

The rising threat of domestic wood burning to respiratory health in high income countries: A case study of England and Wales

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Talk content (Two studies)

1



Where is wood burning happening?

Mapping wood-burning prevalence across
England & Wales using EPC data

2



Is it impacting lung health?

Tracking lung-function decline in older adults
(ELSA cohort)

History of domestic solid fuel burning in Europe

Pre-1950s: Coal was the dominant domestic fuel across Europe

1952 The Great Smog of London:

- Severe air pollution event caused by coal burning
- Estimated 12,000 excess deaths

1956 UK Clean Air Act:

- First country to legislate **Smoke Control Areas (SCAs)**
- Under an SCA, you cannot emit smoke from a chimney unless the appliance and fuel are authorized

Late 20th Century:

- Decline in solid fuel due to cleaner energy sources (gas, electricity)
- Air quality improved significantly in many urban areas

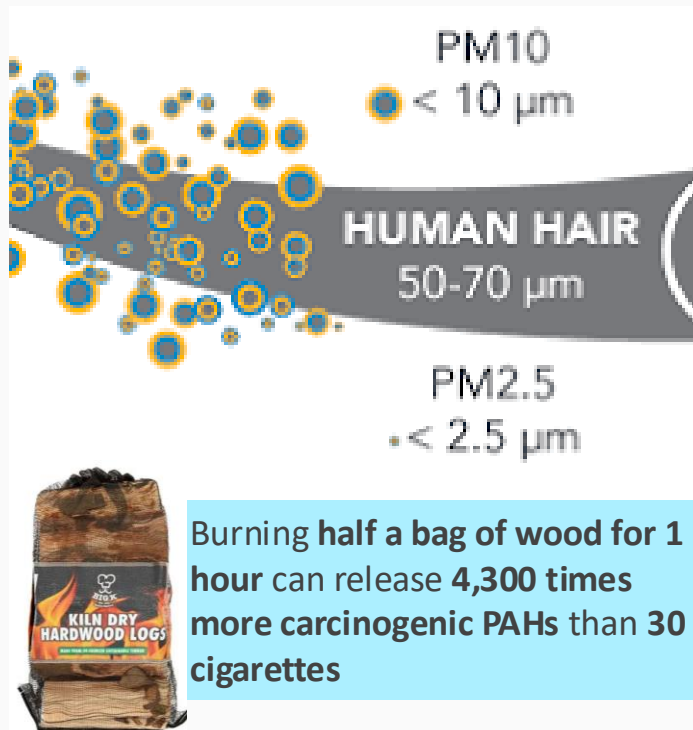
2009 EU Renewable Energy Directive (RED):

- Classified biomass (including wood) as renewable
- Led to a resurgence in domestic wood burning across Europe



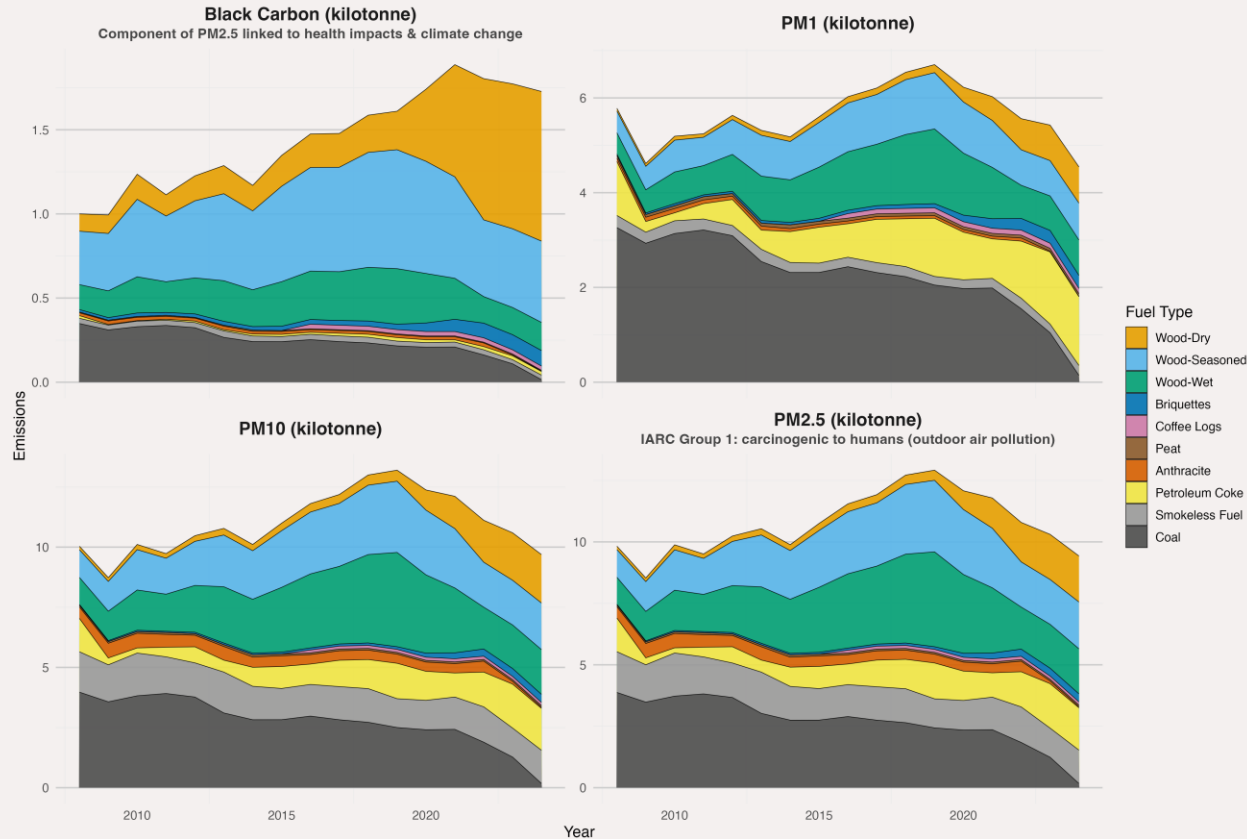
What does domestic wood burning emit?

- **PM_{2.5}**: Tiny particles that reach deep into lungs
 - Linked to heart and lung disease
- **CO**: Reduces oxygen in the body
 - Risky for people with heart issues
- **VOCs**: Includes benzene and formaldehyde
 - Both are cancer-causing
- **PAHs**: Formed from incomplete burning
 - Can cause cancer and weaken immunity
- **Acrolein**: Irritates eyes and lungs
 - Heightened risk for people with chronic lung disease
- **NOx**: Contributes to smog and lung irritation
 - Airway inflammation, worsens asthma, and increases lung infection risk

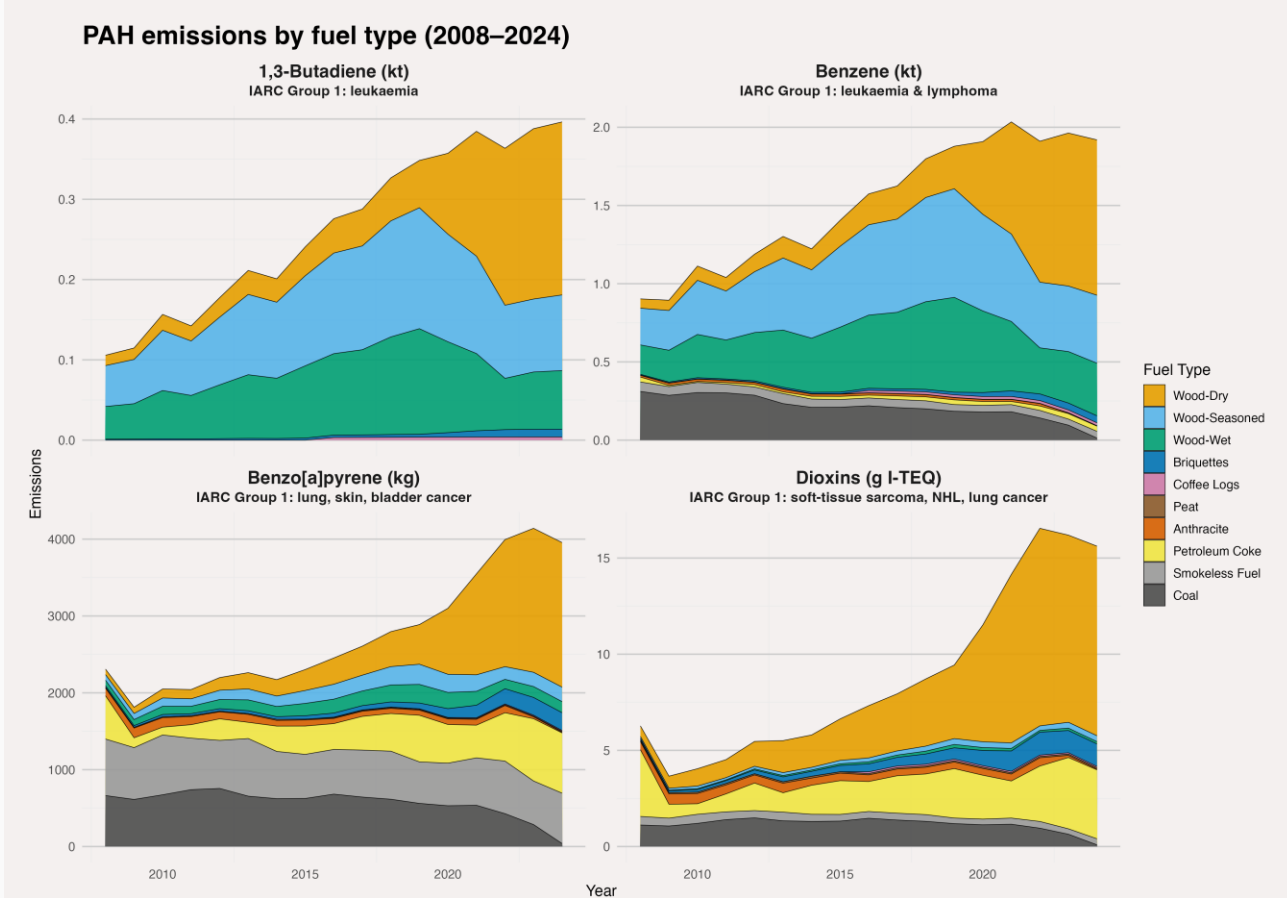


DEFRA/NAEI (2026) estimates by fuel type

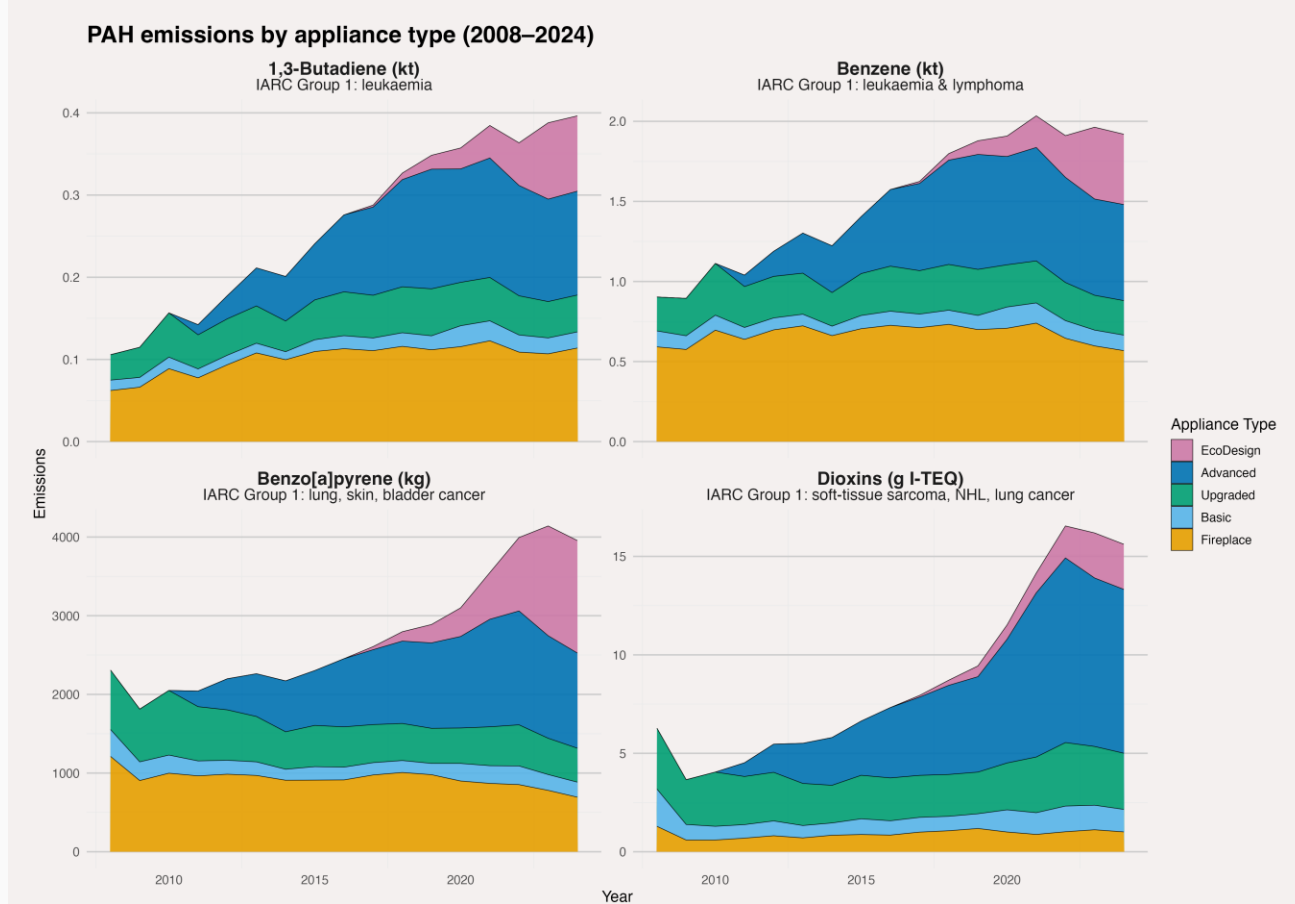
PM emissions by fuel type (2008–2024)



DEFRA/NAEI (2026) estimates by fuel type: PAHs



DEFRA/NAEI (2026) estimates by appliance type: PAHs



Local measurements

Indoor air:

- PM_1 and $PM_{2.5}$ inside the homes using Defra-approved wood stoves were 3× higher than the levels recorded when the stoves were not in use (<https://doi.org/10.3390/atmos11121326>).
- Smaller, less-ventilated rooms had 2–3× higher $PM_{2.5}$ concentrations compared with larger, better-ventilated rooms.

Outdoor/urban emissions:

- Wood burning accounts for 17% of $PM_{2.5}$ in London (LAEI, 2019).
- West Midlands accounts for 25% of $PM_{2.5}$, with winter spikes ~50%. Wood-burning-related $PM_{2.5}$ concentrations were seven times higher than those observed in 2008–2010 (<https://doi.org/10.1016/j.atmosenv.2024.120963>)



You can't manage what you don't measure

IN THEORY

Should be easy to tackle – mostly aesthetic or supplementary heating (99% of homes have central heating).

IN PRACTICE

But hard to measure and monitor (road bias), under-regulated, and difficult to enforce.

WHY IT MATTERS

Knowing where wood burning is a problem is essential for policy, public-health action, and evaluating health impacts through data linkage.

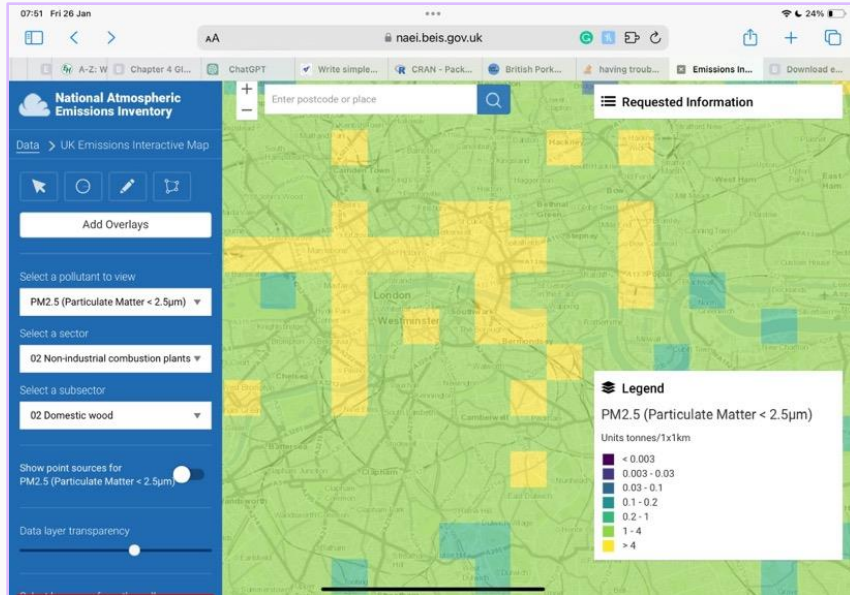


THE ENFORCEMENT GAP

5,600 → 4

complaints led to just four fines in
a year

Mapping residential wood burning at fine scale is challenging



WHAT IT IS

UK NAEI wood PM2.5 emissions maps integrating various data sources (household surveys, Census data) at varying spatial scales.

PROBLEMS

- Spatial misalignment – smoothing biases
- Low-N surveys – imprecise estimates
- Out-of-date data – hard to track short-term changes
- Low resolution in dense urban areas, not linked to policy boundaries

EPCs as an alternative data source

In England & Wales, a valid EPC has been mandatory at point of build, sale, or private rental since 2008 (we used Jan 2009 – Feb 2025).

EPCs contain information on primary and secondary heating sources.

ADVANTAGES

- **High-resolution** – include Unique Property Reference Numbers (UPRNs)
- **Large sample size** – 27.5m EPCs covering 18.7m unique properties (Feb 2025)
- **High-frequency** – dataset updated monthly
- **Openly available** – transparent, accessible, reproducible

LIMITATIONS

- **Missing data** – ~37% of properties have no EPC
- **Selection bias** – missingness correlated with property type (e.g. flats over-represented)
- **Validation** – EPCs not directly informative about wood-burning emissions



Objectives

OBJECTIVE

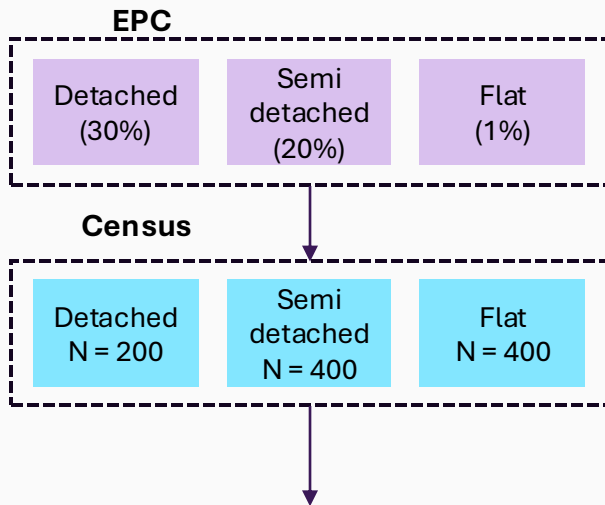
Use EPCs to characterise the spatial distribution of wood-burning heat sources by LSOA across England & Wales.

- Develop a method to account for missing data and selection bias in EPCs

VALIDATE AGAINST

- Air quality data from the national UK monitoring network
- Known relationships between residential wood burning and socio-economic variables (age, deprivation, etc.)

Mapping methods



TWO PRIMARY METRICS

- Spatial **concentration** of wood-fuel heat sources (number per km²)
- Spatial **prevalence** of wood-fuel heat sources (% of houses)
- Reported primarily by LSOA, also by Electoral Ward and Local Authority

CORRECTING FOR MISSING DATA & BIAS

- Calibrate EPC data against 2021 Census housing data
- Estimate prevalence by LSOA × property-type pairs
- Scale to LSOA concentration / prevalence using Census

Validation methods

Validation against UK air quality monitoring networks

- Use daily $\text{PM}_{2.5}$ measurements from 'urban background' UK air quality monitoring sites in 2022–2024
- Plot correlation between concentration of wood-fuel heat sources around the monitor and daily average $\text{PM}_{2.5}$ and the daily average difference between peak / non-peak $\text{PM}_{2.5}$
- Separate analysis by summer / winter seasons

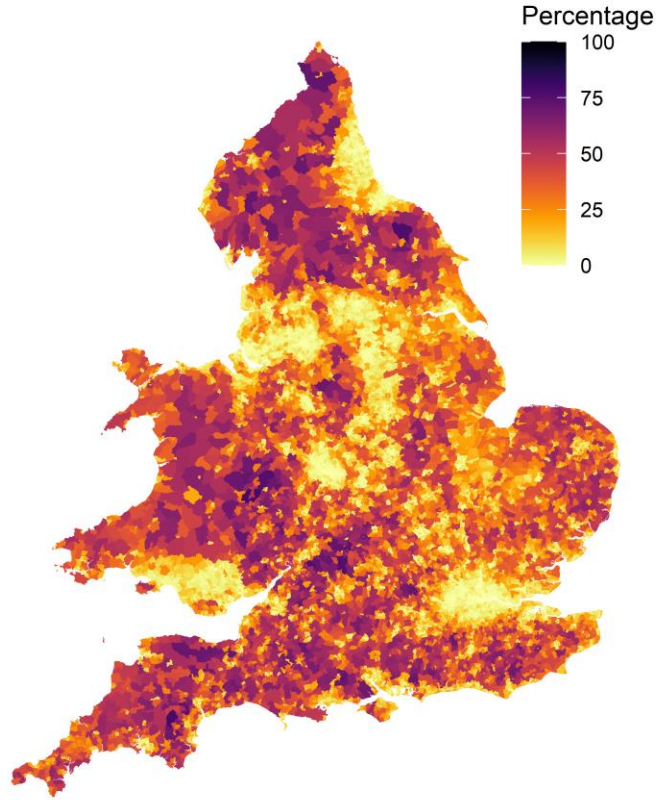
Relationship between residential wood burning and socio-economic variables

- Linked LSOA prevalence / concentration of wood-fuel heat sources to LSOA IMD score, median age, and percentage white ethnicity

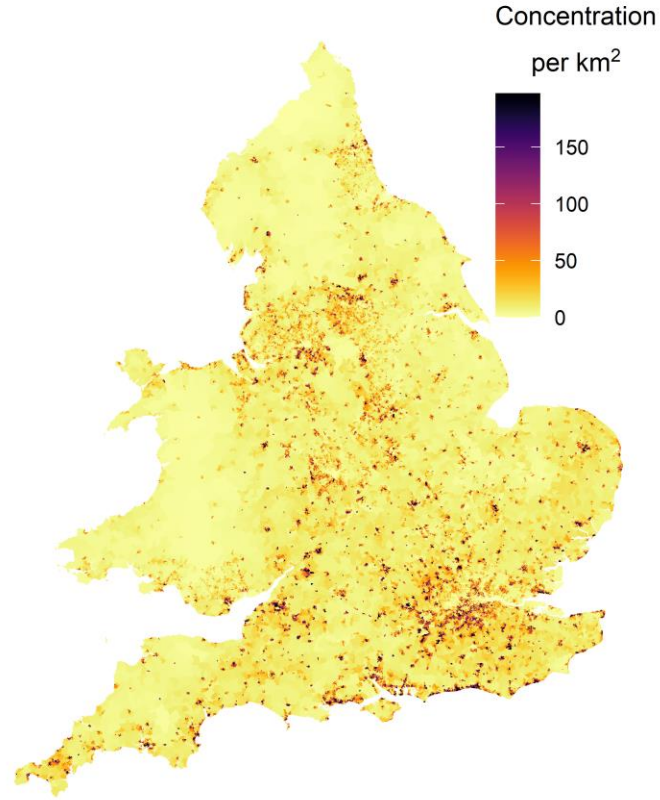


Results – spatial distribution of wood-burning heat sources

A



B



A • Prevalence

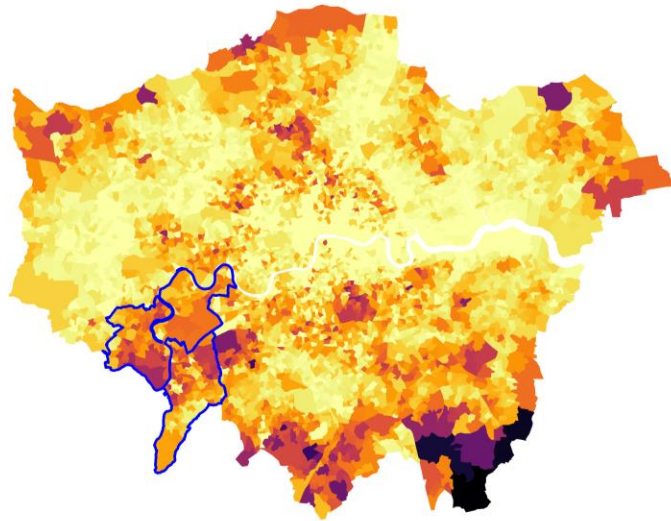
% of homes

B • Concentration

Sources per km²

*Widespread by prevalence;
concentrated in urban hotspots.*

Results – spatial distribution of wood burning in London



Percentage

0 5 10 15 20



Concentration

per km² 0 50 100

A • Prevalence

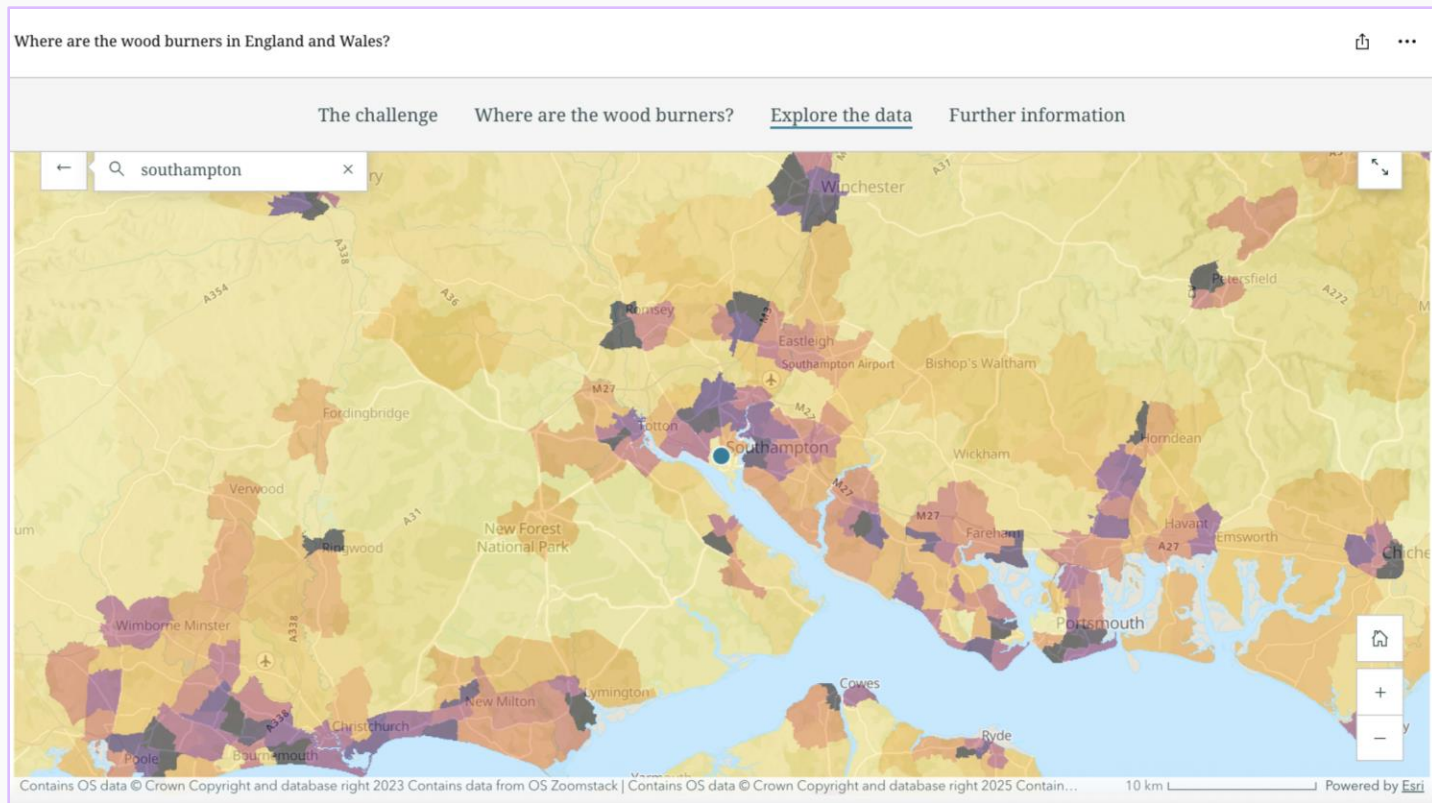
% of homes

B • Concentration

per km²

Blue outline marks the focus area.

Online searchable maps (Ward level)

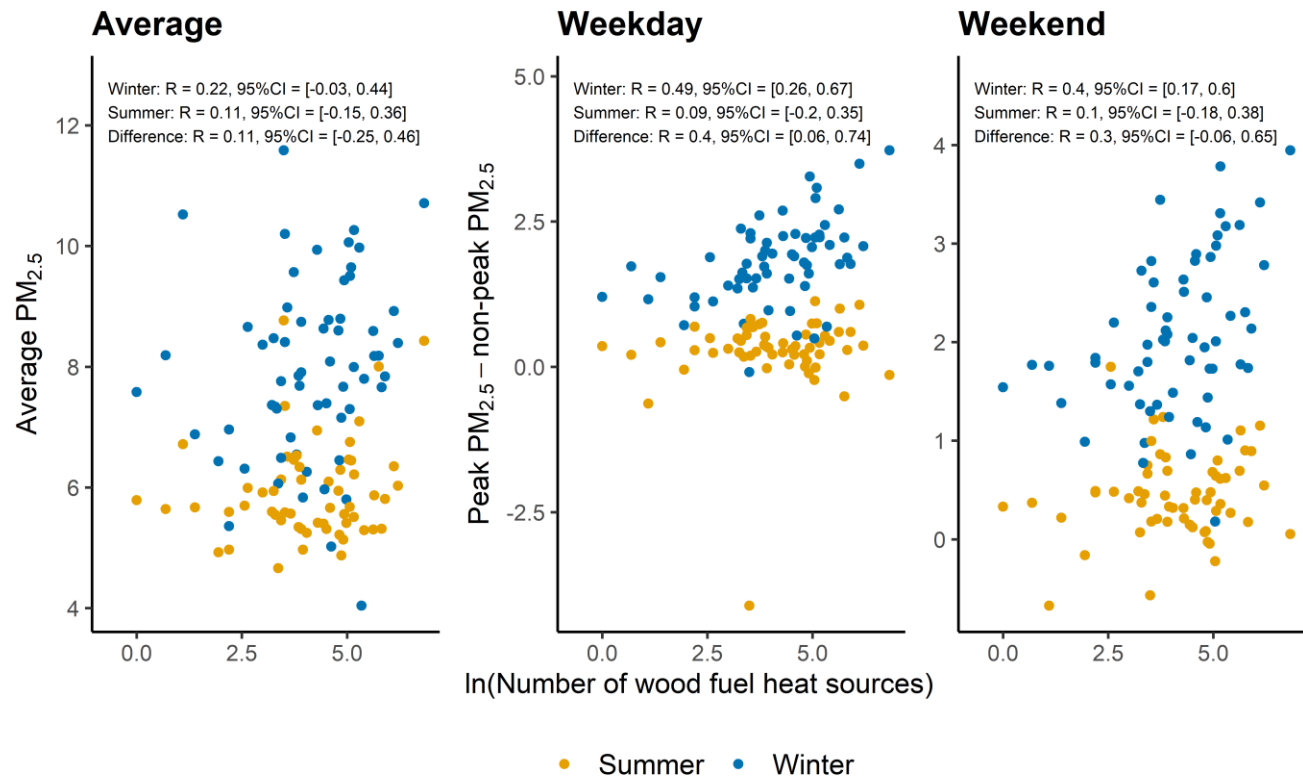


SEARCHABLE ONLINE MAPS

Explore wood-burning prevalence at Ward level across England & Wales.

- Search any place by name
- Guided sections explain the challenge and the data

Results – validation against national air quality monitoring networks

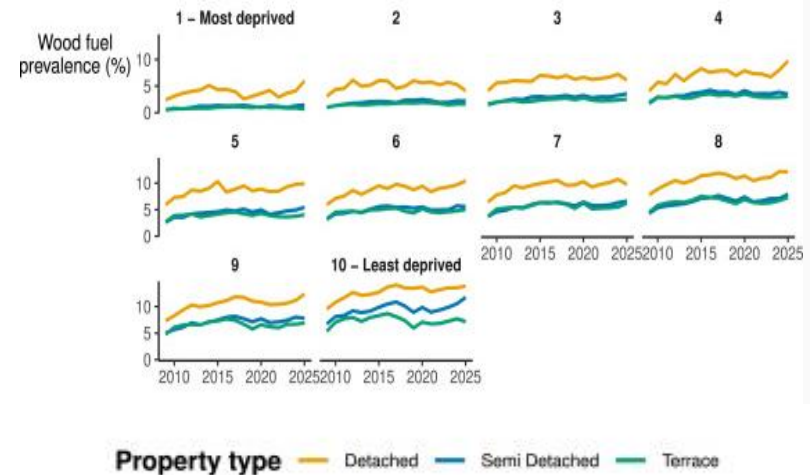
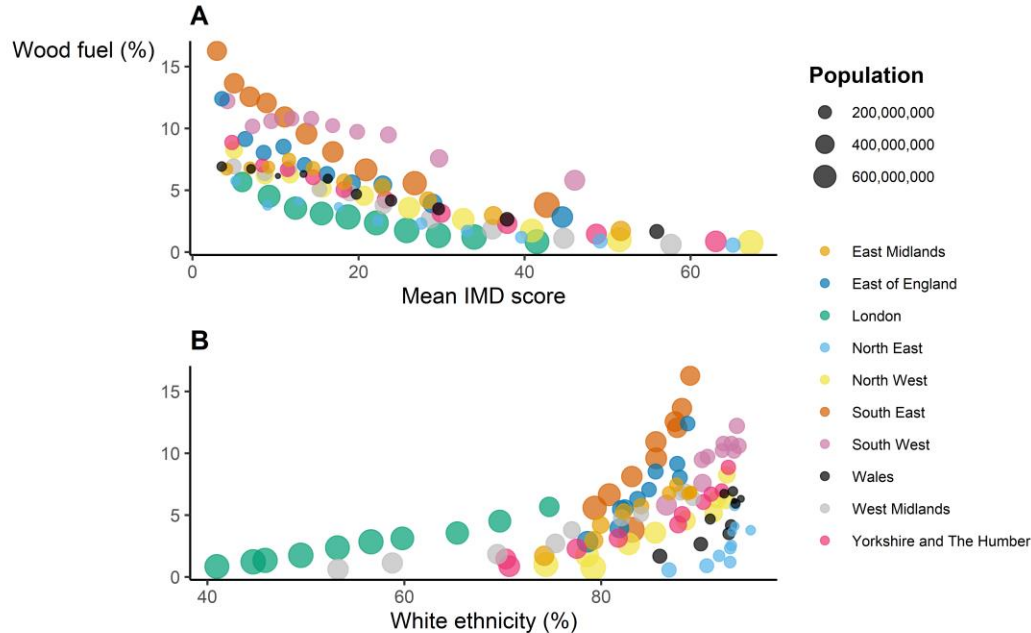


KEY FINDING

A higher density of wood-fuel heat sources is associated with higher $PM_{2.5}$.

- Stronger in winter (blue) than summer (orange)
- Similar on weekdays/weekends

Relationship with time & socio-economic variables



Key finding: wood-fuel prevalence falls with deprivation (higher IMD) and rises with % white ethnicity; detached homes show the highest prevalence across all deprivation deciles.

EPC summary

- Wood-fuel heat sources are common in rural areas but densely clustered in urban Smoke Control Areas (SCAs) and historic smaller towns.
- Urban exposure is mainly outdoor; rural exposure is mostly indoor.
- Affluent, older, white communities show higher wood-burning rates, often discretionary.
- Urban wood burning may worsen pollution inequality and reinforce historic deprivation gradients.
- EPCs can help identify potential emission hotspots and guide targeted awareness, expanded residential monitoring, and regulation (e.g. SCAs).



EPC PREVALENCE

7.0% → 10.3%

2009 → 2024

Why study solid fuel and wood smoke in high-income countries?

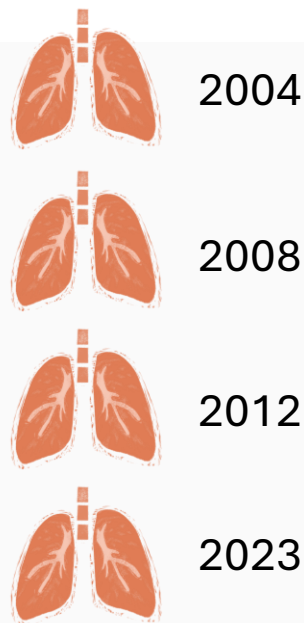
- **A major global health risk (WHO):** household air pollution from solid fuels (wood, coal, dung, crop waste) and kerosene causes ~3.2 million premature deaths a year – COPD, pneumonia, stroke, heart disease and lung cancer.
- **Concentrated in LMICs:** ~2.1 billion people still rely on solid fuels and open fires, mainly in low- and middle-income countries – where exposures are highest and most of the evidence comes from.
- **A high-income evidence gap:** in wealthier countries wood is burned mainly for secondary “amenity” heating; evidence is sparser, exposures lower and harder to measure, and confounding greater (wood-burners tend to be wealthier, healthier).
- **Why it matters now:** domestic wood burning is rising and is now a major source of PM_{2.5} in many high-income countries – so we need robust, population-based evidence to quantify the risk at these lower exposures and guide policy.



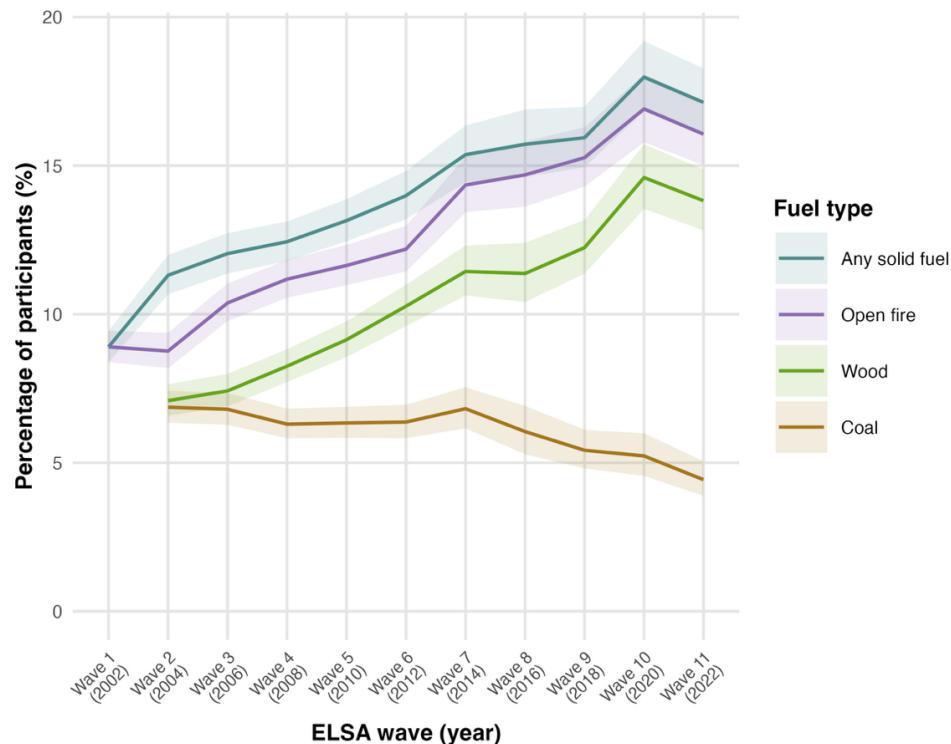
The English Longitudinal Study of Ageing (ELSA)



- **Aim:** To understand the relationship between solid fuel use and lung health over time.
- **Population:** Nationally representative sample of individuals aged 50 and over living in England.
- **Cohort design:** Longitudinal panel study following the same individuals every two years since 2002.
- **Data collection:** Face-to-face interviews, self-completion questionnaires, and nurse visits (every four years) for physical measurements and biological samples.
- **Domains covered:** Health (physical and mental), social and economic circumstances, cognition, well-being, family structure, work, retirement, and use of health and social care.



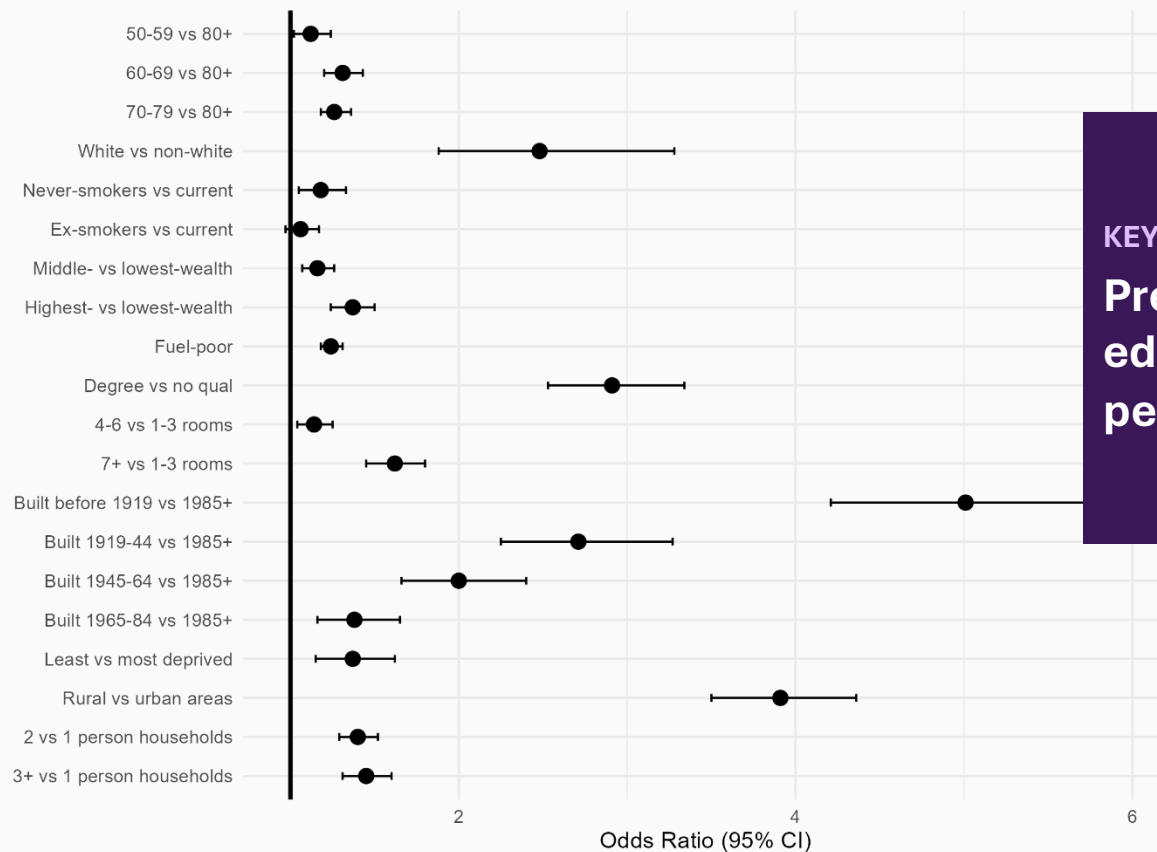
ELSA – reported solid fuel use for heating



KEY FINDING

Solid-fuel use for home heating roughly doubled as the cohort aged – driven mainly by wood (age vs. period effects?)

Characteristics associated with domestic solid-fuel use



KEY FINDING

Predominantly wealthy, educated, ethnically white people in older properties

Associations with lung function decline (FEV₁)



- Linear mixed-effects model of FEV₁ decline over time
- Adjusted for age, sex, height, smoking, ethnicity, respiratory disease, SES & housing
- Among adults aged **60–69**, FEV₁ declined faster in solid-fuel users over 19 years:
 - **322 mL** in solid-fuel users vs **250 mL** in non-users
 - Additional **72.3 mL** adjusted reduction – 3.8 mL/year faster (95% CI 0.4–7.3; $p = 0.030$)
- No association with FVC decline, indicating an **obstructive pattern** of lung-function change
- Same obstructive signature as cigarette smoke: at 60–69, current smoking gave a **186.2 mL** greater FEV₁ reduction vs never-smokers, with no FVC impact
- No associations with diagnosed respiratory disease, respiratory-related hospital admissions, or mortality

ELSA summary



- Solid fuel use (including open fires) doubled among older adults in England between 2002/03 and 2021/22
- Nearly 1 in 5 senior adults now use solid fuel for heating
- Use is more common in affluent, educated, white communities, often for discretionary purposes
- Solid fuel users show faster lung function decline than non-users
- Studying health impacts is challenging due to strong social confounding

Wood fuel burning and health in high-income countries

What the studies show (UK, US, Canada, Australia, Nordics):

- **Respiratory:** faster lung-function decline, COPD, higher respiratory mortality, and worse asthma/airway inflammation.
- **Cancer:** higher lung-cancer incidence – including in never-smokers – rising with how frequently wood is burned.
- **Cardiovascular:** more heart-failure and heart-attack admissions; within hours, exposure stiffens arteries and lowers heart-rate variability.
- **Brain:** higher dementia incidence.
- **Mortality burden:** substantial premature deaths from residential wood combustion, much of it driven by very local emissions.
- **Most at risk:** older adults, people with existing heart or lung disease, and never-smoking women.



OVERALL

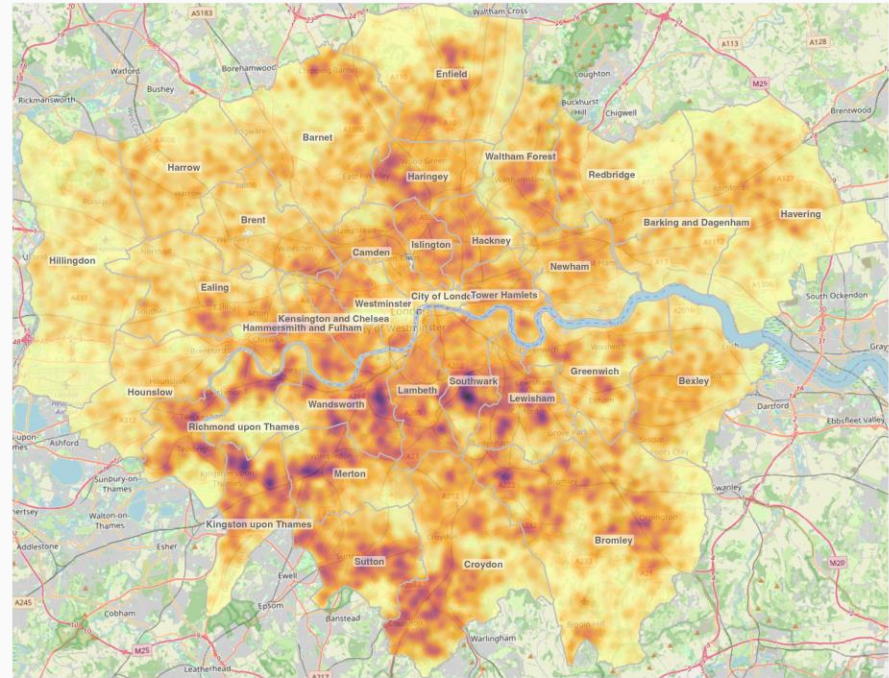
Even at the low pollution levels common in high-income countries, wood smoke is consistently harmful – there is no safe level.

Next steps

- Integrate EPC, topographic and meteorological data to model daily emissions in major cities using ADMS Urban and link to health outcomes using national electronic health records.
- Develop an easy-to-use dashboard for EPC data and public health animation to support campaigns.

Kernel density of predicted wood-burning properties

Smoothed surface (bandwidth 1.0 km) - 42,250 predicted properties



Basemap © OpenStreetMap contributors. EPC data modelled with XGBoost; census-reweighted.

The wider team

- Mr Calum Kennedy (UCL Statistical Science)
- Prof. Pia Hardelid (UCL Institute of Child Health)
- Prof. John Hurst (UCL Respiratory Medicine)
- Prof. Matt Loxham (University of Southampton)
- Prof. Adam Dennett (UCL Centre for Advanced Spatial Analytics)
- Prof. Jon Taylor (University of Tampere, Finland)
- Prof. Nicola Shelton (UCL Epidemiology and Public Health)
- Prof Paola Zaninotto (UCL Epidemiology and Public Health)
- Dr Shaun Scholes (UCL Epidemiology and Public Health)
- PPIE Panel



Links

Full EPC paper:

<https://www.sciencedirect.com/science/article/pii/S0160412025002880>

Replication code: https://github.com/UCL-Wellcome-Trust-Air-Pollution/EPC_mapping_project_code

Non-EPC data: <https://zenodo.org/records/15453789>

ArcGIS Storymap:

<https://storymaps.arcgis.com/stories/9231a18627b94b3a80e4f33fb3b4a9fd>

