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Present trends, and some thoughts on future prospects for air quality management and health in the UK

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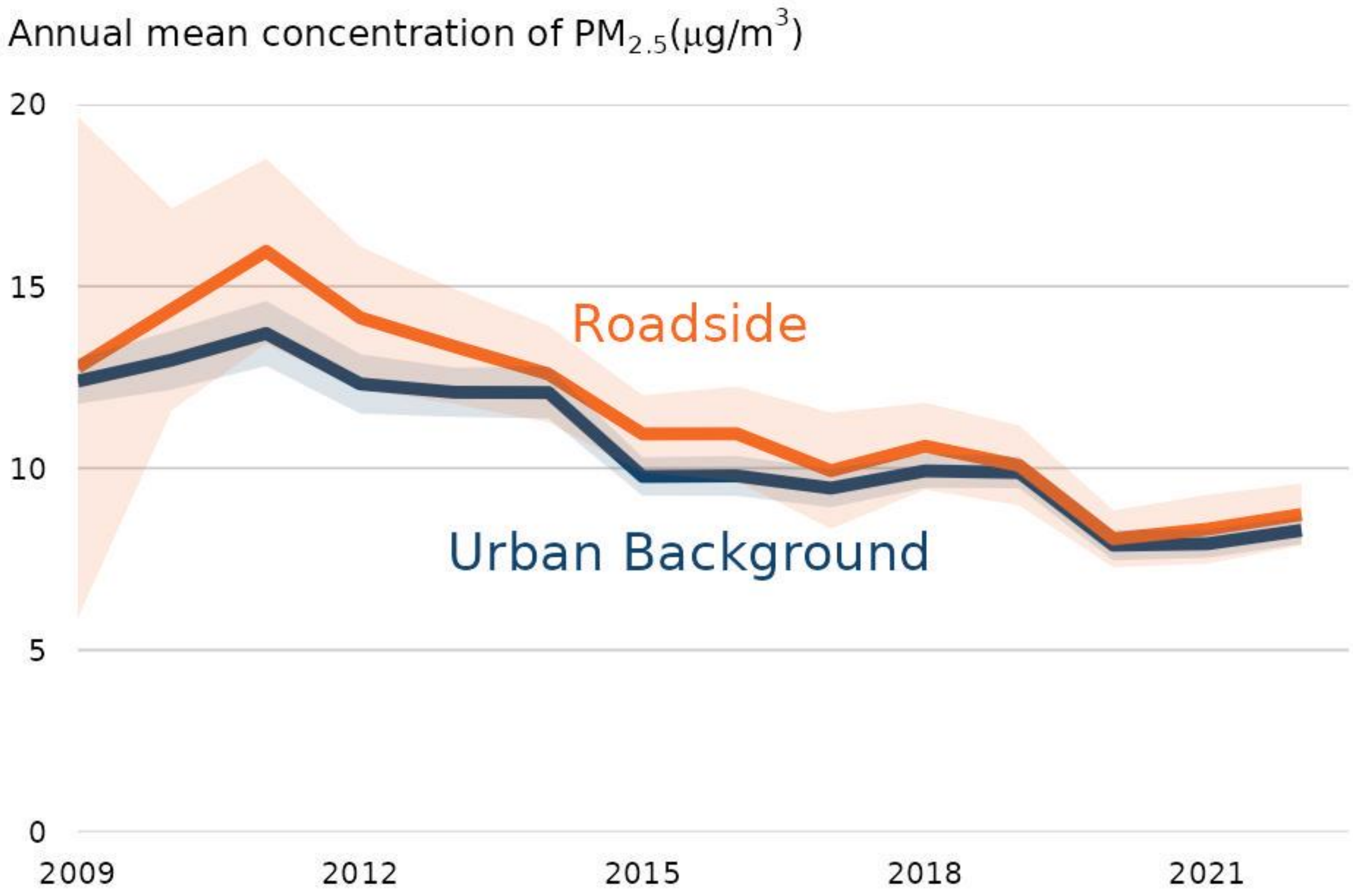
The Adverse Impacts of Air Pollution Globally

7 million premature deaths annually[b,5]	4th most deadly health risk worldwide[6]	**9 out of 10** outdoor air pollution deaths are in LMICs[7]
570,000 deaths of children under 5 per year[c,8]	**$8.1 trillion** in annual global health costs[d,9]	**6.1%** reduction in global GDP[e,10]
Shortens global average life expectancy by **2.2 years**[f,11]	Global crop yield losses of between **3-16%**[g,12]	**1.2 billion** work days lost globally each year.[13]

Recent Trends

Annual concentrations of $PM_{2.5}$ in the UK, 2009 to 2022 (Defra statistics)



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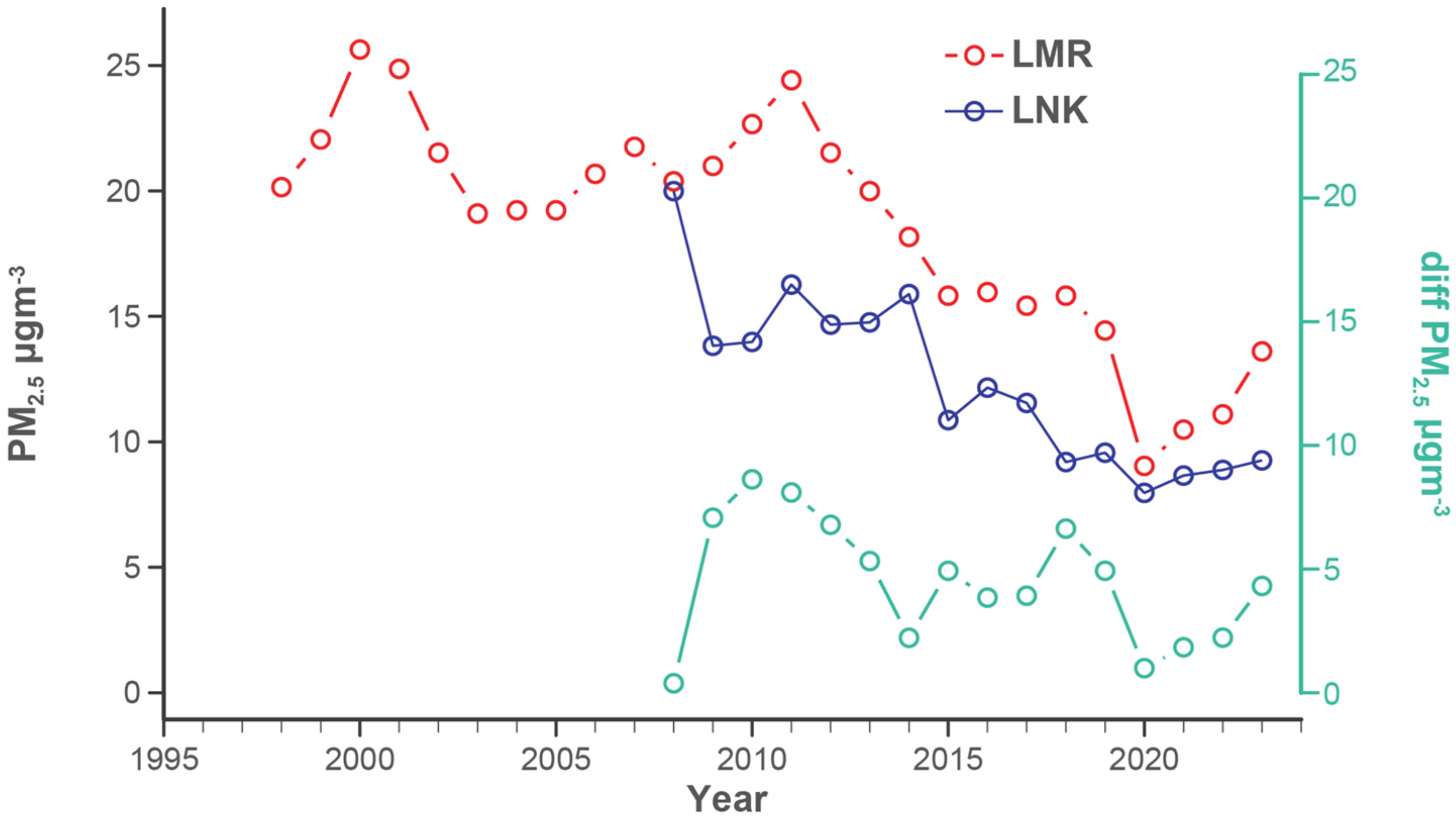
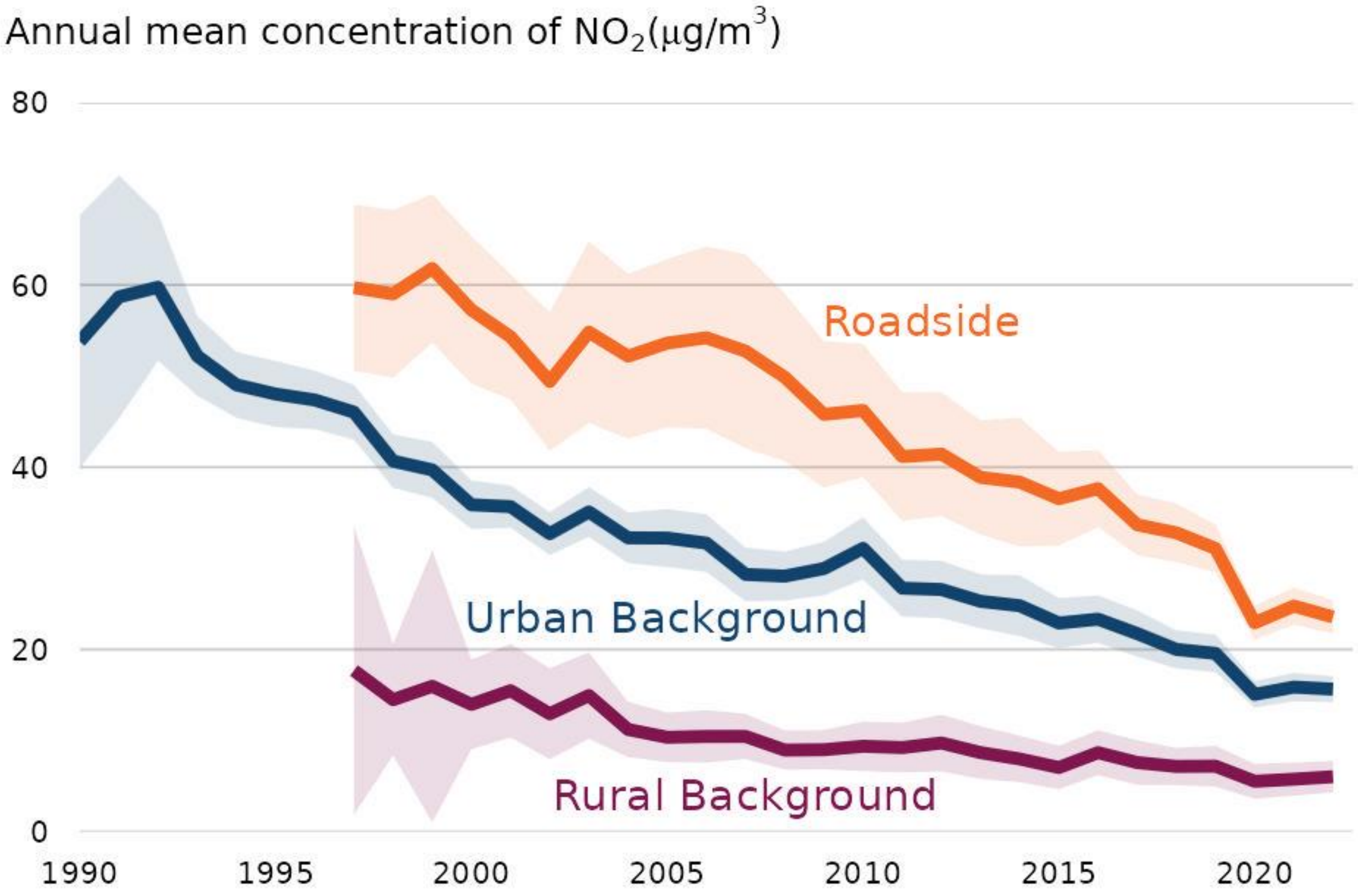
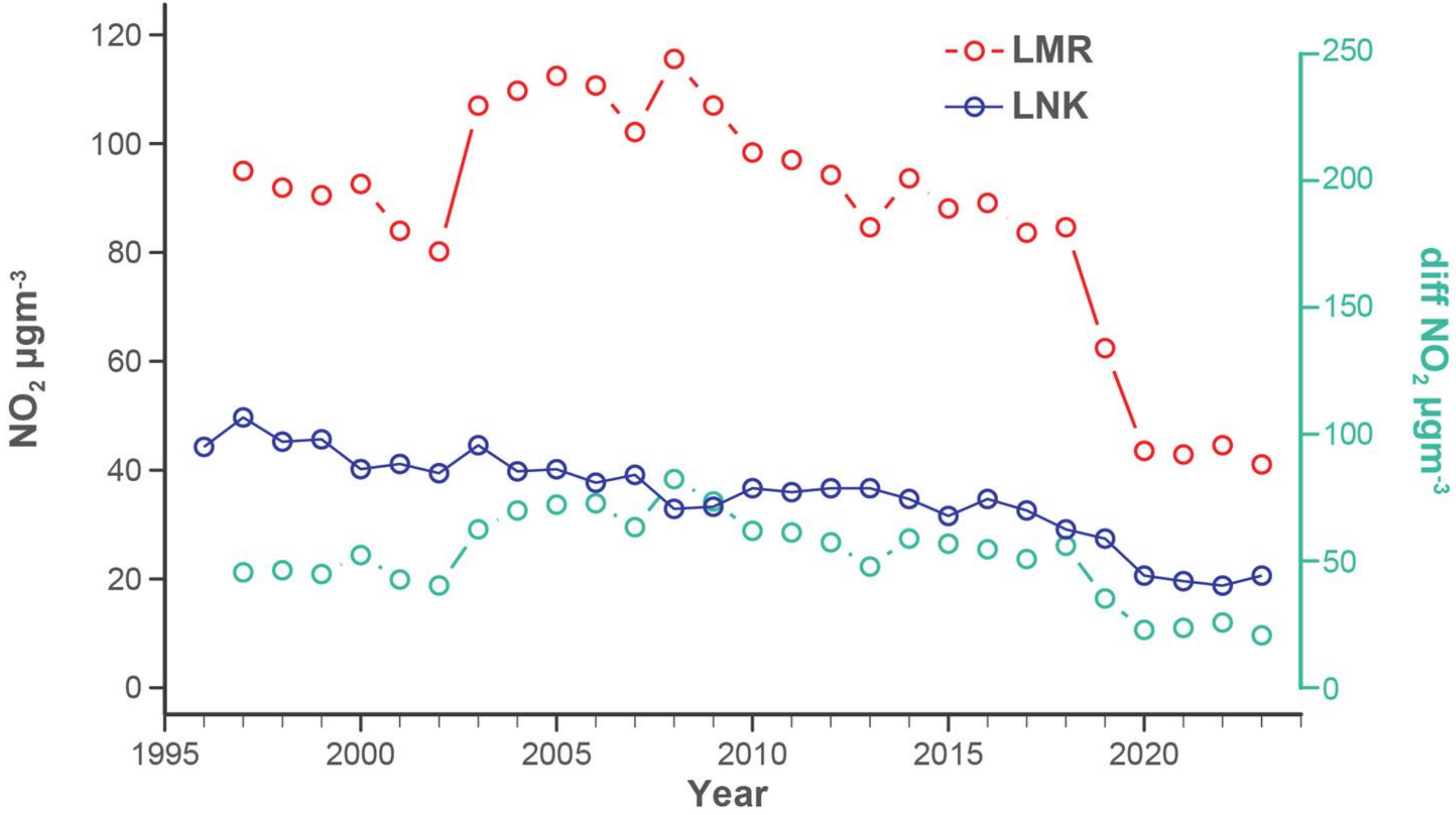
$PM_{2.5}$ concentrations at London, roadside and background, and difference, 1996-2023



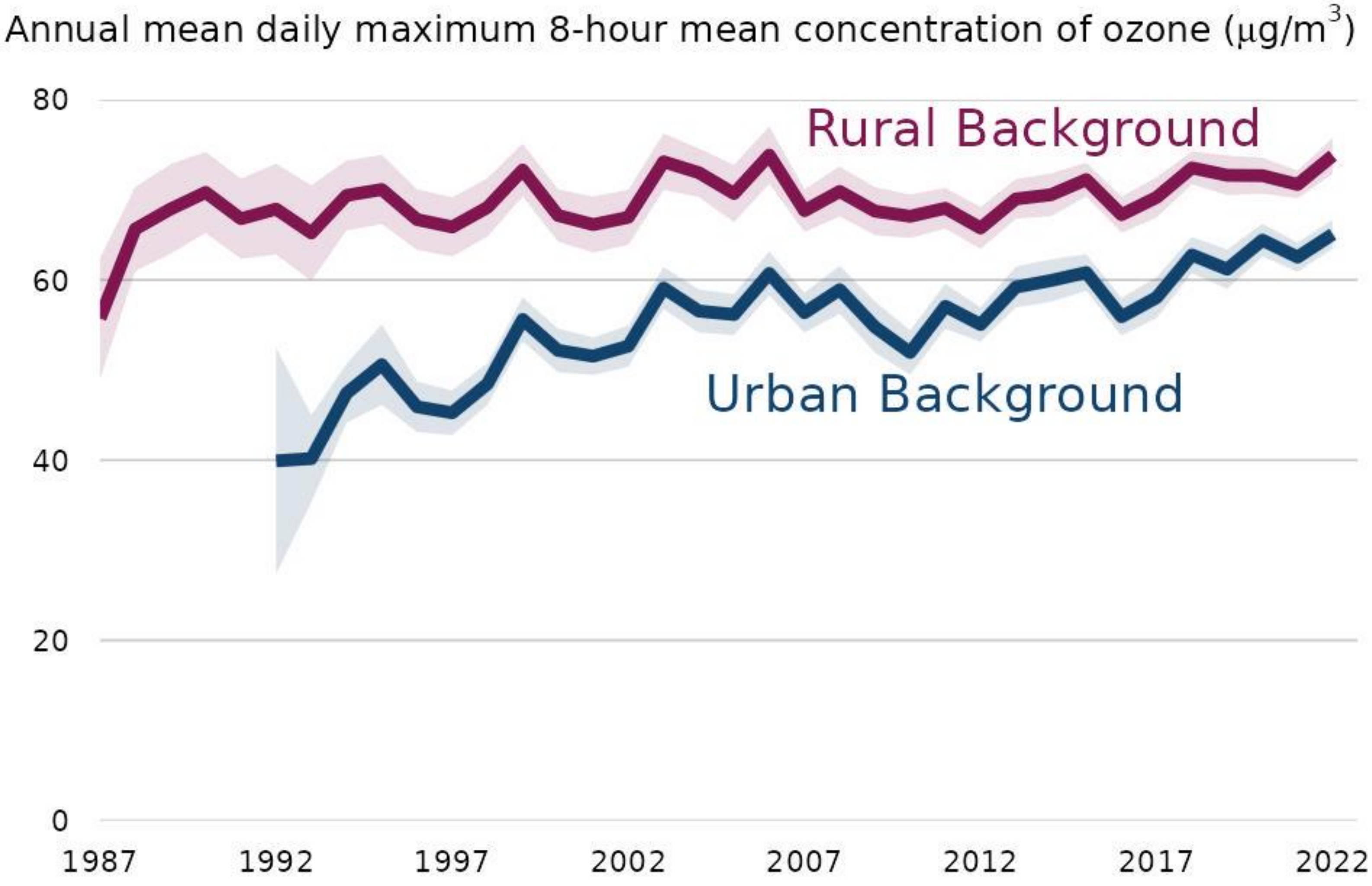
Annual mean concentrations of NO_2 in the UK, 1990 to 2022 (Defra statistics)



Nitrogen dioxide concentrations at London, roadside and background, and difference, 1996-2023



Annual mean concentrations of O_3 in the UK, 1987 to 2022 (Defra statistics)



What are the recent (10-20 years) trends in concentration in Western Europe?

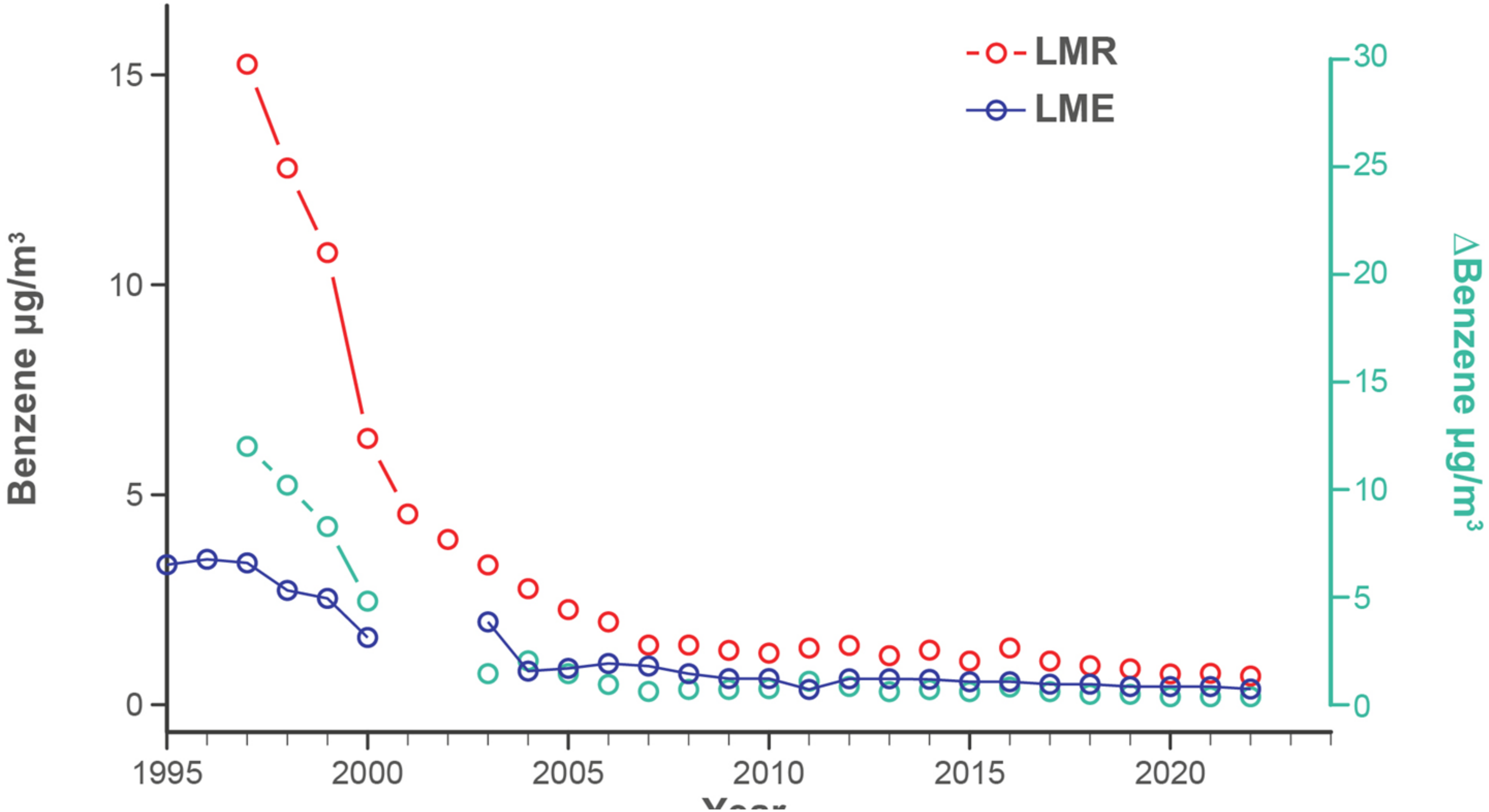
POLLUTANT	TREND
Particulate Matter	Slow improvement
Sulphur Dioxide	Fast downward
Nitrogen Dioxide	Flat, then slow improvement
Ozone	Peaks down; baseline upward
Carbon Monoxide	Fast downward
Benzene	Fast downward
Polycyclic Aromatic Hydrocarbons	Flat

Air quality pollutants

There have been some **success stories**, notably:

- Smoke and sulphur dioxide in many developed countries
- Carbon monoxide and benzene in most developed countries
- Lead from motor vehicles

Benzene concentrations at London, roadside and background, and difference, 1996-2023



Air quality pollutants

There have been some **notable failures**, e.g.

- *Nitrogen dioxide*, for two reasons
  - (a) failure to reduce NO_x from diesels
  - (b) Increased contribution of primary NO_2 from diesel
- *Ozone*, for which abatement policies in Europe have achieved a reduction in episodic peak concentrations, but the hemispheric background has increased
- *Particulate matter* ($PM_{2.5}$ and PM_{10}), mainly because of a large secondary contribution and poorly characterised primary sources

Why has progress been slow?

- **$PM_{2.5}$**

  - the diesel particle problem was recognised long before it was addressed

  - growth in domestic wood burning

  - non-linearities in secondary pollutant controls

  - failure to tackle ammonia emissions from agriculture

- **Nitrogen dioxide**

  - poor design of test procedure and cheating by motor industry

Diesel Vehicle Emissions And Urban Air Quality

December 1993

Second Report of the
Quality of Urban Air Review Group

Prepared at the request of the
Department of the Environment

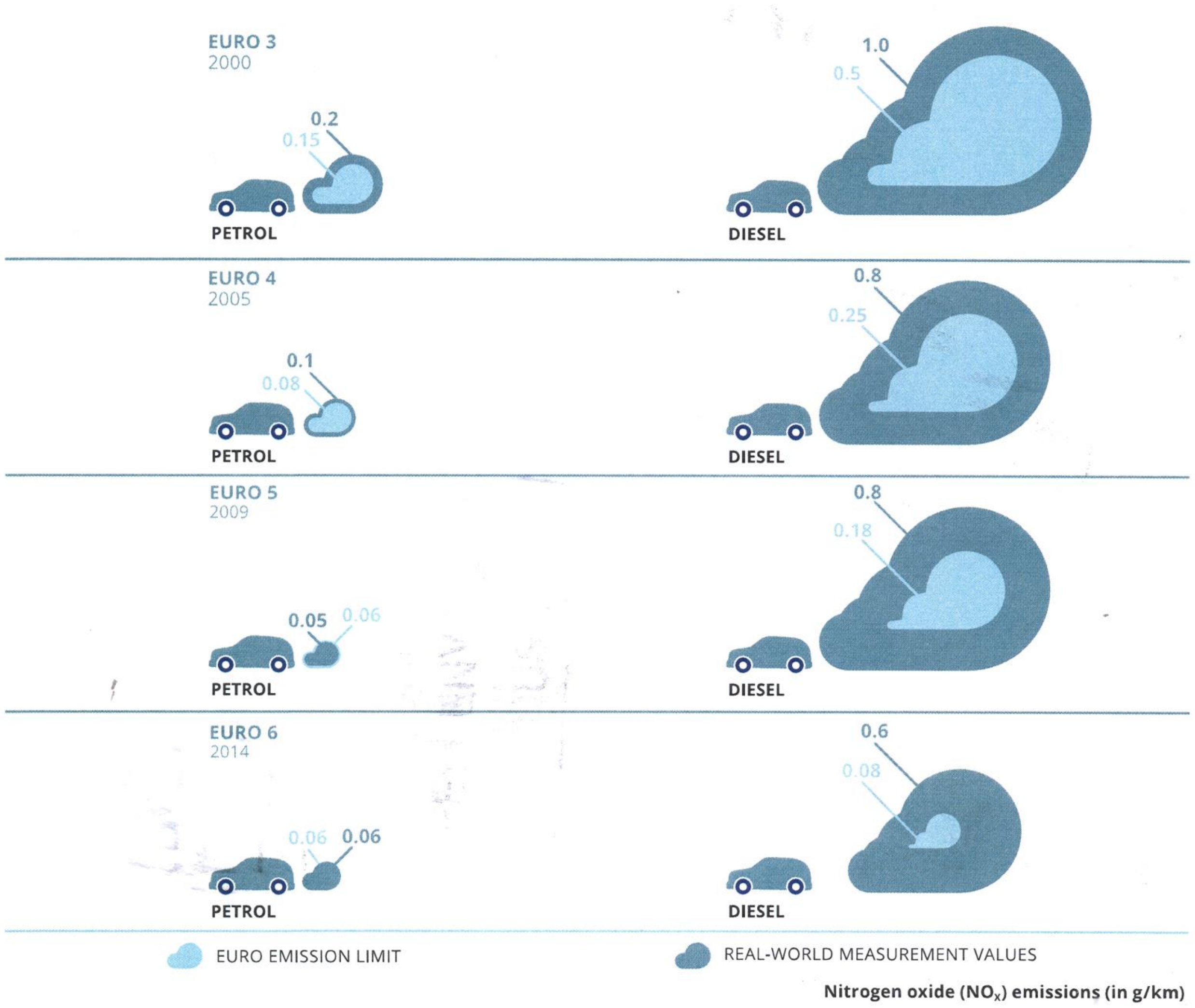
Diesel vehicles and urban air quality

"In the view of the Review Group, the impact of diesel vehicles on urban air quality is a serious one. Any increase in the proportion of diesel vehicles on our urban streets is to be viewed with considerable concern unless problems of particulate matter and nitrogen oxides emissions are effectively addressed."

Quality of Urban Air Review Group

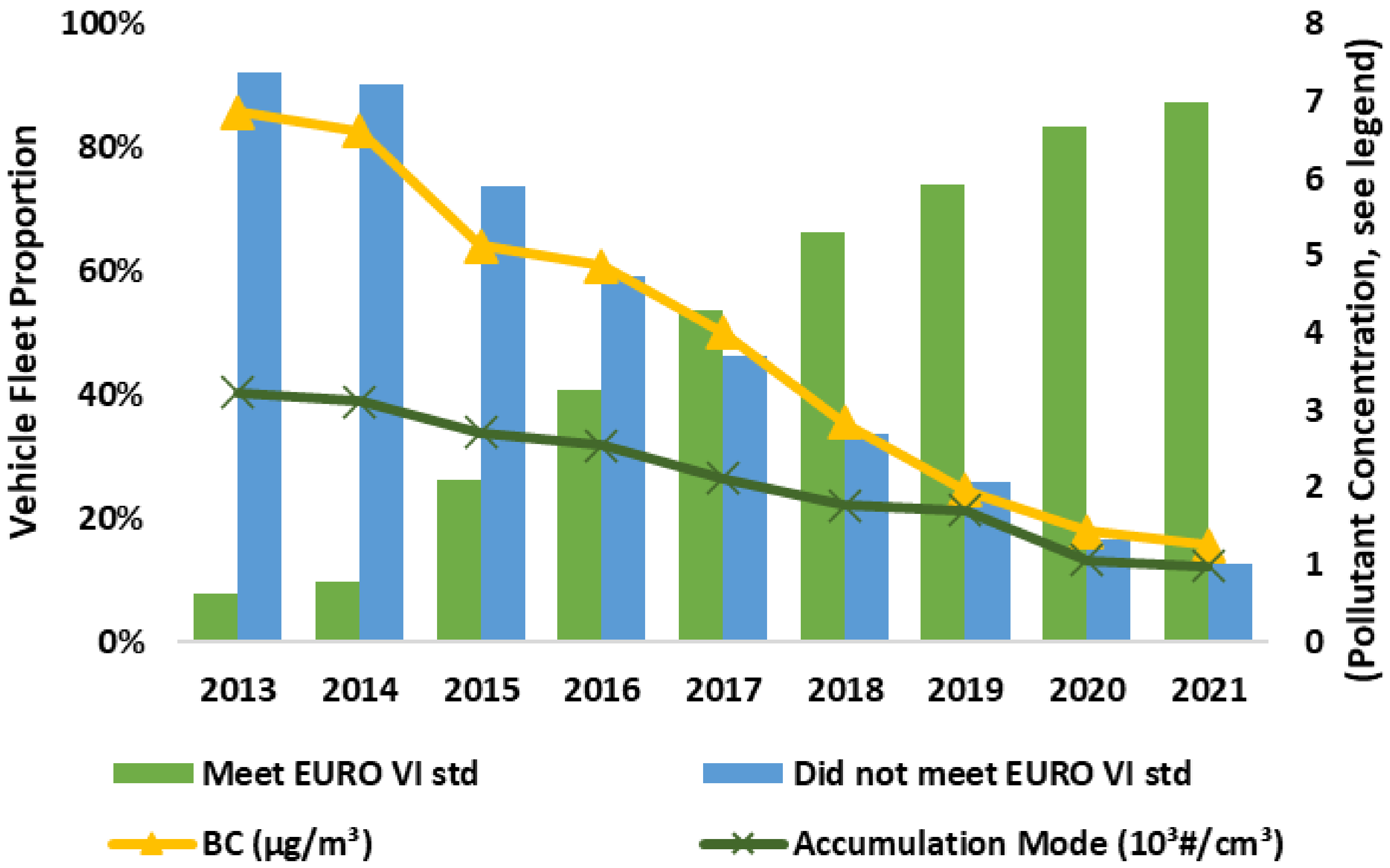
Diesel Vehicles and Urban Air Quality, December 1993

Comparison of NO_x standards and emissions for different Euro classes



Source: EEA, 2016d.

Temporal trends in Black Carbon and Accumulation Mode particle concentrations in relation to heavy duty truck traffic which did not meet the Euro VI emissions standard, 2013-2021



Ultrafine Particles

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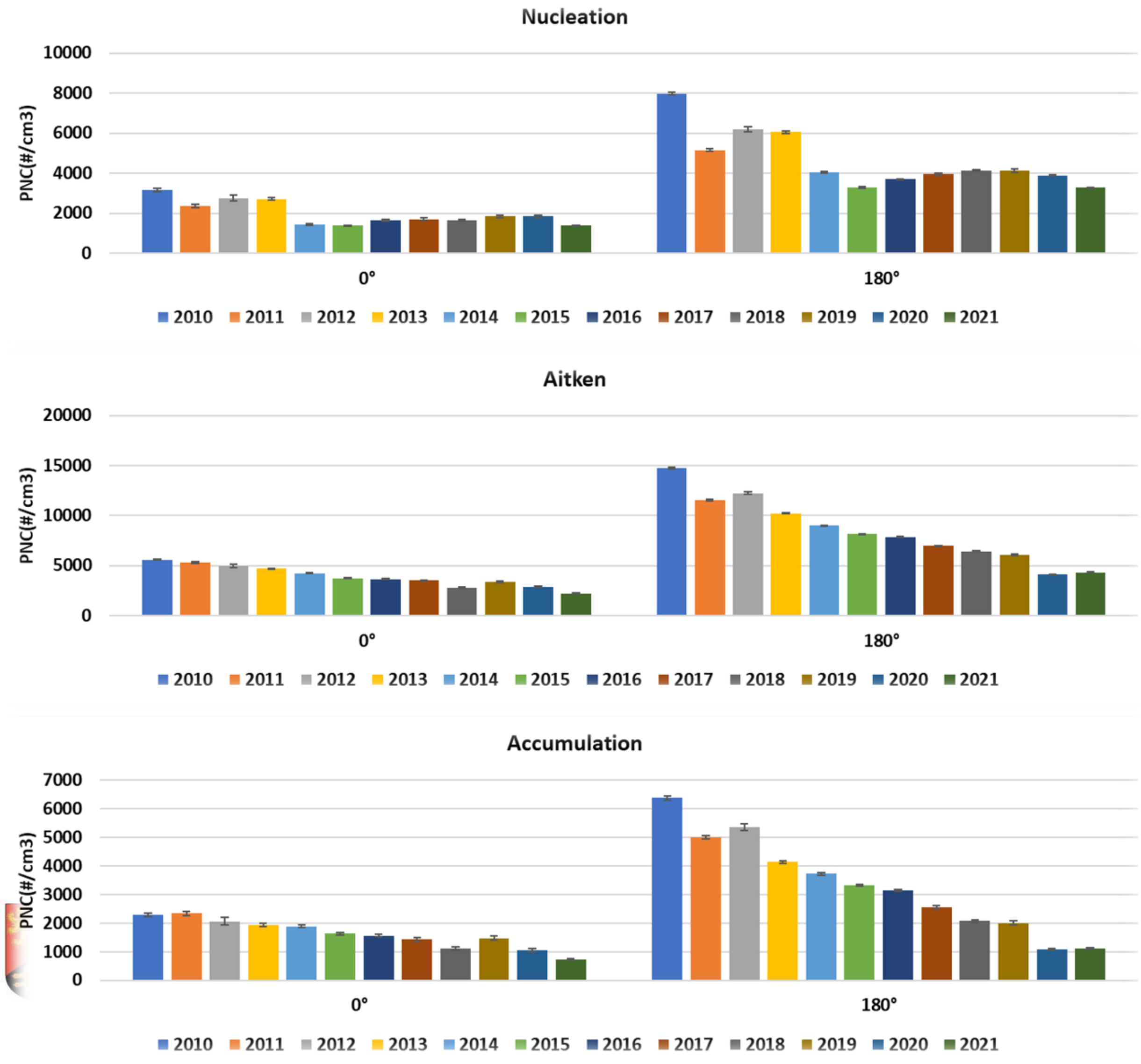
Trends in Particle Number at London, Marylebone Road



Trends in particle number: 2010 -2021

Nucleation : <30nm

Aitken: 30-100nm

Accumulation: >100nm

Annual mean concentration of each particle size mode split by year (2010-2021) and wind direction

The 180° and 225° data show the greatest contribution of Marylebone Road traffic

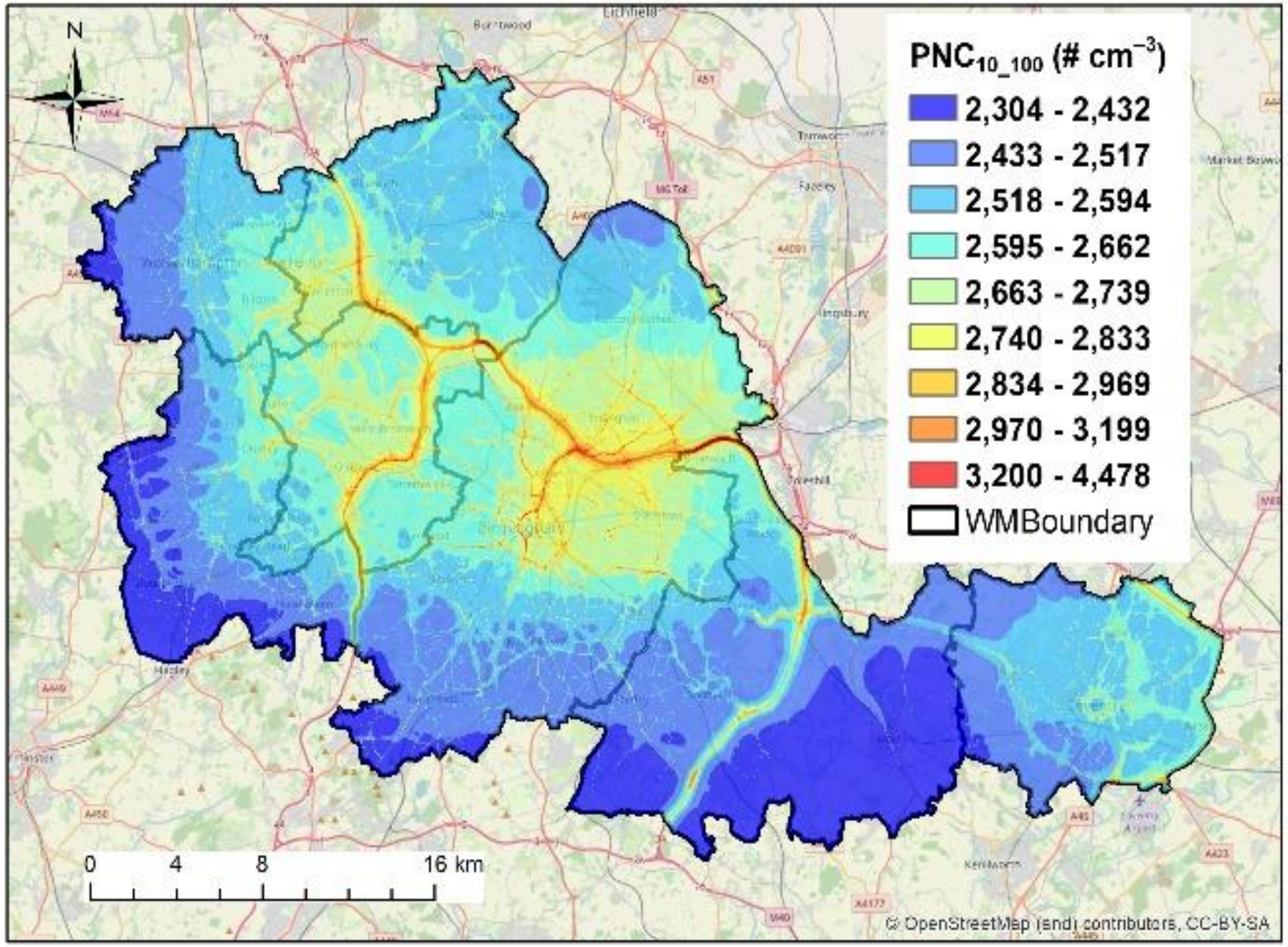
The 0° and 315° data are more reflective of background north London air

Damayanti et al., Limited impact of diesel particle filters on road traffic emissions of ultrafine particles. *Environ. Int*, 107888(2023)

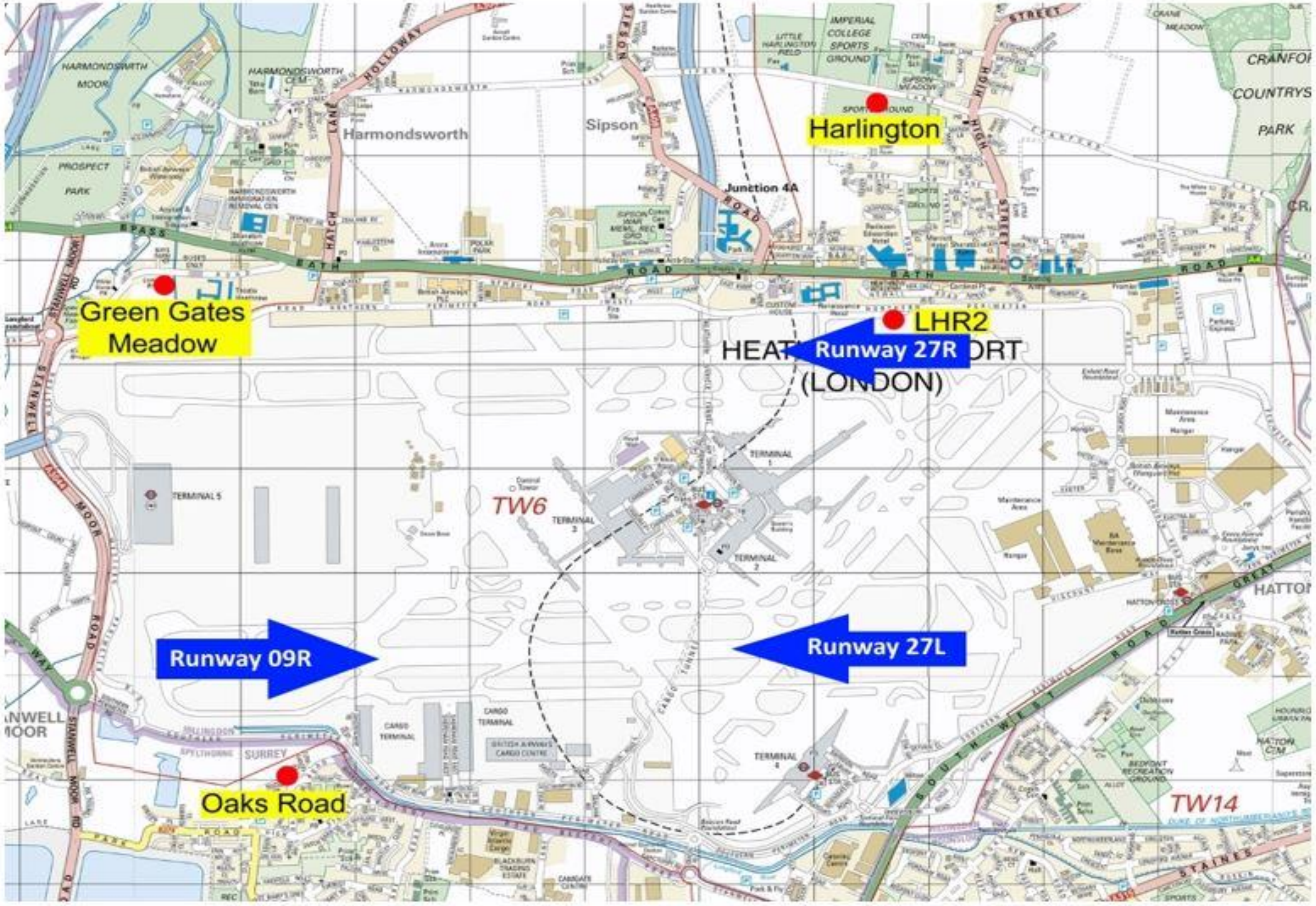
Trends in particle number

- We interpret the **rapid reduction in BC and PNC** as being largely **attributable to the progressive uptake of diesel particle filters as Euro 5 and 6** standard vehicles have entered the fleet since 2011.
- **The greatest impact has been upon the BC and Aitken and Accumulation mode particles**, **with little change seen in the Nucleation mode particles**, which are comprised largely of condensed lubricating oil, and form in the cooling exhaust after passage through the particle filter (Harrison et al., 2018)

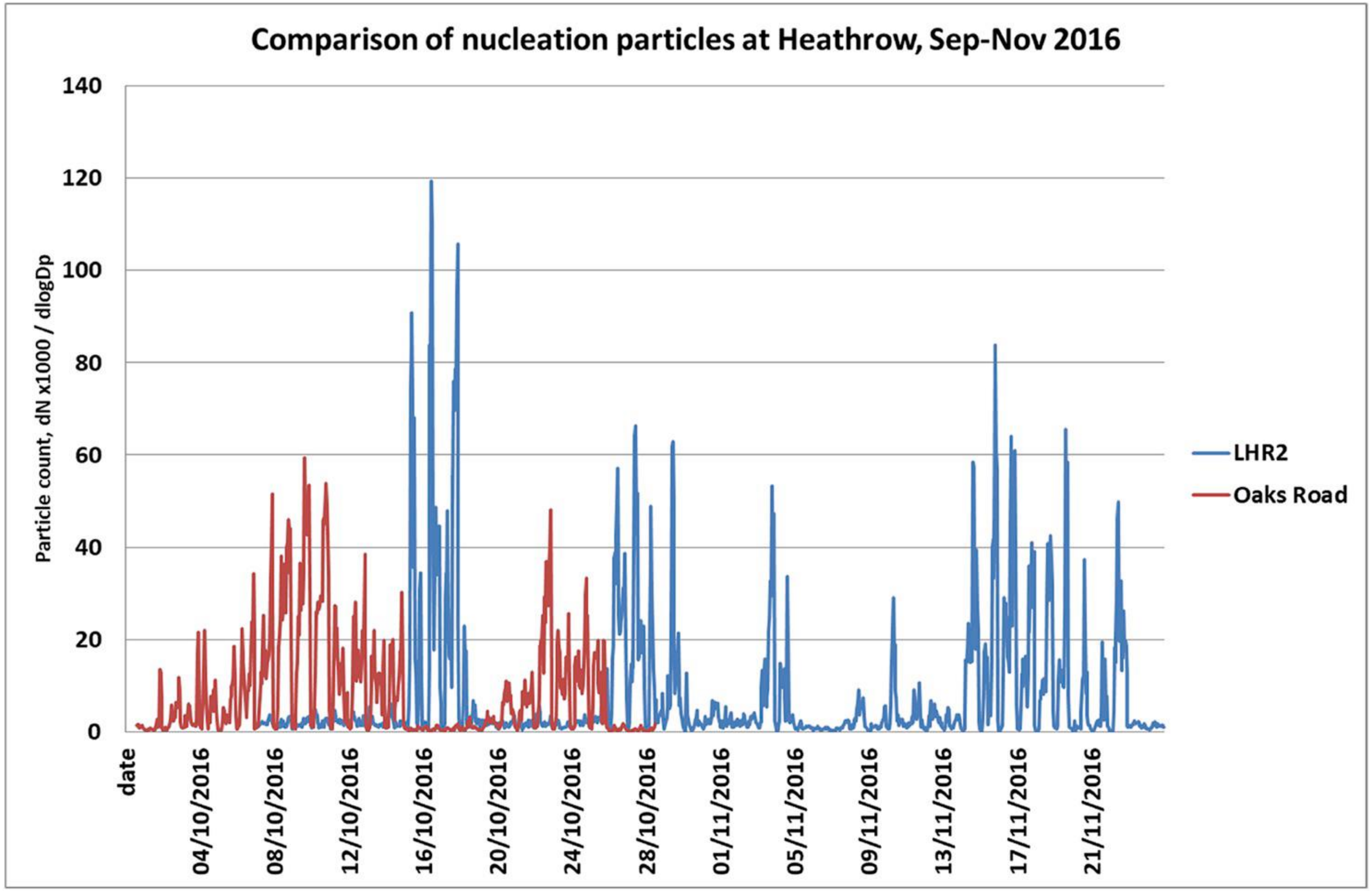
Annual map for PNC between 10 and 100 nm (PNC_{10_100}) at 10 m × 10 m resolution for the 2019 BAU case



Heathrow Airport



Time series of nucleation mode particles at the Heathrow Airport sampling sites, October and November 2016



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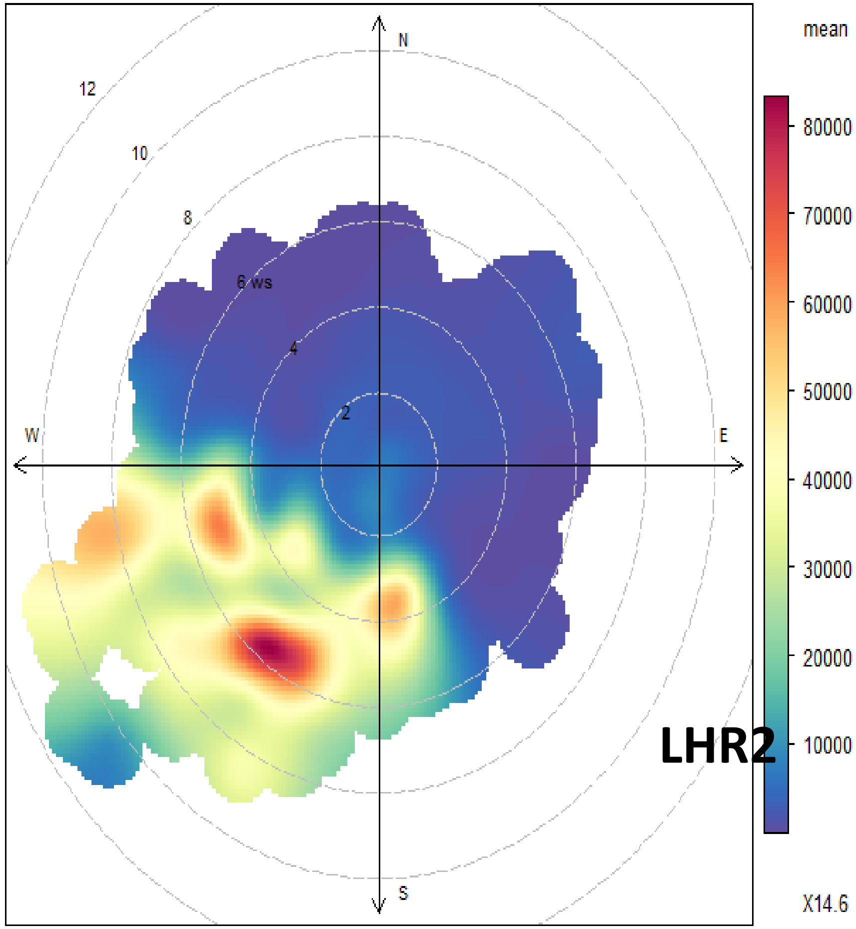
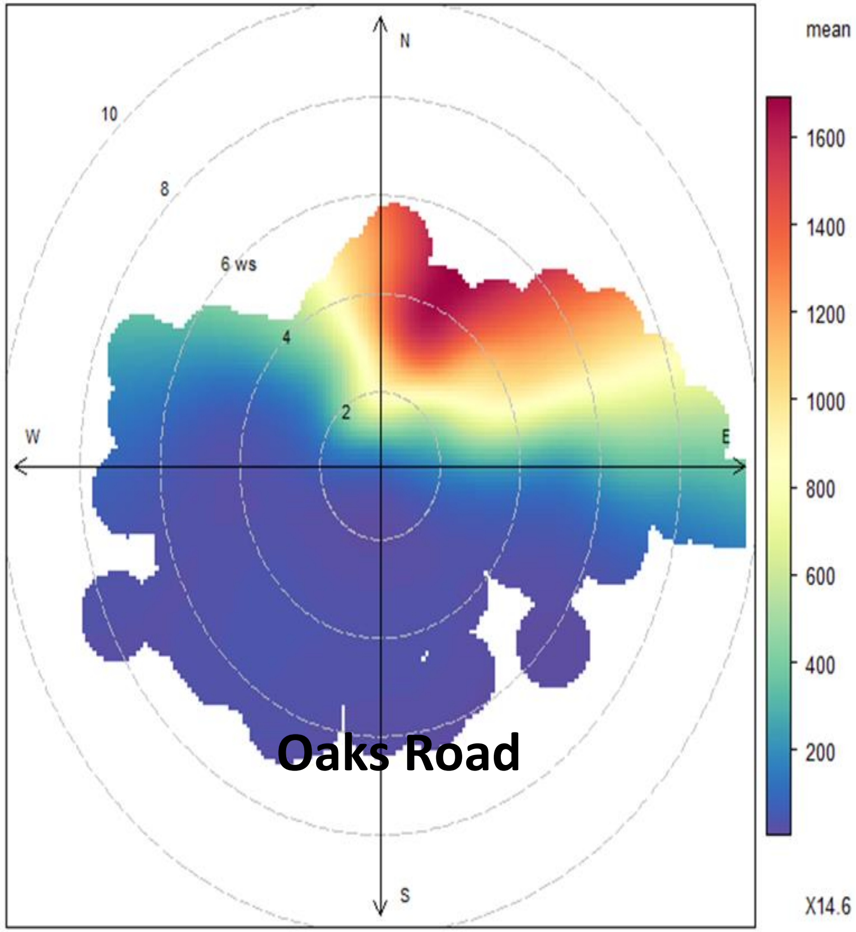
What is the source of these finest particles?





Stacey et al., *Atmos. Environ.* **222**, 117148 (2020)

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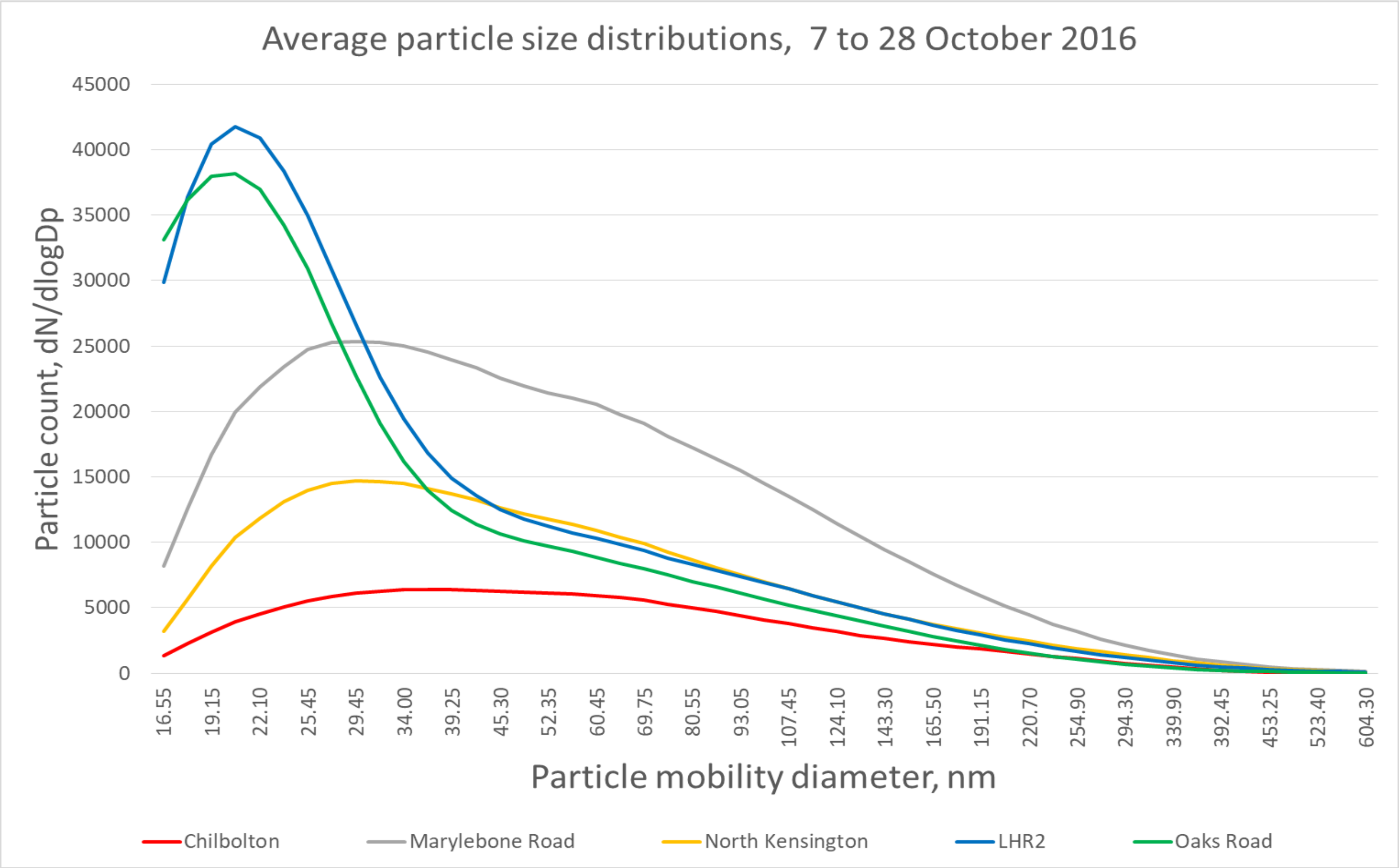
Comparison of particle size distributions at 5 locations

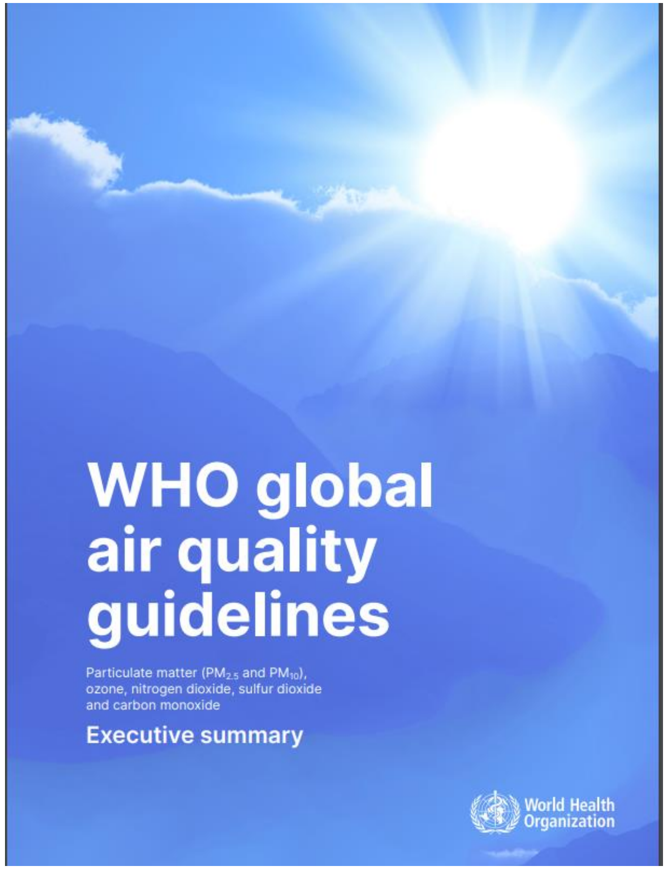


The Future

Will the UK meet WHO Guidelines?

Revised WHO Guidelines (2021)

- $PM_{2.5}$ from 10µg m^{-3} to 5µg m^{-3} (annual) is very challenging
- NO_2 from 40µg m^{-3} to 10µg m^{-3} (annual) should be achievable
- Ultrafine particles:
  - Low, <1,000 cm^{-3} (24h mean)
  - High, >10,000 cm^{-3} (24h)
  - High, >20,000 cm^{-3} (1h)



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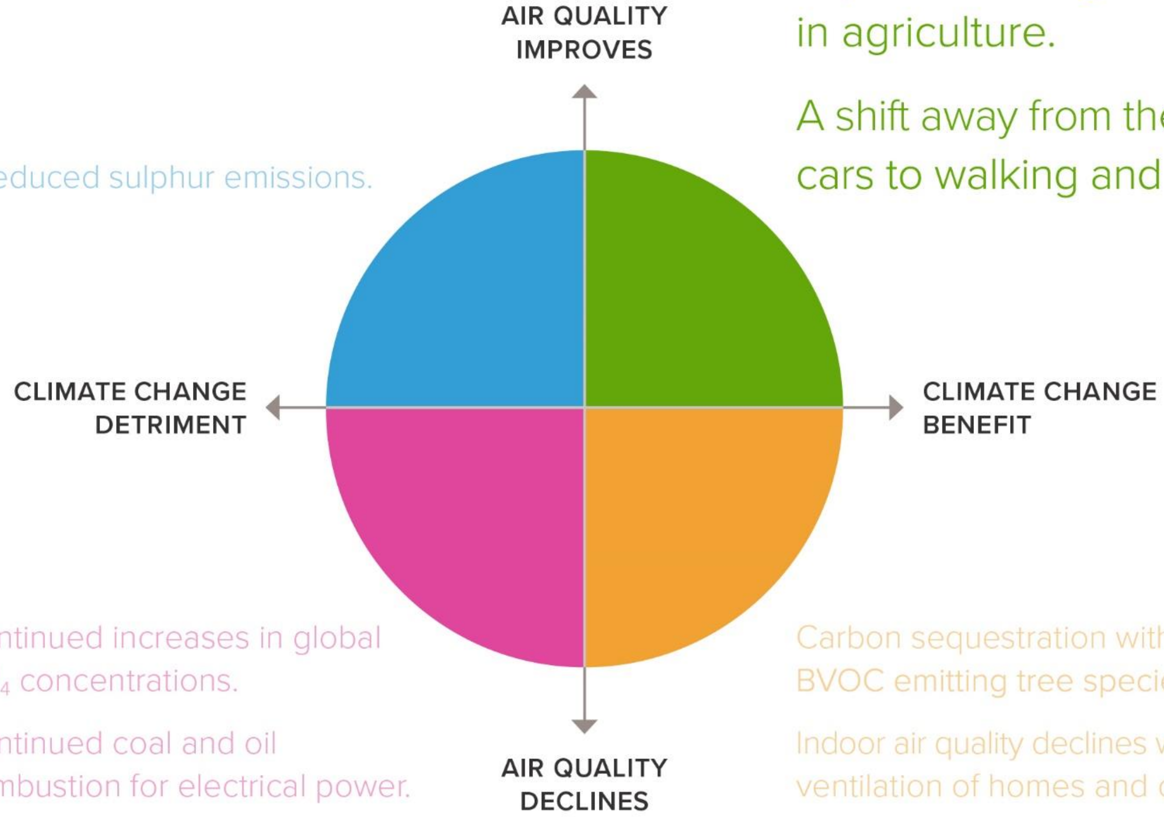
Electrification of transport and home heating with wind and solar power.

Carbon sequestration with low BVOC emitting tree species.

Improved nitrogen efficiency in agriculture.

A shift away from the use of passenger cars to walking and public transport.

Reduced sulphur emissions.



Continued increases in global CH_4 concentrations.

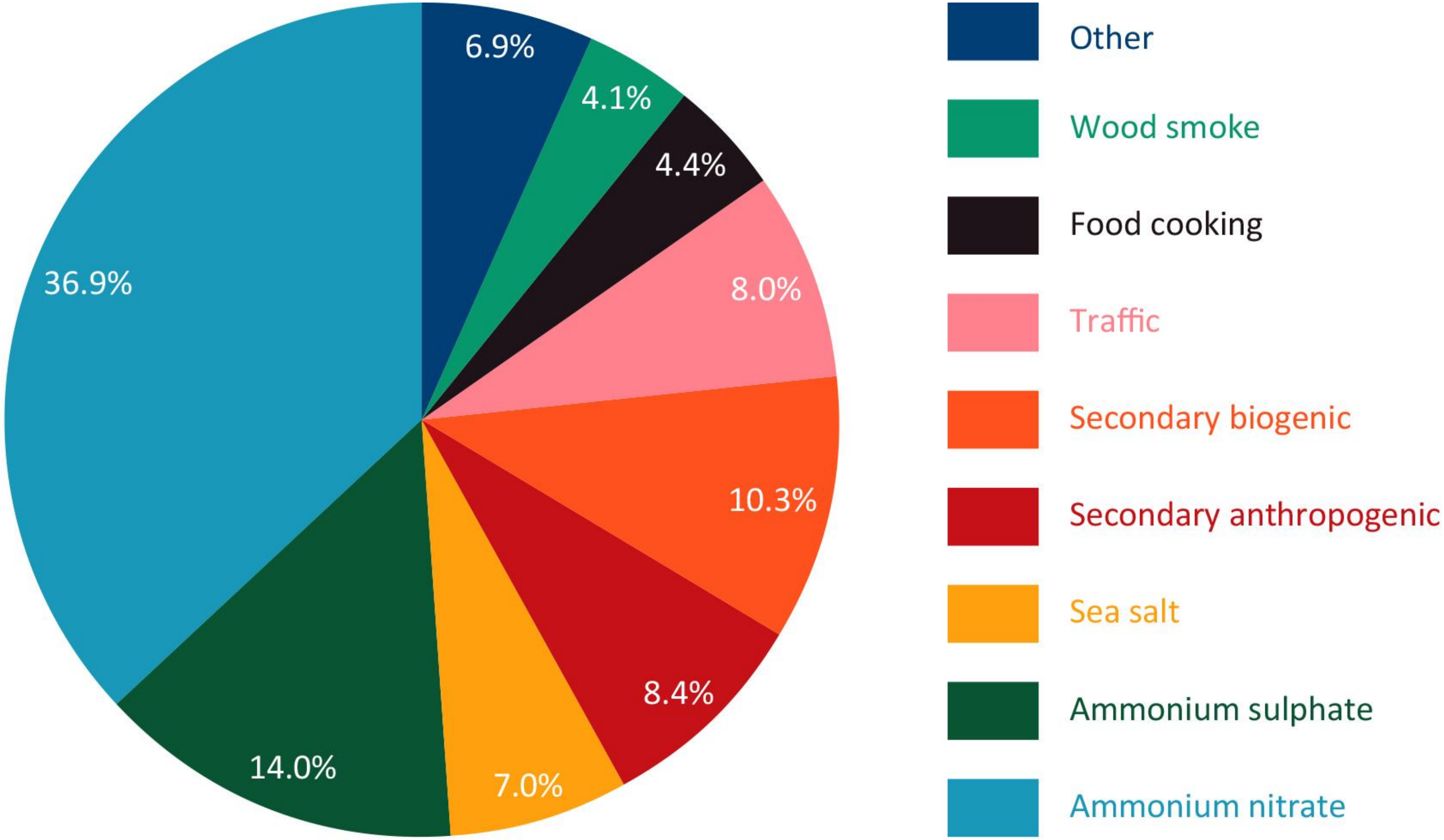
Continued coal and oil combustion for electrical power.

Carbon sequestration with high BVOC emitting tree species.

Indoor air quality declines with reduced ventilation of homes and offices.

Combustion of biomass or hydrogen increases NO_x and $PM_{2.5}$.

Source contributions to $PM_{2.5}$ at North Kensington (%)



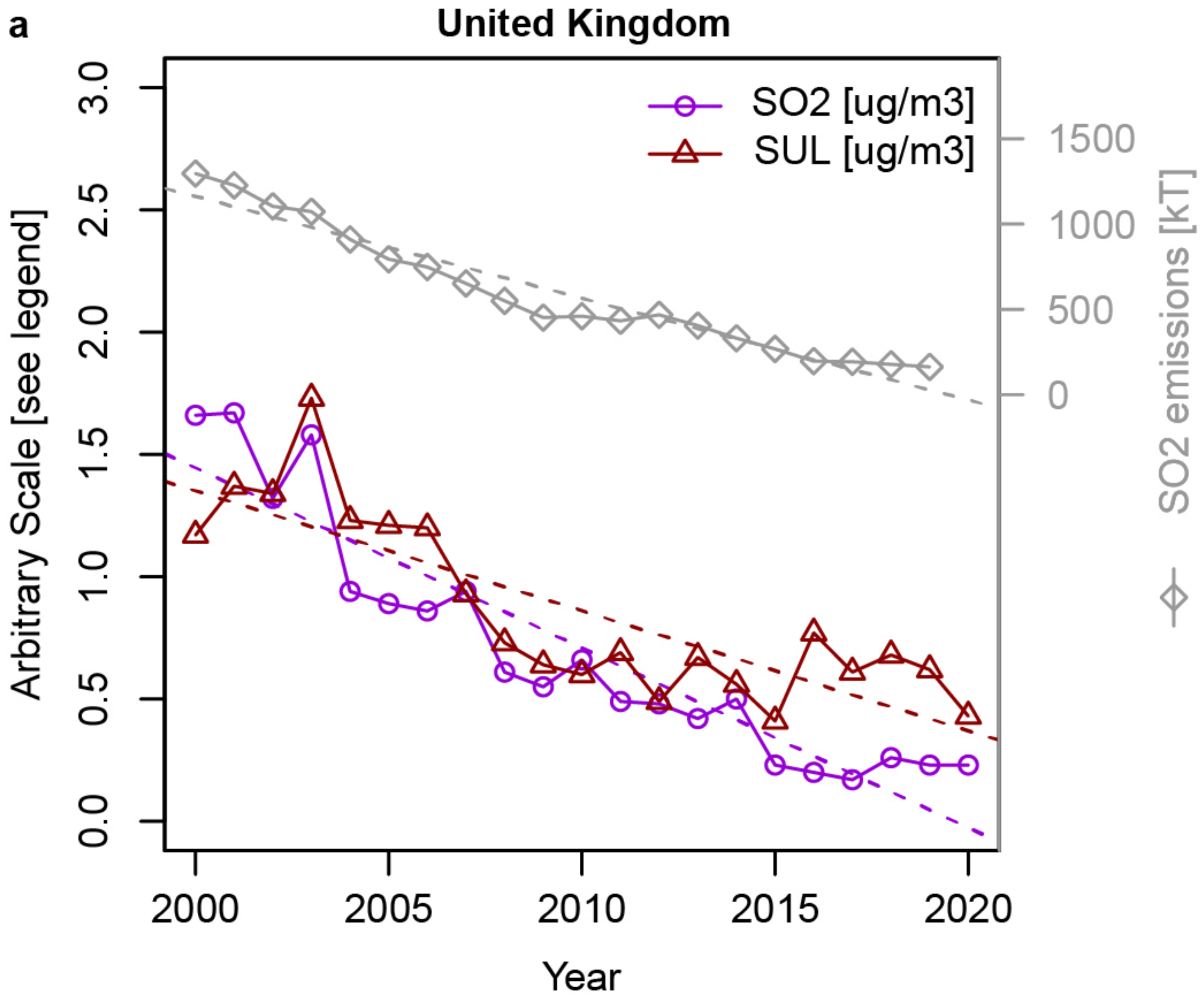
Other = dust/soil (2.2%); coal (1.1%); vegetation (1.3%); natural gas (0.3%); unidentified (2.0%)

Domestic woodsmoke emissions (from the National Atmospheric Emissions Inventory)

	1970	1980	1990	2000	2010	2020
$PM_{2.5}$ Emissions (kt)	5.8	5.8	8.6	9.8	10.0	14.0
Heat Generation (TJ)	7207	7207	10724	12577	14691	30303
Ratio (kT/TJ x 10,000)	8.0	8.0	8.0	7.8	6.8	4.6

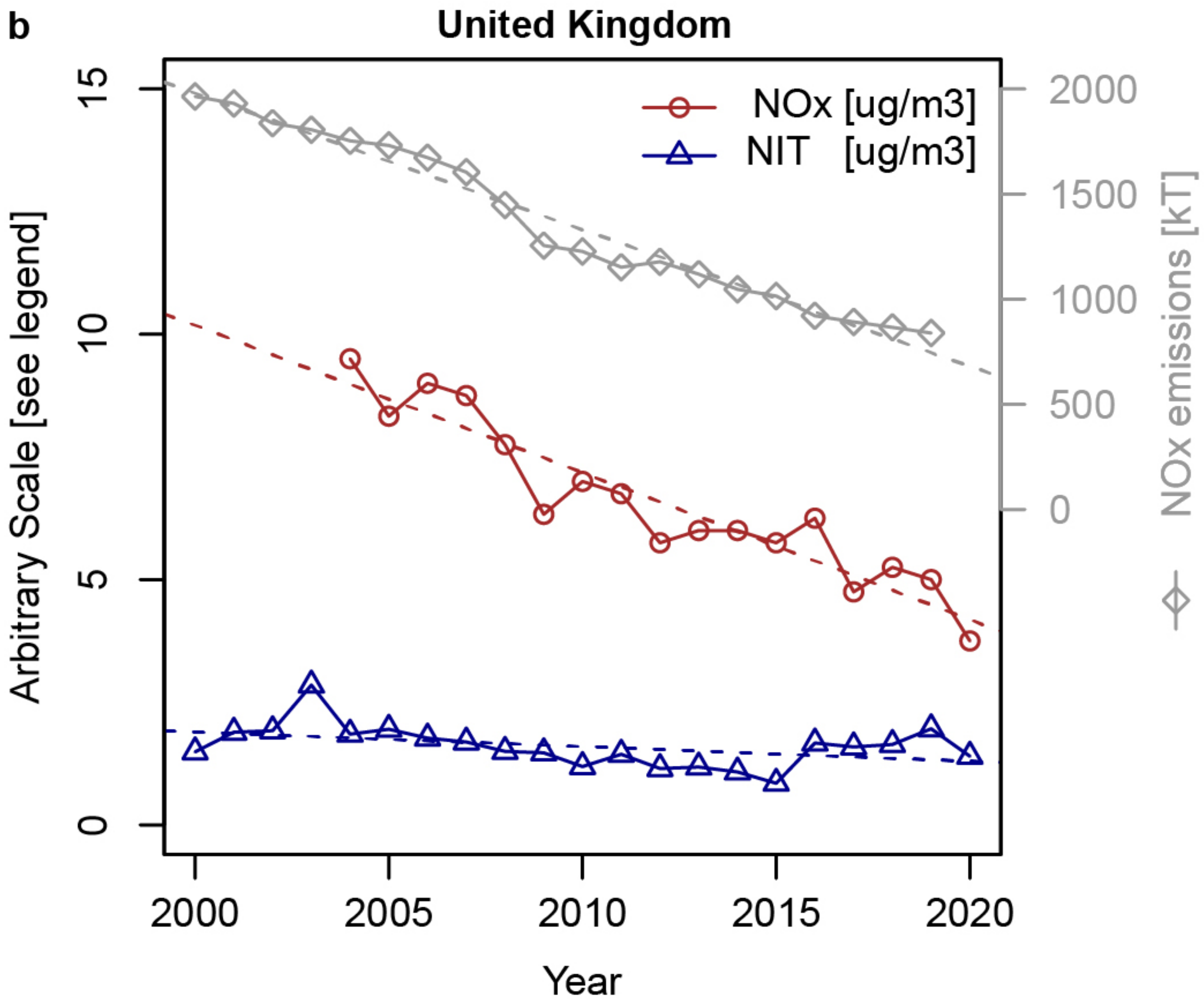
Trends in sulphate from the AGANET sites

(a) UK and relevant European emissions, and concentrations of SO_2 and sulphate

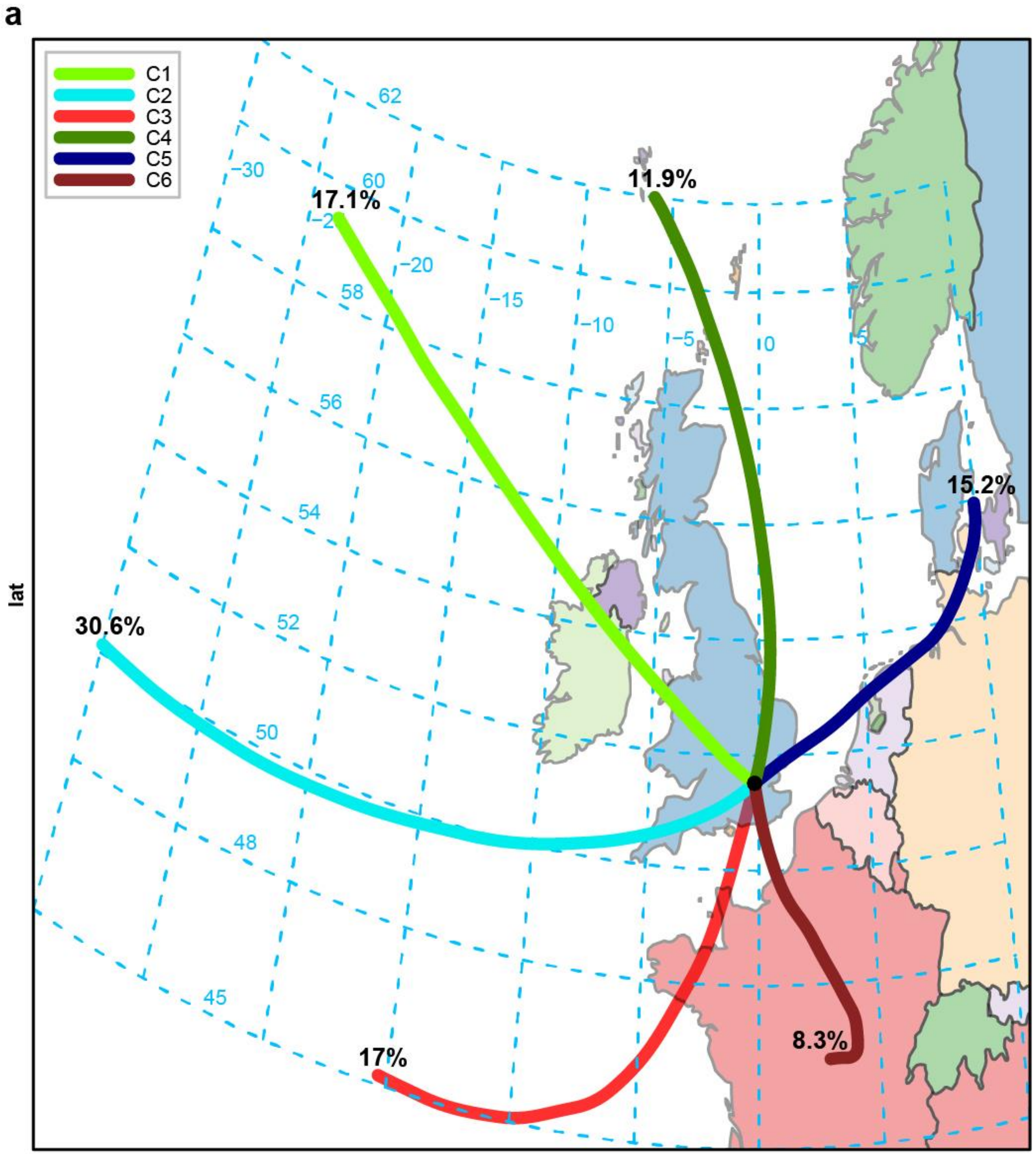


Trends in nitrate from the AGANET sites

(b) emissions and concentrations of NO_x, and nitrate concentrations, from 2000 to 2020 from the AGANET data



Clustered air mass back trajectories terminating in London, 2014-2018



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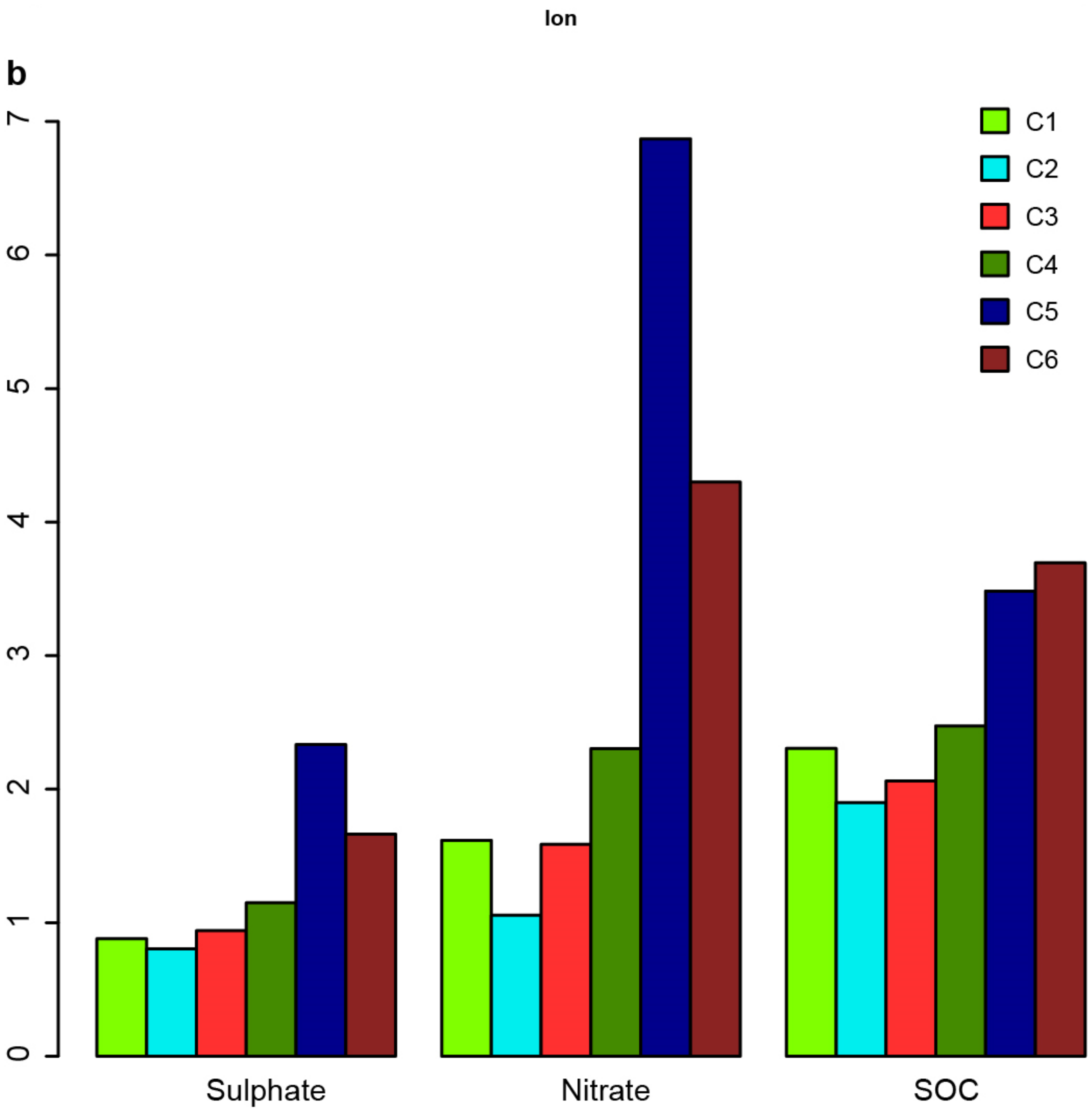
Results of air mass clustering (b) mean concentration of nitrate, sulphate and SOC associated with each back trajectory (µg/m³). Clusters C1 to C4 are maritime; Clusters C5 and C6 are continental



Air pollution abatement

- In southern England, 55% of nitrate, 42% of sulphate and 35% of secondary organic aerosol arrive in trajectories from mainland Europe. Much of this is generated in mainland Europe. These components comprise >60% of $PM_{2.5}$ at North Kensington.
- Consequently, the UK should have a strong interest in strengthening measures which limit emissions in other countries, i.e. the Gothenburg Protocol.
- Nonetheless, UK national emissions remain important, increasingly so when moving from south-east to north-west in Great Britain, so control of UK emissions is also important, especially ammonia from agriculture.

What are the European Union and UNECE considering?

- Euro 7 emissions standards, with:
  - Stricter exhaust emissions controls
  - A limit for brake wear emissions
  - A limit for tyre wear emissions
- Achieve 10μg/m^3 $PM_{2.5}$ by 2030 (94% of monitors predicted to achieve); c.f. UK target, also 10μg/m^3 to be met everywhere by 2040.
- Achieve “zero air pollution” by 2050
- Enhanced air quality monitoring
  - A requirement for air quality supersites to provide detailed near-real time information on particle composition and gases such as ammonia
- Strengthening the Gothenburg Protocol and NECD

Birmingham Air Quality Supersite (BAQS)

- Siqi Hou
- David Beddows

- Roy Harrison
- Zongbo Shi
- William Bloss

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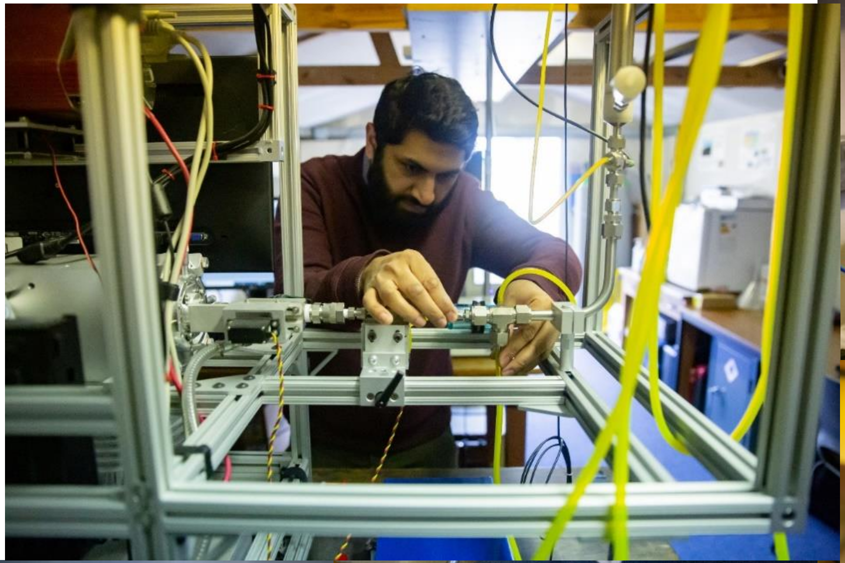

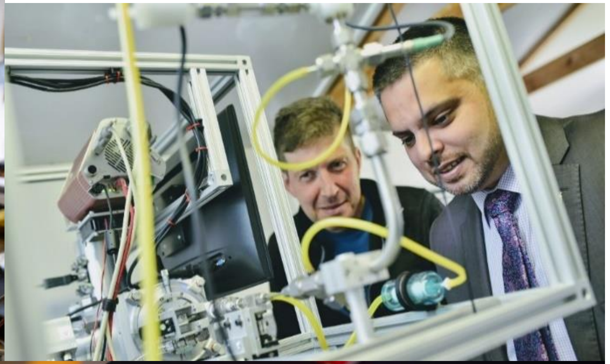

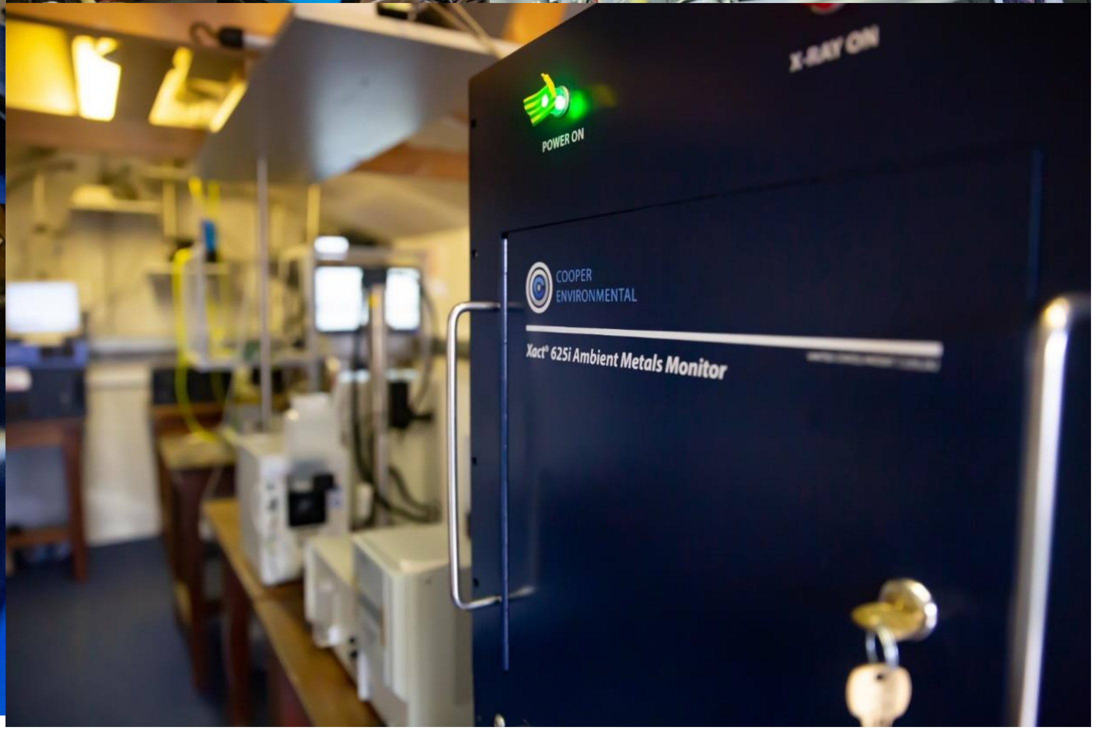

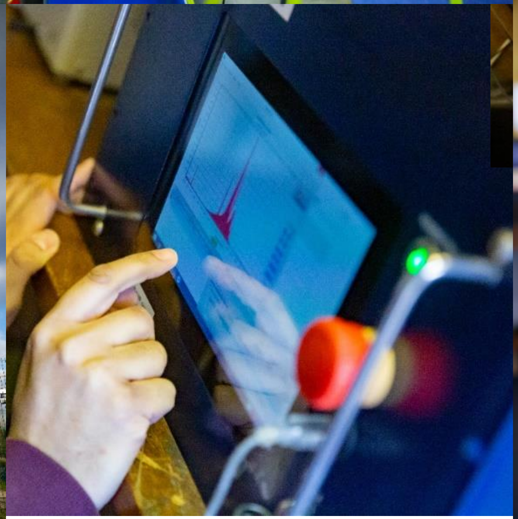

Typical supersite measurements

- $PM_{2.5}$ mass and composition in near-real time:
  - Nitrate, sulphate, chloride, ammonium
  - Elemental (black) carbon (multi-wavelength)
  - Secondary (oxidised) organic carbon
  - Primary organic carbon (biomass smoke; coal smoke, traffic exhaust, cooking)
  - Tracers of tyre wear and brake wear
  - Other trace metals
- Coarse Particles
- Ultrafine particles and particle size distributions
- Ammonia
- Volatile Organic Compounds

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Capabilities of supersites

These include:

- Measurement of novel pollutants for source apportionment and health effects studies, e.g. ultrafine particles, Black Carbon, Oxidative Potential
- Near-real time source apportionment of particulate matter mass and number
- Understanding ammonia sources
- Quantifying wood smoke and cooking particle concentrations
- Quantifying non-exhaust particles from road vehicles
- Evaluation of ozone-precursor relationships
- Source apportionment of Volatile Organic Compounds

Conclusions

- Slow but steady progress in improving air quality
- Some pollutants continue to cause concern due to poorly controlled sources
- Air Quality Supersites offer great potential for advancing scientific understanding of pollutant sources and health impacts
- Health impacts of some novel pollutants (e.g. ultrafine particles) remain poorly defined, largely due to a sparse measurement database
- Oxidative Potential is, as yet, unproven as a predictor of adverse health outcomes and needs further research

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