Priority Challenges for Future Air Quality Research

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Challenges

- Changes in pollution environment in future cities
- Future drivers of air quality policy
- Moving to exposure based risk to public health
- Evaluating the relative toxicity of different sources of air pollution

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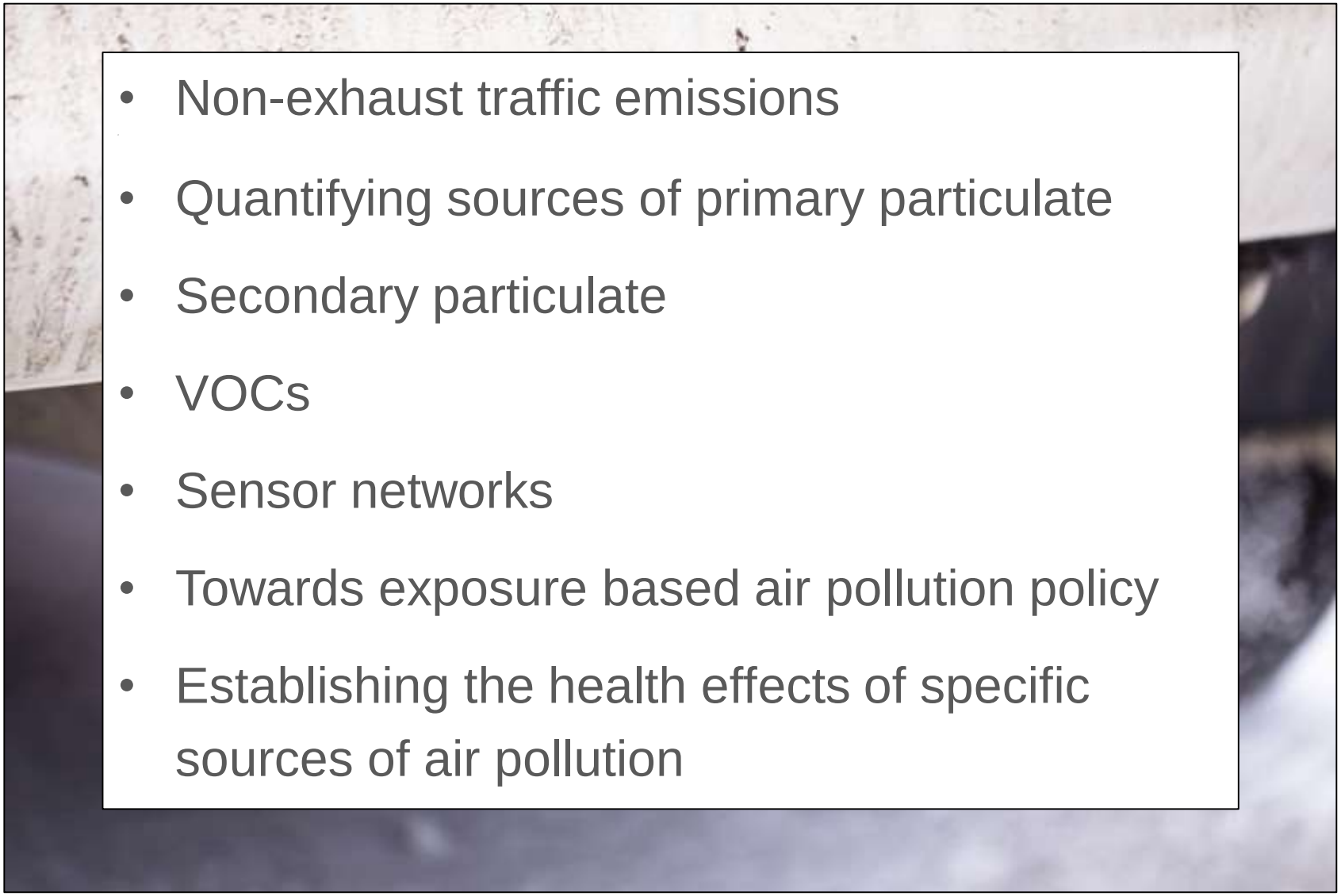
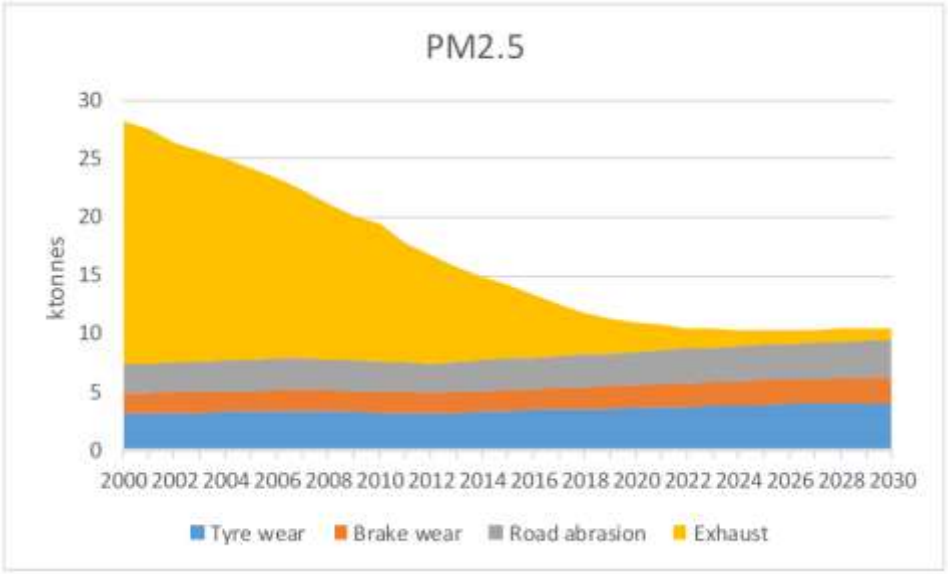
Challenges

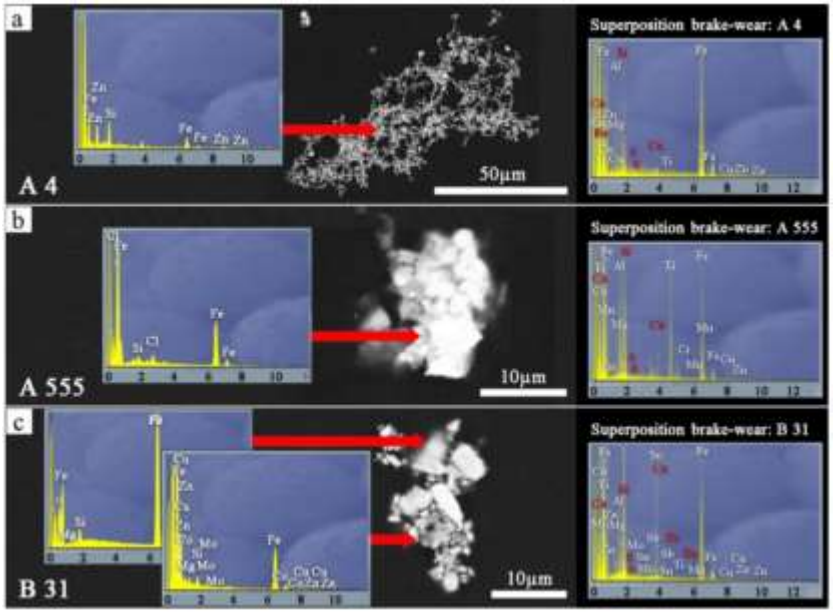


- Non-exhaust traffic emissions
- Quantifying sources of primary particulate
- Secondary particulate
- VOCs
- Sensor networks
- Towards exposure based air pollution policy
- Establishing the health effects of specific sources of air pollution

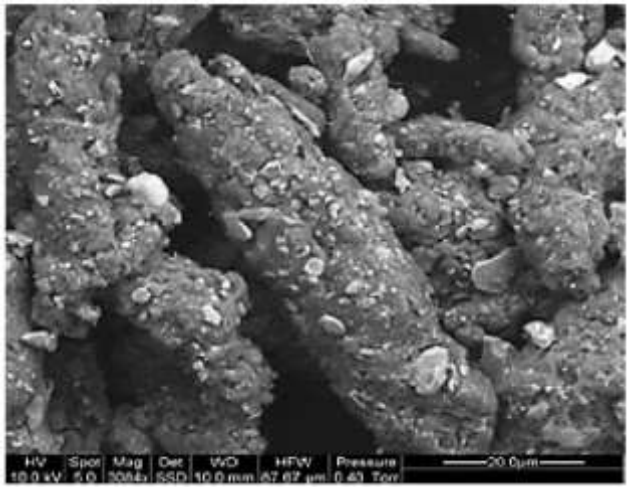
Non–exhaust road traffic emissions



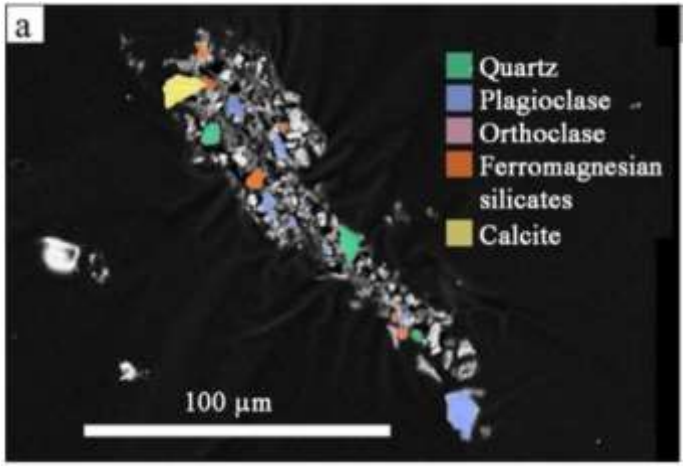
AQEG, *Non Exhaust Emissions from Road Traffic*, DEFRA, 2019



Sommer et al., *Aerosol and AQ Research*, 18, 2018



Panko et al., *Atmosphere* 10, 99, 2019.



Research questions

- What is the extent of non exhaust emissions?
  - Do we expect emission hotspots in locations not traditionally monitored, e.g. motorway slip roads?
- What is the size and composition of these particles?
  - If tyre abrasion particles are large, are they even a problem for PM_{10}?
- Can we obtain good source profiles for receptor modelling of source contribution?
- Are they having an effect on people's health and/or the wider environment?
- What do we expect these emissions to do in the future?
  - Will we see a net benefit or disbenefit from electric/hybrid/self-driving cars?
- How can we mitigate these emissions and public exposure?

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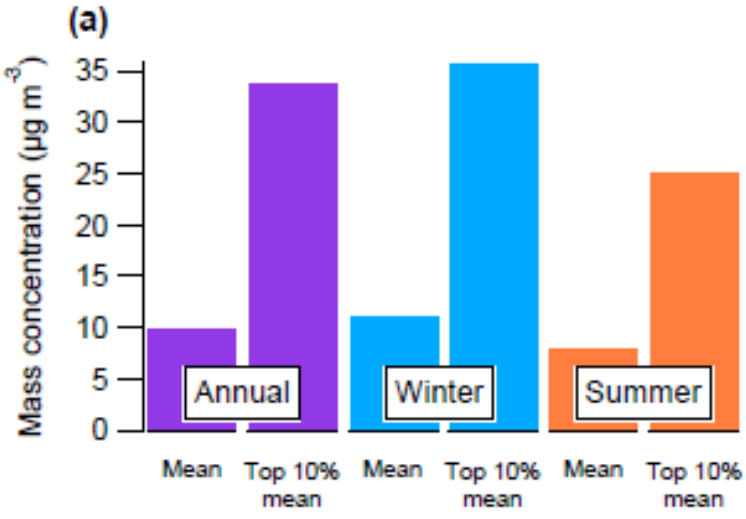
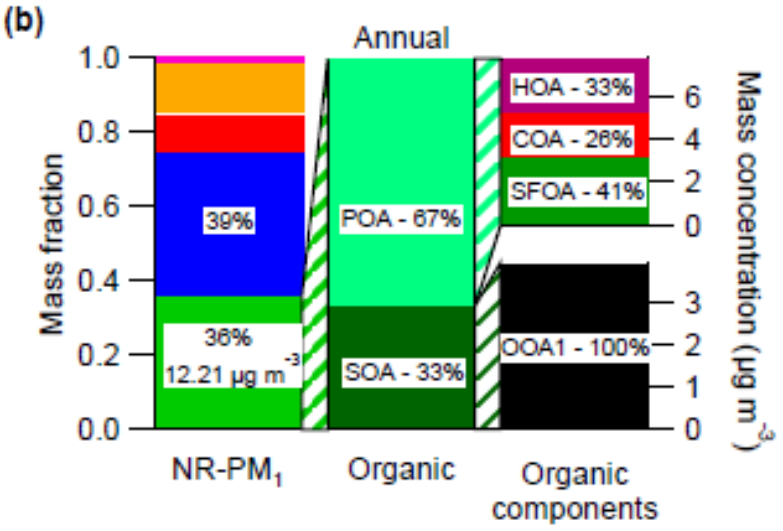
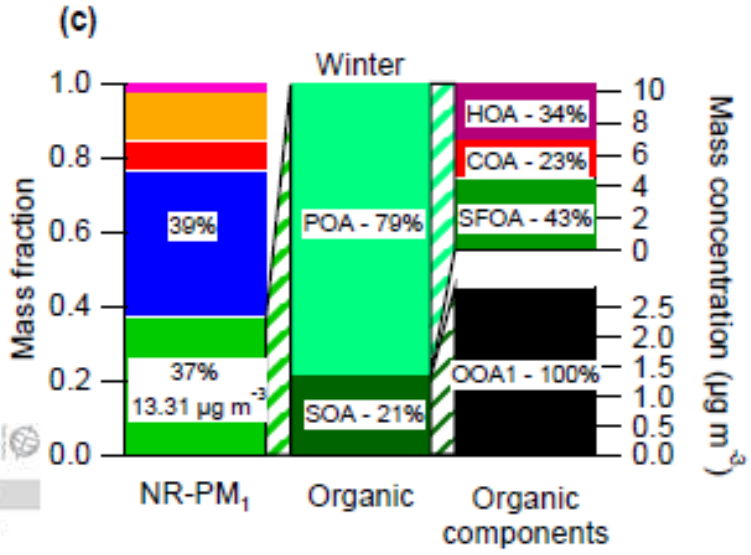
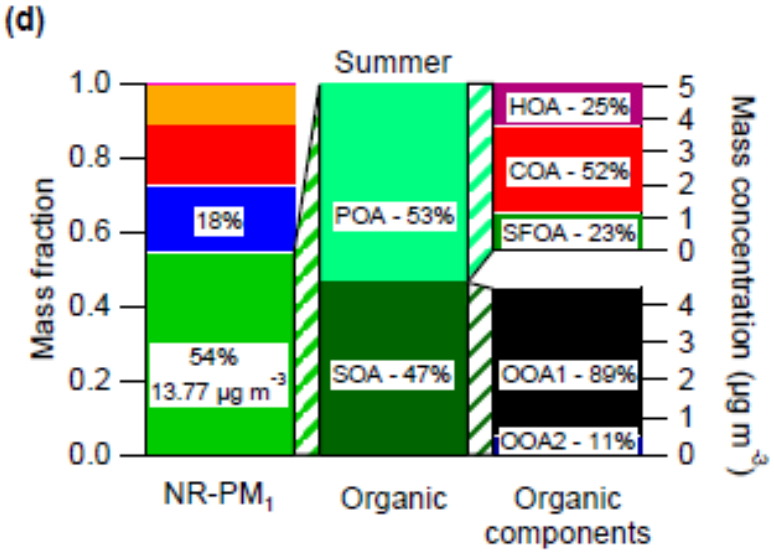
Composition of PM2.5









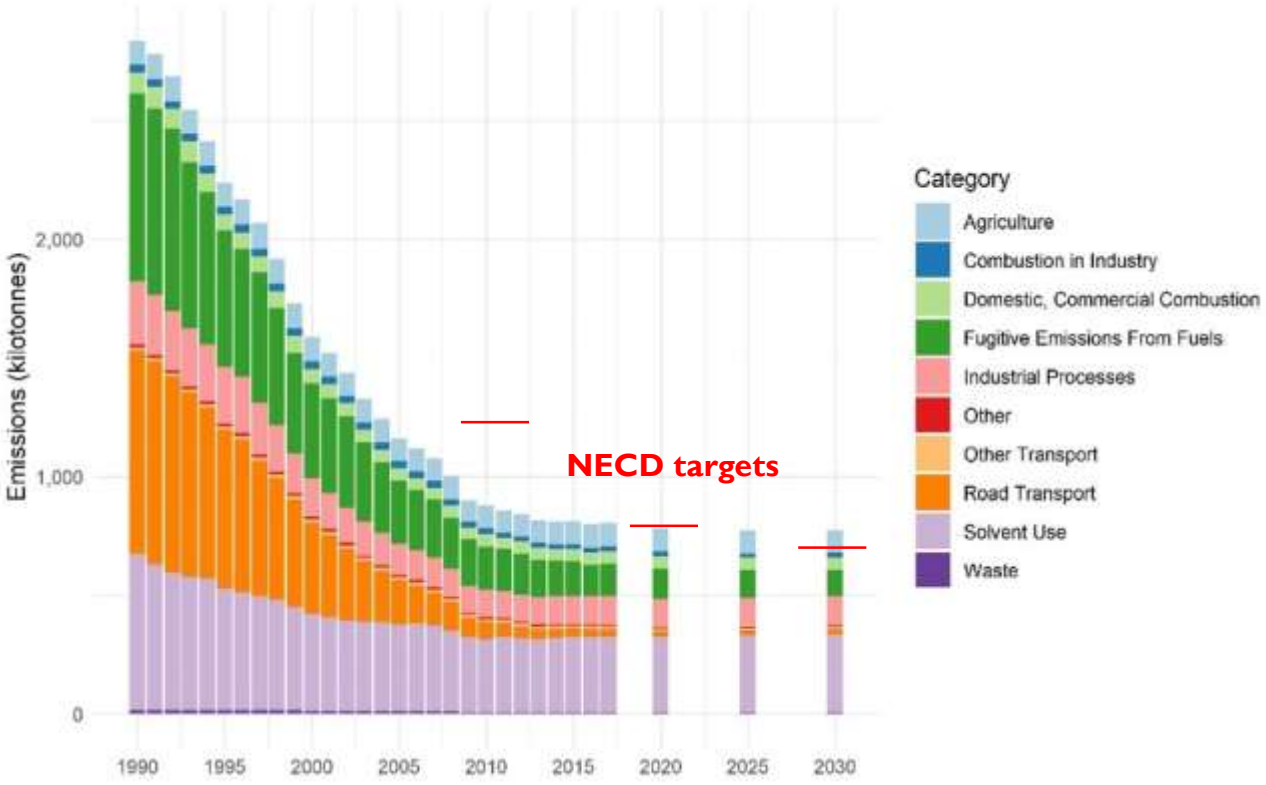
Investigating the annual behaviour of submicron secondary inorganic and organic aerosols in London

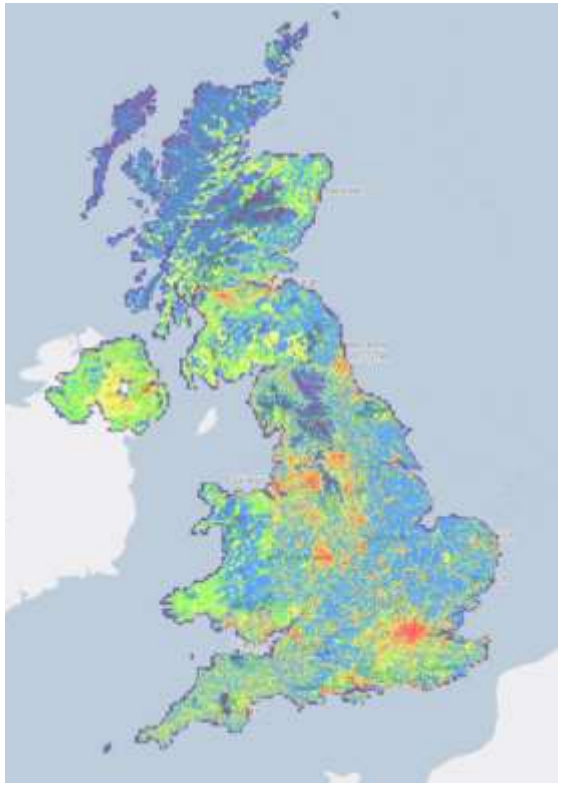
Wood Burning - Outstanding Issues

- Accurate and representative emission estimates are challenging since the number of installed units, frequency of use, operation, fuel type, performance, and fuel supply rates are not well known
- National spatial variability is poorly known, increased urban emissions
- Better and repeated survey data is necessary
- Real world emissions measurements
- Currently there are insufficient measurements to determine long term trends
- It isn't clear if current measurement networks are optimal for WB
- Methods for source attribution are not consistent and work is required to understand and resolve this

VOC emissions

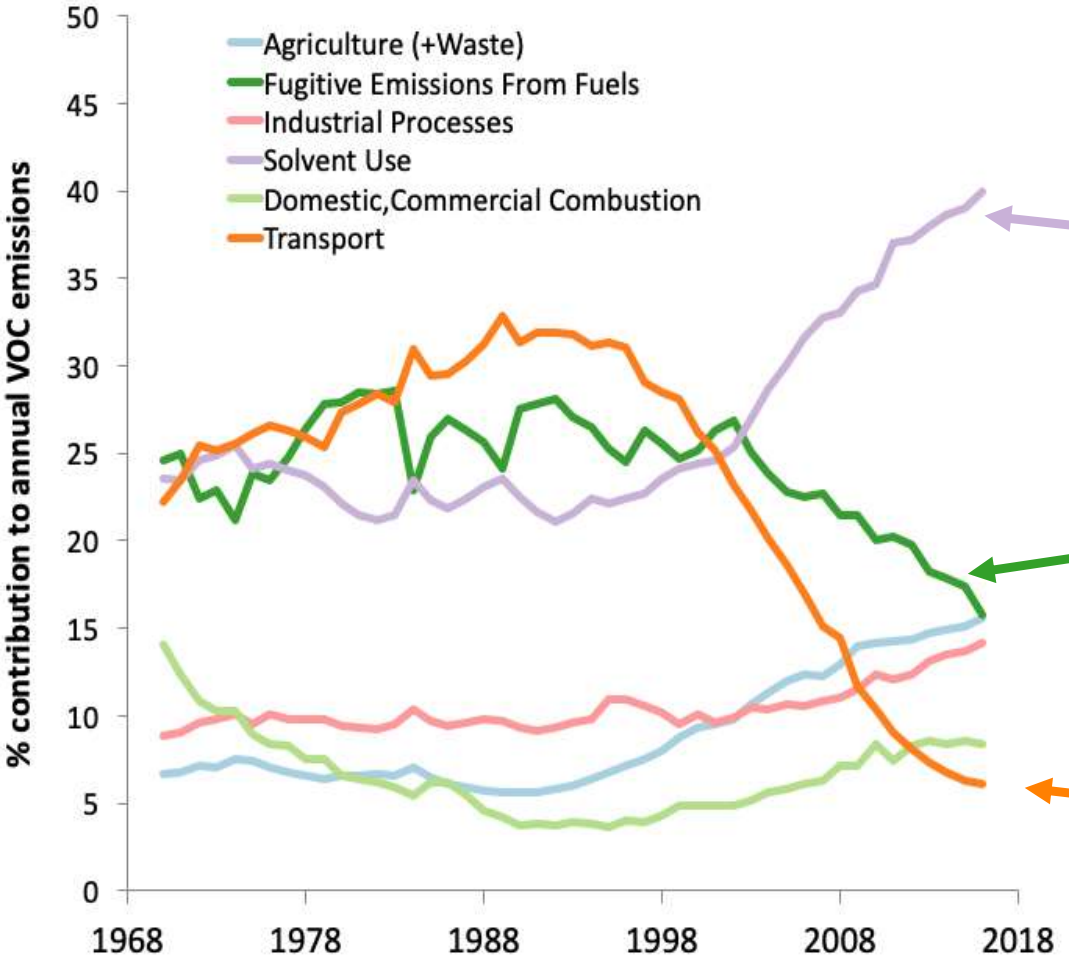
- Emissions of VOCs have reduced significantly since ~1990.
- Major reductions from road transport, 3-way cat convertor, vapour recovery.
- Rate of decline has slowed in recent years, shift in sources has occurred.
- UK not on track to meet NECD targets in 2030





Growth in the significance of solvents

- Consumption of solvents has not declined and in some sectors increased
- Increasing fraction of emissions as alcohols
- Unclear impact of solvent VOCs (and IVOCs) on UK $PM_{2.5}$



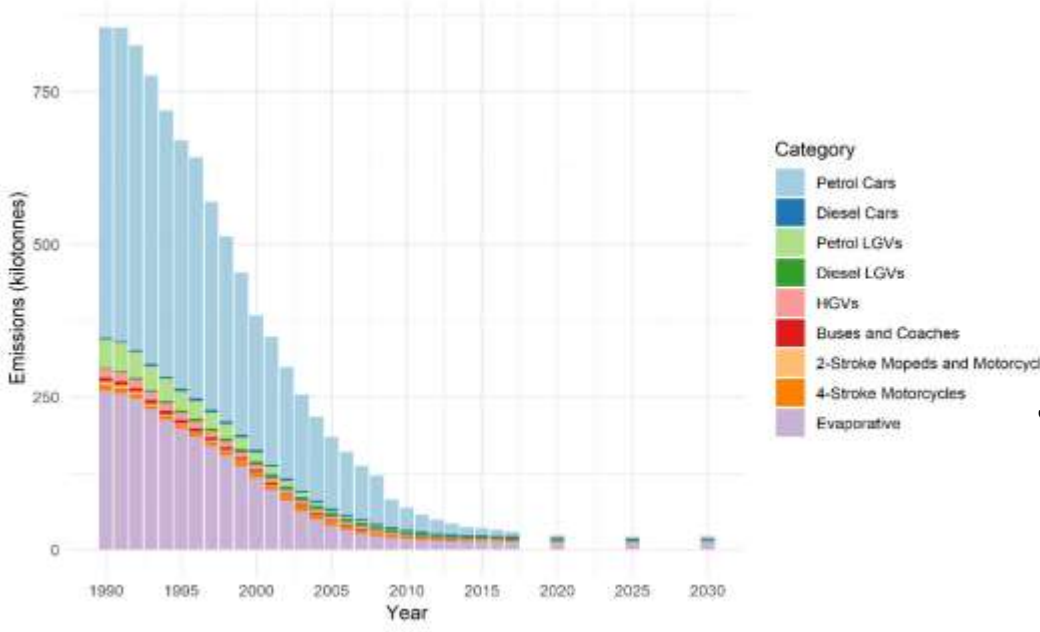
Aerosols, glues, inks, cleaning products, fragrances, degreasers, de-icers, paints, sealants, pesticides – volatile chemical products (VCPs)

Fuel spillage and re-fueling, petrol evaporation, gas leakage

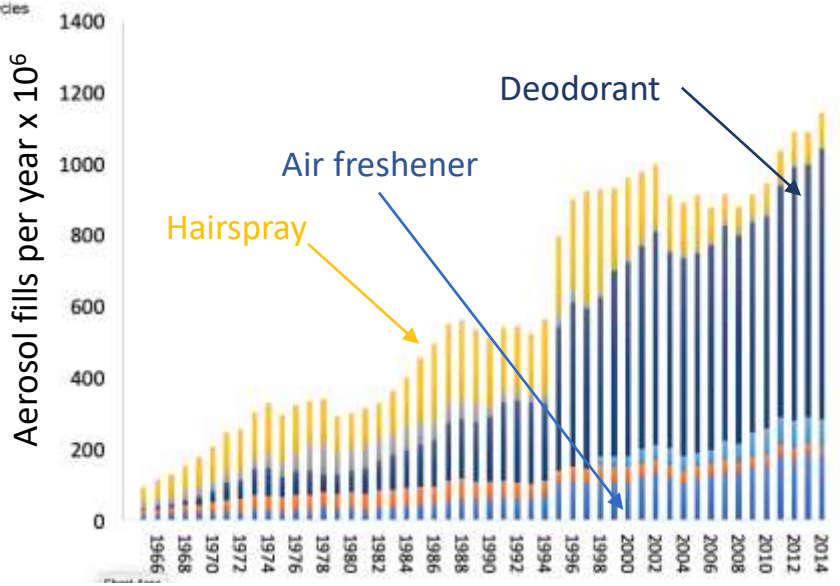
Tailpipe emissions, mainly petrol cars and motorbikes

Example trends in sub-sectors of VOC emissions

Reduction in tailpipe VOC emissions



Increase in VOC emissions from aerosols



Research Challenges for VOC and AQ

- As NOx emissions reduce there is a need to reduce VOCs in a commensurate way
- Since the majority of VOCs now come from non-traffic sources VOC reductions will not reduce below 2030 NECD targets by switching to electric vehicles.
- Understanding the emissions and the source contributions is a huge challenge.
- Could ozone production efficiency go up in the UK as a result of these changes?
- How important are primary VOCs in contributing to UK PM2.5?
- If the UK adopts a 10 ug / m^3 limit for PM2.5, which will be very tight in many places, how important might solvent emissions (including intermediate volatilities) become?

Low cost sensors for air pollution research

Large number of commercially available devices based on low cost sensor tech

Generally use similar sensor tech, but this covers a range of analytical methods

Metal oxide
~ £5
~ 1960

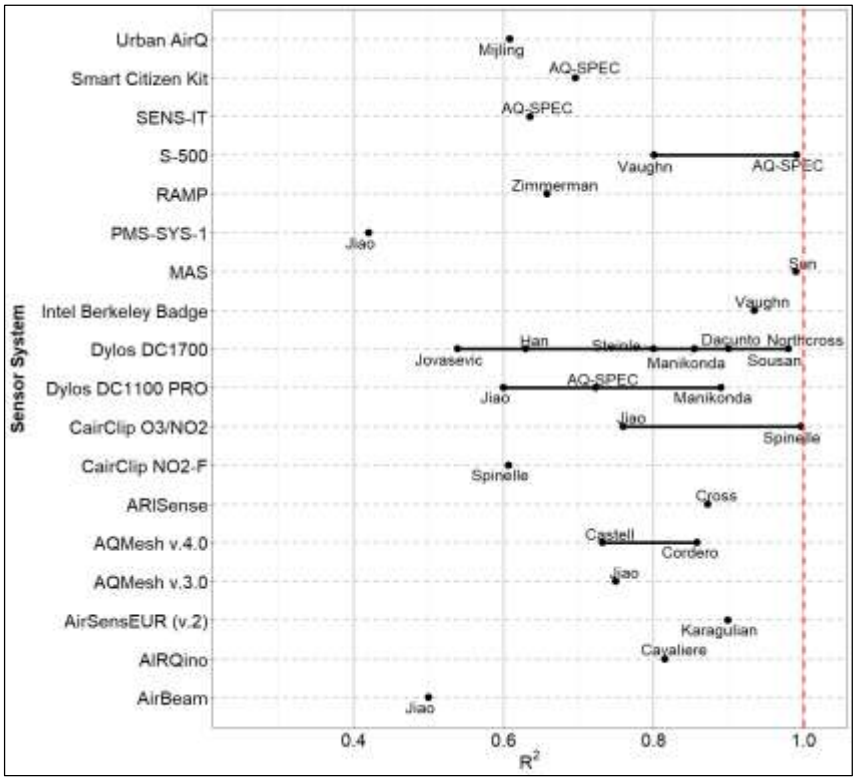
Electrochemical
/ voltammetric
~ £50
~ 1980

Photochemical
~ £100
~ 1990

Micro-optical
> £100
~ 2000

Largest difference between devices often the calibration algorithms used

Key challenges



Taken from EC Joint Research Centre report
"Review of sensors for air quality monitoring" 2019.

Variability
- Market
- Sensor to sensor
- Evaluation

Complex interferences from other pollutants and physical parameters

Factory calibrations not applicable to real world

Data quality **MUST** fit with application

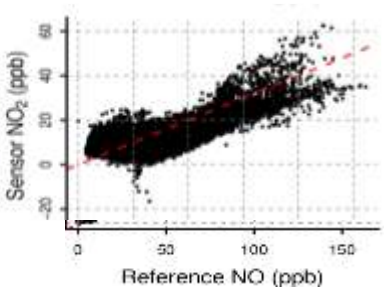
New methods needed to exploit the potential of these technologies!

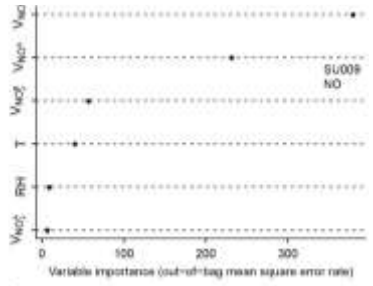
Example:

Performance of NO, NO_2 low cost sensors and three calibration approaches within a real world application

Alessandro Bigi[1], Michael Mueller[2], Stuart K. Grange[3], Grazia Ghermandi[1], and Christoph Hueglin[2]

Complex calibration algorithms identify and compensate for key interferants, but still drift over time.





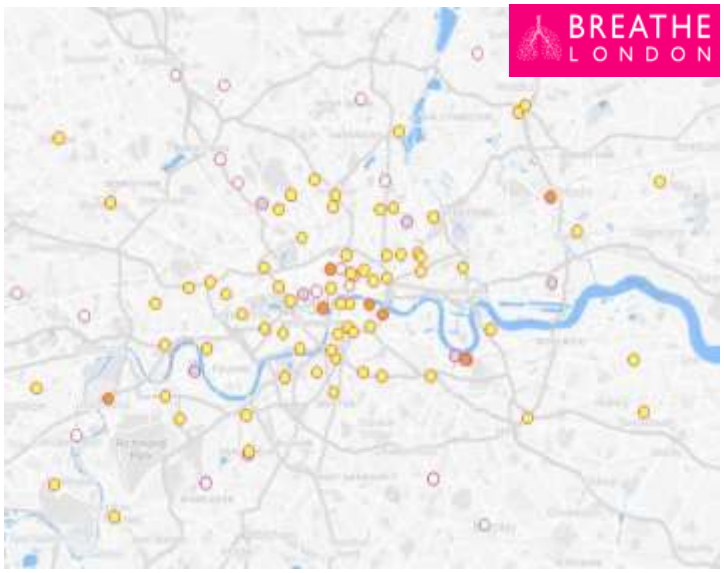
The power of the network

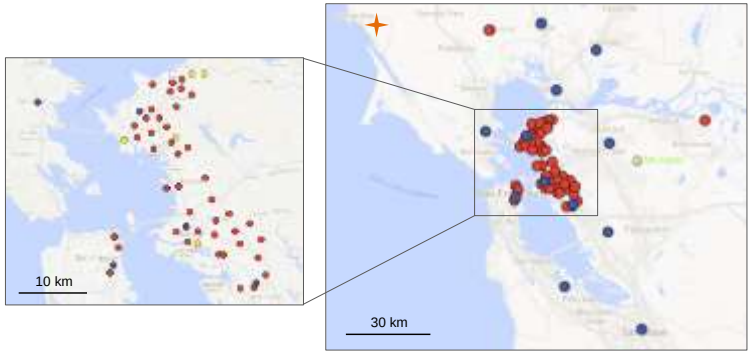
Low cost sensor networks are a VERY exciting opportunity!

Regular in-field calibration of every node in a sensor network not practical

New methods needed for both validation and use of data
(e.g. using nearby reference monitors under certain conditions to check sensor to sensor variability)

Trials are costly but progress is being made

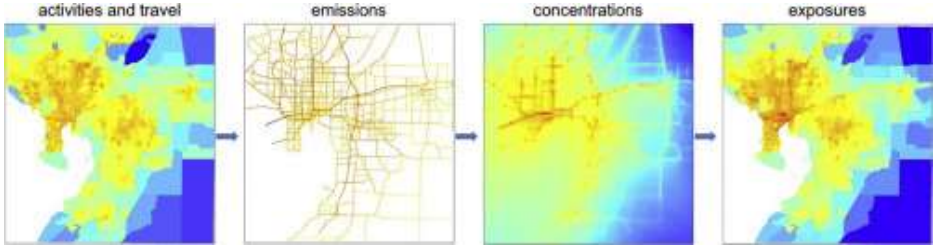




The BErkeley Atmospheric CO_2 Observation Network

Clean Air: Analysis and Solutions: **Data integration model for exposure modelling (DIMEX-UK)**

- *To develop a framework to integrate modelled estimates of ambient concentrations with an agent based model of individual level activity to estimate personal exposures to air pollution*
- *To build and implement an agent-based model to create exposure profiles, together with associated measures of uncertainty, for defined populations (e.g. different demographic groups in specified locations) in a form that can be readily used in subsequent analyses by a variety of users, i.e. health impact analyses, epidemiological studies and policy development.*



City, Supersite, Uncertainty quantification

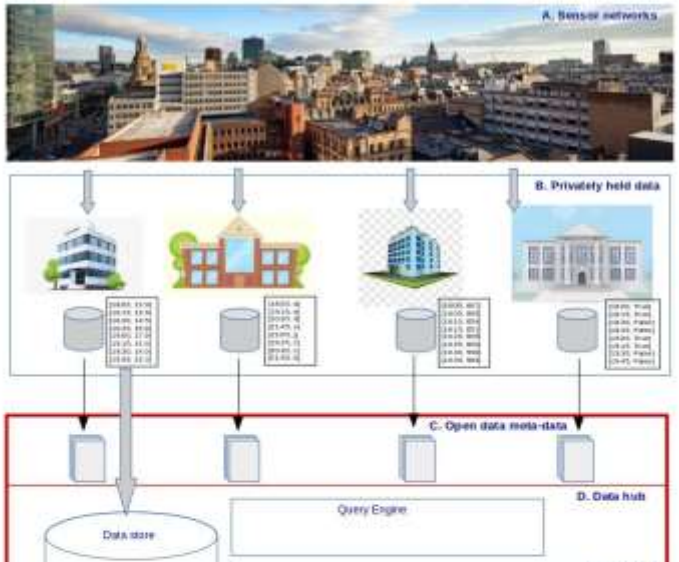
Detailed demographic & socioeconomic data at the small area level

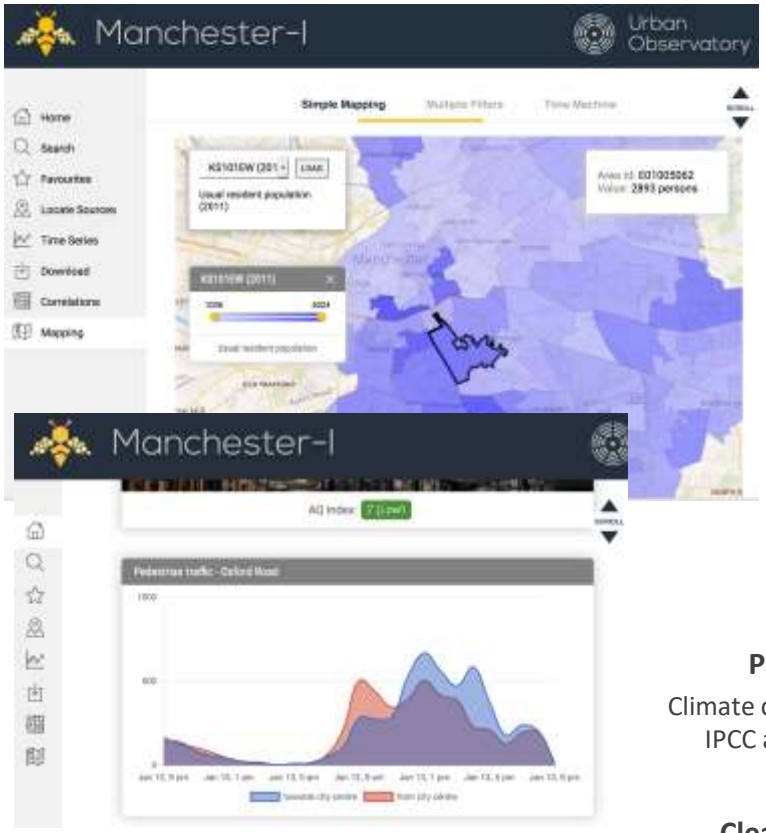
Detailed demographic, socioeconomic and health data

Small area level origin-destination (home-work) data

Detailed daily activities in/out households.

Real time data on air quality





Embedding air quality data into wider connected city datahubs with e.g. socio-economic data engages a range of stakeholders

The Environment Act/SDGs

Holistic approach encompasses the quadruple helix

Infrastructure Renewal

£100 billion of infrastructure renewal – how do we make the right choices

Paris Agreement/Net Zero

Climate change is a wicked problem – IPCC admits they don't know what works

Clean Air Act

Requirements to improve the air we breath. Monitor, and learn what works

UKCRIC National Observatory Programme is the only city data programme to encompass a large number of partner cities working towards shared governance, access and curation for city data. All open and transparent.

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Effects of exposure of human participants to controlled subsets of pollutants and / or emission sources

EUROCHAMP 2020 Trans-National Access study of acute cognitive impairment on exposure to diesel exhaust

Summary

- Changes in pollution environment in future cities
  - Particle sources other than tailpipe; changes in our use of VOCs; Greening of our cities
- Future drivers of air quality policy
  - What needs controlling if we are to meet 10µgm^{-3} PM2.5 compliance?
  - Future NACD limits
- Moving to exposure based risk to public health
  - Improved sensing capability and monitoring network design
  - Integrating AQ with wider data networks and integrated models
  - Assessment of exposure to indoor air as well as outdoor air
- Evaluating the relative toxicity of different sources of air pollution