Atmospheric Emissions Inventory (LAEI) 2013

Current London Atmospheric Emissions Inventory methodology

- LAEI is based on a proportion of the NAEI, and is determined by employment in the construction sector and distributed geographically using the London Development Database.

  - Emissions are calculated based on estimated NRMM fleet composition and fuel consumption data.

  - Employment was selected as an appropriate indicator of construction activity.



Tier 2 : technology dependant approach

Activity data is resolved into more detailed machinery classifications. This method classifies the equipment into the fuel types and layers of engine technology.

Algorithm:

$$E_i = \sum_j \sum_t FC_{j,t} \times EF_{i,j,t}$$

where,

E_i=mass of emissions of pollutant i during the inventory period

$FC_{j,t}$=fuel consumption of fuel type j by equipment category c and of technology type j

$EF_{i,j}$=average emission factor for pollutant i for fuel type j for equipment category c and of technology type t

i = pollutant type (e.g. NO_X, CO_2, PM_{10})

j = fuel type (e.g. diesel, gasoline)

t = off-road technology (e.g. Stage I, Stage II,..., Stage V)

**EMEP/EEA air pollutant emission inventory guidebook, 2016*

Tier 3 : equipment specific and technology stratified approach

The NRMM is disaggregated to the equipment level, including specific operational data and size of engine. This method requires hours of operation, and the emissions are presented as 'emissions/kWh'.

Algorithm:

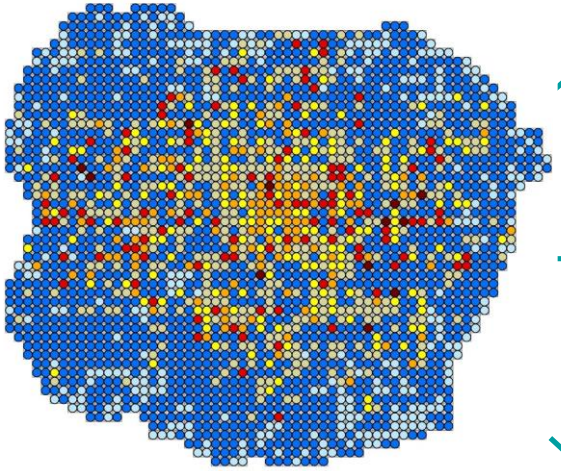
$$E = N \times HRS \times P \times (1 + DFA) \times LFA \times EF_{Base}$$

where,

E	= mass of emissions of pollutant i during inventory period
N	= number of engines (units)
HRS	= annual hours of use
P	= engine size (kW)
DFA	= deterioration factor adjustment
LFA	= load factor adjustment
EF_{Base}	= base emission factor (g/kWh)

**EMEP/EEA air pollutant emission inventory guidebook, 2016*

‘Bottom-up’ emissions inventory development



Real World Emission Factors

- Engine test bed emissions factors
- PEMS measurements
- mini-PEMS measurements

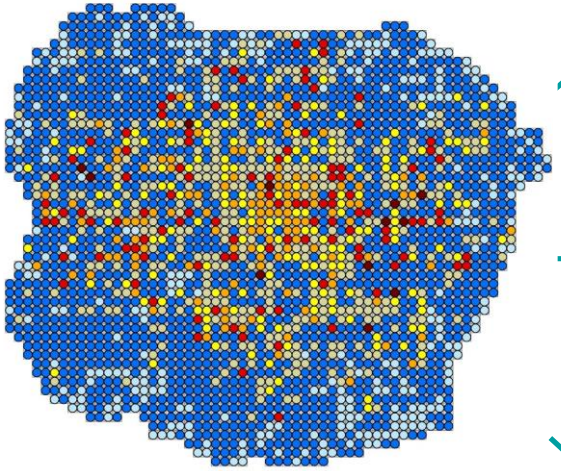
Fleet Composition and Location

- NRMM register
- Supplier data (e.g. JCB LiveLink)
- Hire company data
- Compliance visits

Activity Data

- Engine Telematics
  - Supplier data (e.g. Komatsu’s ‘komtrax’)
  - Generator suppliers
  - Direct measurements

Real-world emission factors



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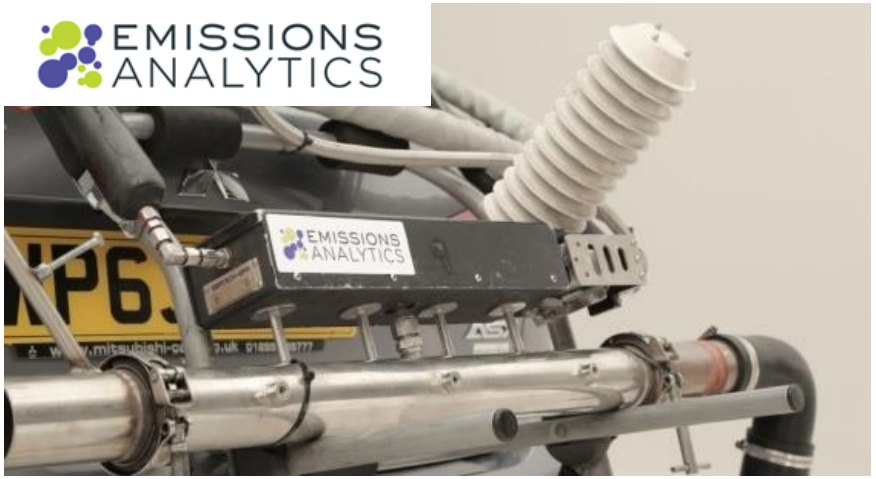
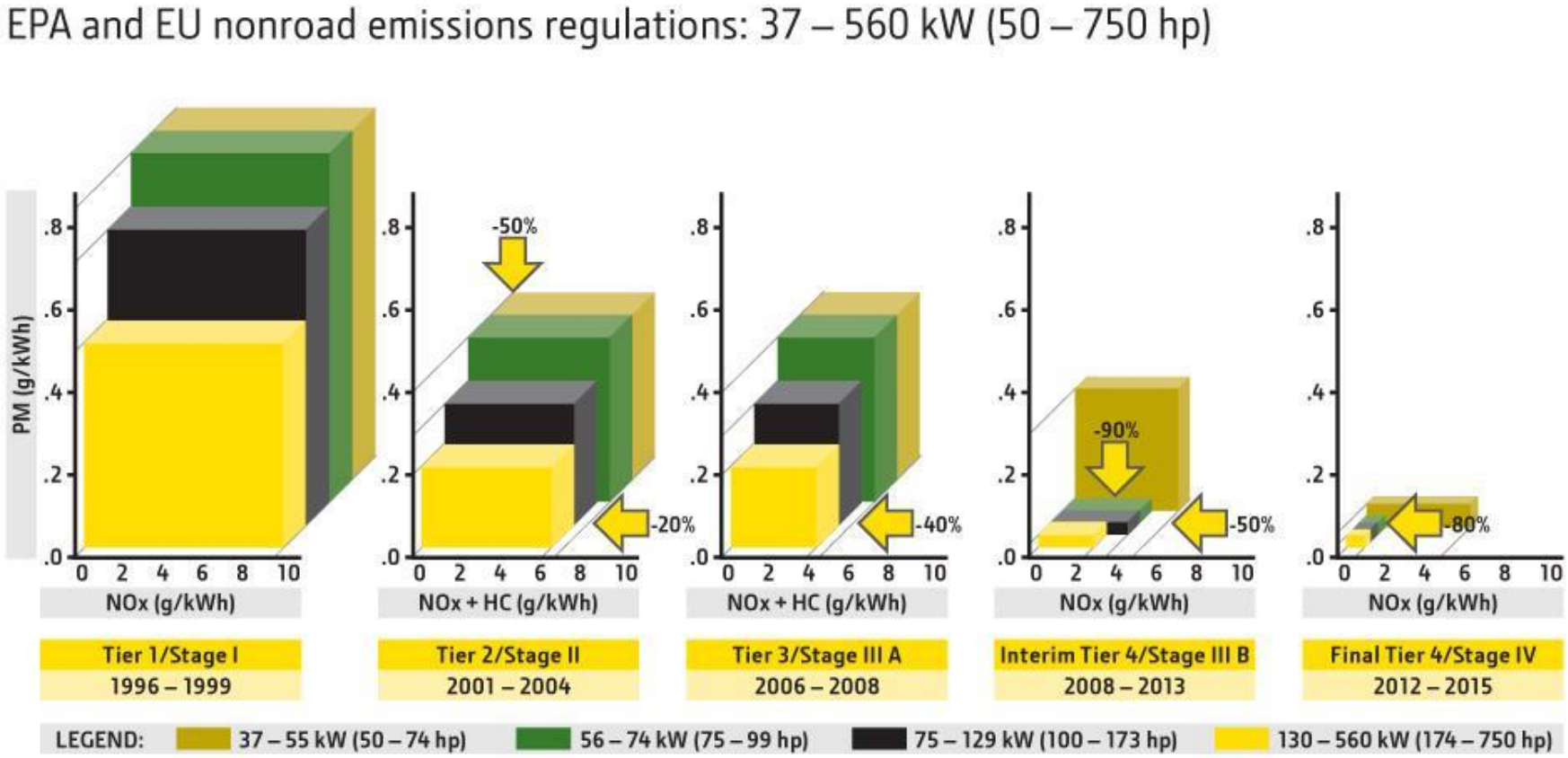
Portable Emissions Measurement System

- Why do we need real-world emission factors: “Diesel gate”
- PEMS is used to measure tail-pipe emissions from on-road vehicles.
- ‘In-use’ real-world emissions measurements.
- Measures CO/CO_2, NO/NO_2, THC, PM/PN.
- Laboratory grade instruments; conform to UN-ECE R-49 and EU No. 582/2011



NRMM – PEMS

Regulatory NRMM Emissions Standards

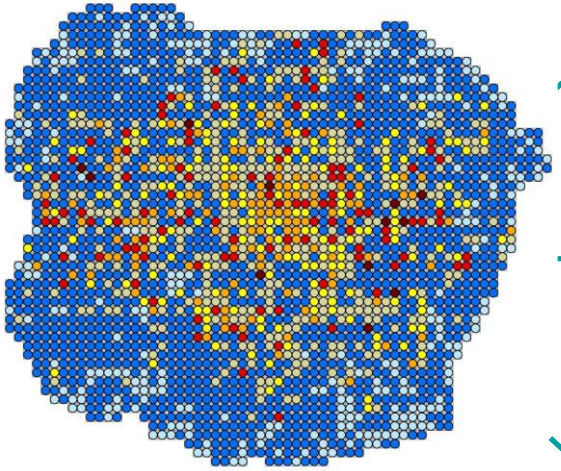


mini-PEMS

- The LLECP and KCL have developed a ‘mini-PEMS’ as part of the PhD.
- The mini-PEMS is used to measure NO_X.

- Advantages of the mini-PEMS:
    - Small
    - Light-weight
    - Low setup time
    - Small setup footprint
    - Can measure a wider range of NRMM

Fleet composition and Location



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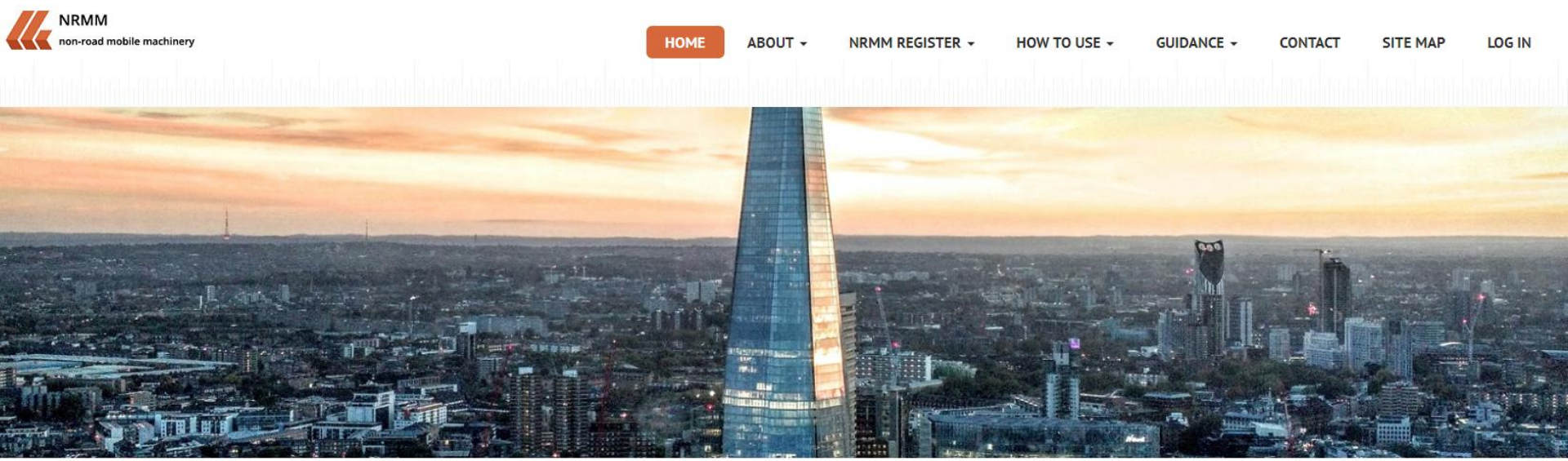
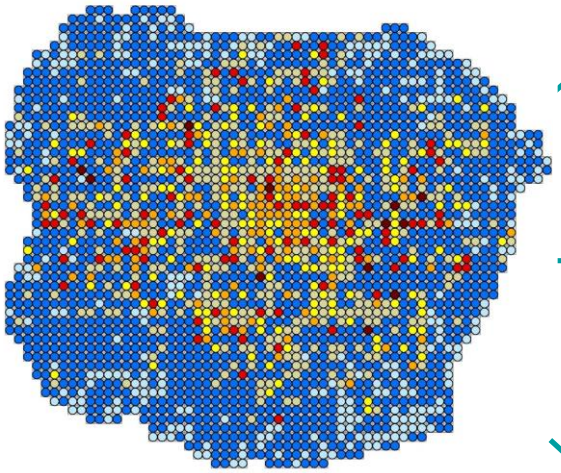
London’s NRMM register



LONDON'S 'LOW EMISSION ZONE' FOR NON-ROAD MOBILE MACHINERY

Air pollution is one of the most significant challenges facing London. We are in breach of European legal limits for Nitrogen Dioxide (NO2) and many areas exceed safe limits for Particulate Matter (PM) as set by the World Health Organisation. Bold new measures have been proposed by the Mayor to tackle emissions from road transport, particularly diesel vehicles, including an expansion of the Ultra Low Emission Zone. However, this is only half the problem – current estimates of emissions from NRMM used on construction sites are shown to be responsible for 7% of NOx emissions, 14% for PM2.5 and 8% of PM10 emissions across the Capital and this is why the Mayor is determined to take action.

Activity Data



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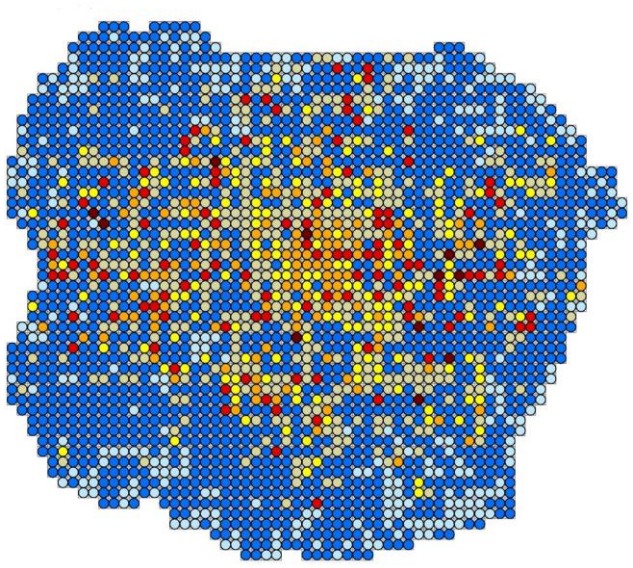
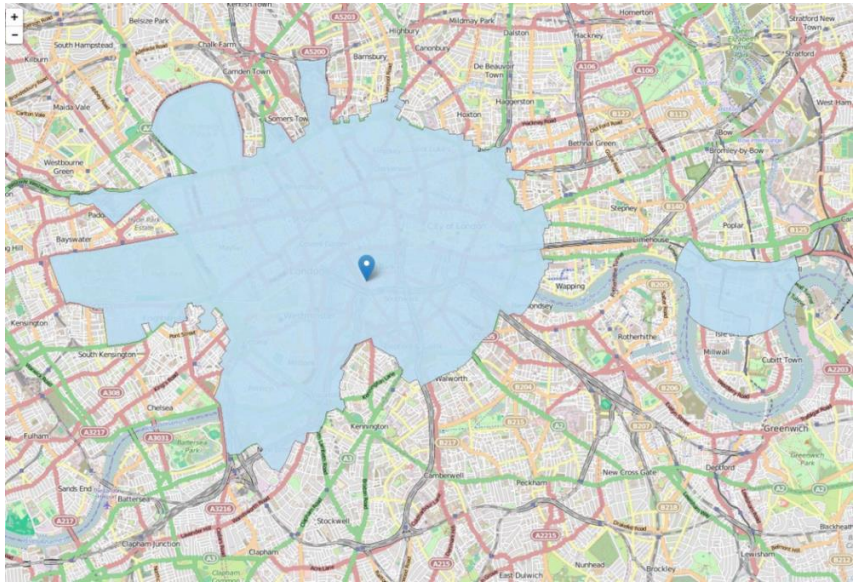
Activity Data: Supplier data and direct measurements

- Engine telematics
  - Idle time and working time
  - Start and end date
  - Longitude and latitude of machines
- Direct measurements: engine data loggers
  - Engine On-Board Diagnostics data
  - Parameters include idle time, torque, speed

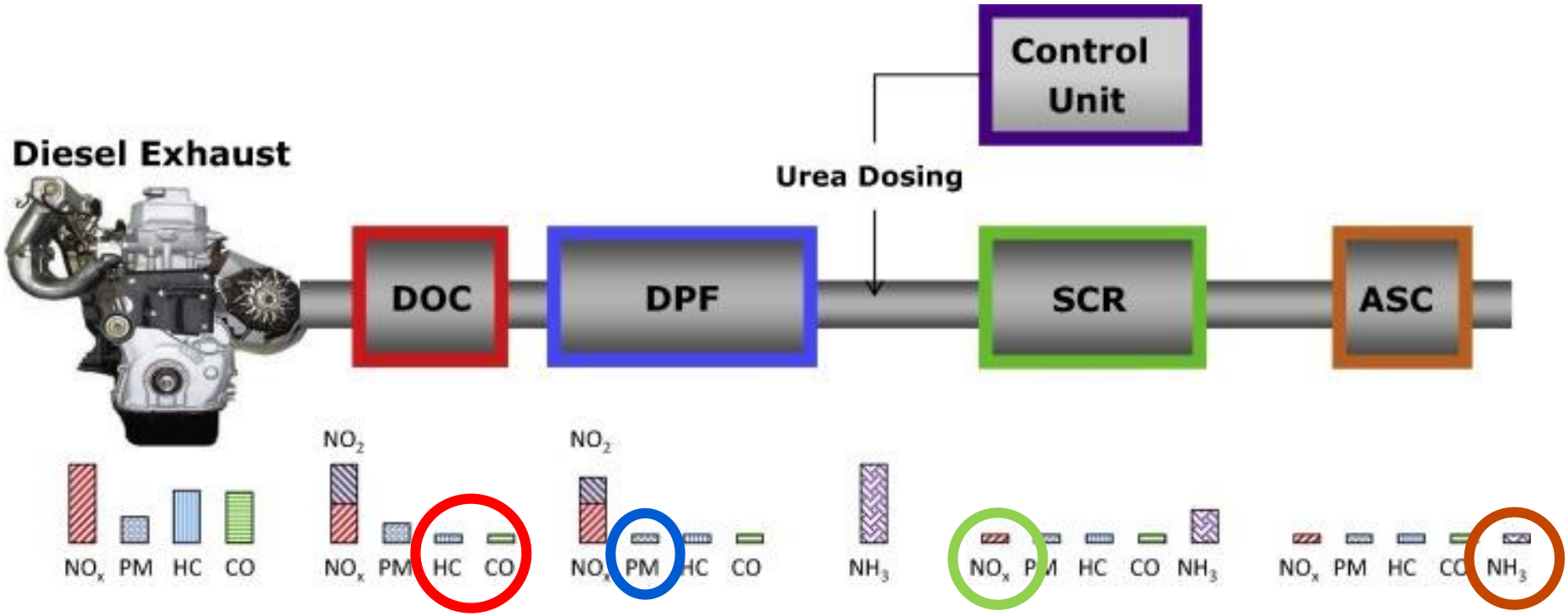
Testing future policy scenarios

- Using the bottom-up inventory to test future policy:
  - Retrofitting older Stage III-A generators.
  - Using cleaner Stage IV excavators instead of Stage III-B excavators.





Emission reduction: exhaust gas after-treatment



source: Andreas Åberg et. al "Parameter estimation and analysis of an automotive heavy-duty SCR catalyst model", 2017, Journal of Chemical Engineering Science

Inventory estimations for retrofitting generators

- 85% reduction in NO_X, using SCR technology to retrofit generators.
- If all Stage III-A generators were retrofitted, 3% reduction in overall NO_X from NRMM.

- 2 orders of magnitude reduction in particle number, using DPF.

Inventory estimation replacing III-B with IV

- Most common used type and standard of NRMM.

- Minimal change in particle emissions, since no DPF for Stage IV.

- 96% reduction in NO_X, going from Stage III-B to Stage IV, for excavators.
- If Stage IV excavators were used in place of all Stage III-B excavators, 24% reduction in overall NO_X from NRMM.

Summary

- NRMM is an important part of the inventory, as an emissions source:
    - 8% of PM_{10} and 7% of NO_X
- There are large uncertainties in the way the current inventory is developed:
    - emission factors: fuel use
    - activity data: employment in the construction sector
- The 'bottom-up' approach is more robust and detailed:
    - emissions factors: PEMS tests
    - activity data: NRMM register and data loggers

- The 'bottom-up' emissions inventory gives us the ability to test future policy scenarios.
- Feedback to the industry (machinery use) as well as the government (policy).
- Enables us to identify and develop policy, based on the results from our findings.

Acknowledgements

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EMISSIONS ANALYTICS

JCB

GREEN URBAN TECHNOLOGIES

Speedy

mace

Firefly HYBRID POWER

SUPPORTED BY
MAYOR OF LONDON

TRANSPORT FOR LONDON

Further information

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