# Modelling the Health Burden of Air Pollution in the UK using Updated Exposure-risk Relationships

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1. Fine particulate matter (PM$_{2.5}$) air pollution and disease burden

- Long-term exposure to ambient PM$_{2.5}$ is a leading cause of global premature mortality.
- In the UK, PM$_{2.5}$, dominated by agricultural emissions of ammonia (Kelly et al., 2023), is linked to **29,000-34,000** adult early deaths a year, estimated using models that relate exposure to health risk (Gowers et al., 2014, Macintyre et al., 2023).
- Recent cohort studies have identified a supralinear relationship between exposure and risk at relatively low PM$_{2.5}$ concentrations typical of the UK (5-12 µg m^{-3}) (Brauer et al., 2022).
- Here we use this new knowledge to estimate adult premature mortality in the UK for present day (2019) and future (2030).

Fine particles or PM$_{2.5}$ cause **respiratory** and **cardiovascular diseases** when inhaled
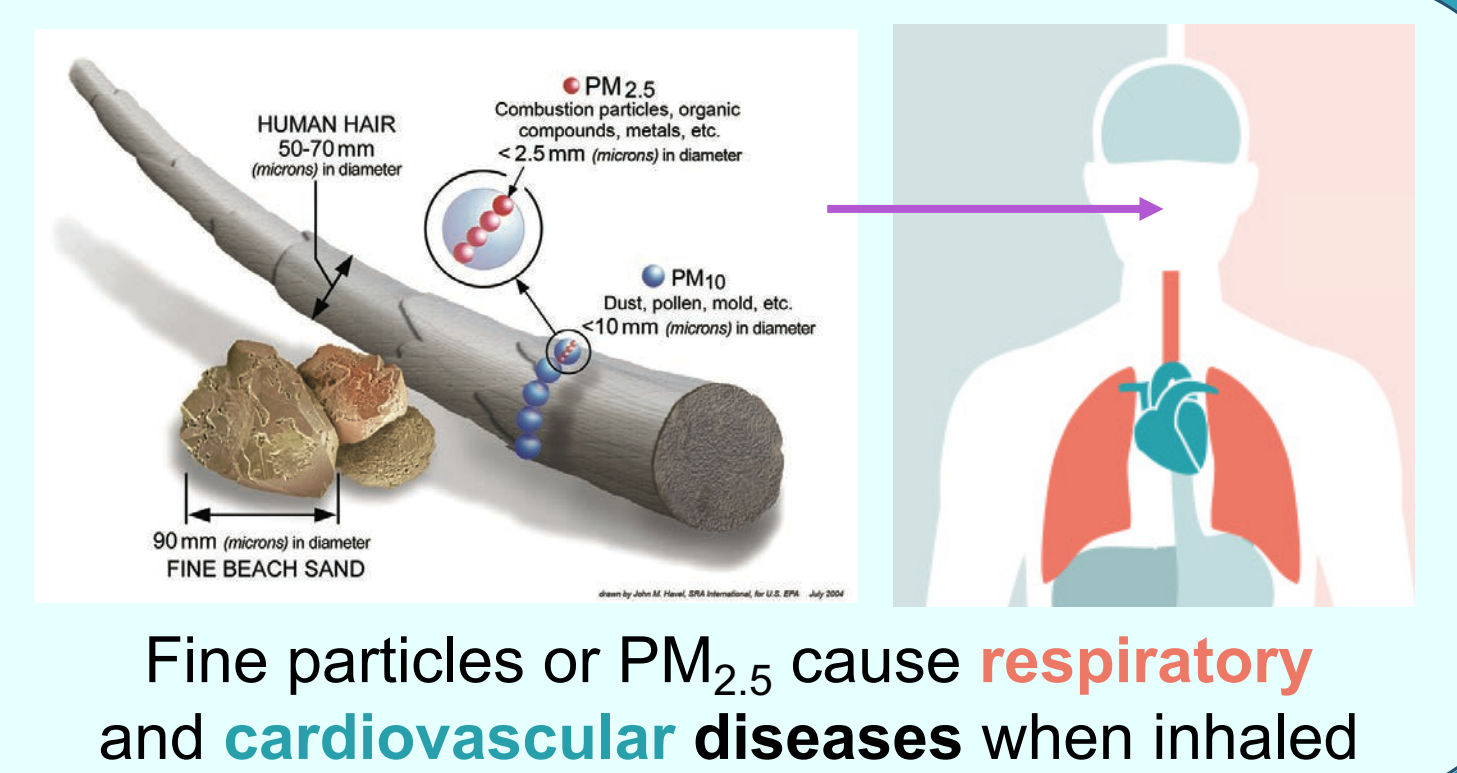
2. Methodology   A four-step approach to estimate premature mortality from long-term (annual) exposure to PM$_{2.5}$
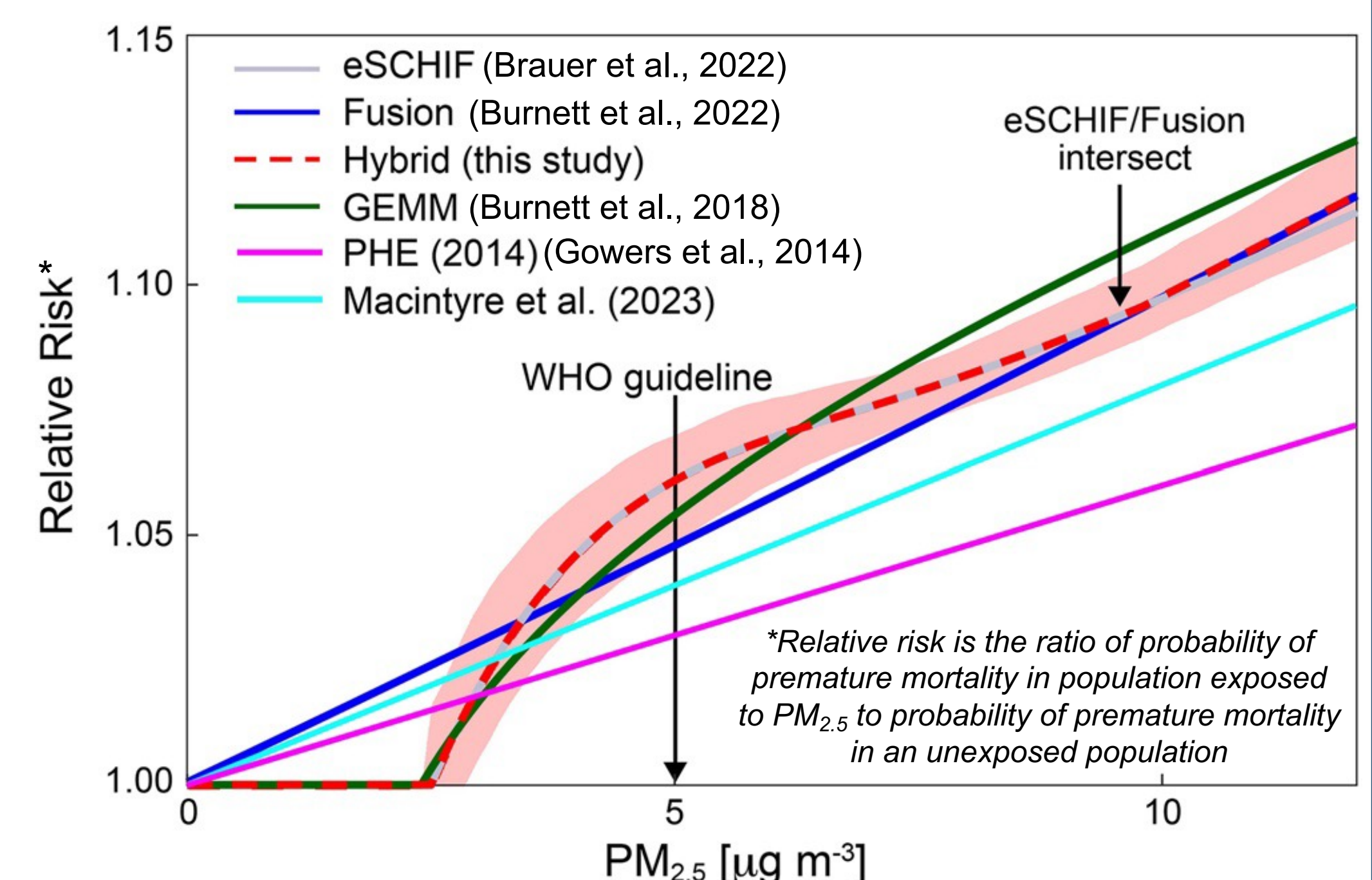
2.1. Simulate UK annual mean PM$_{2.5}$

- We use the *GEOS-Chem* atmospheric chemistry model to simulate ambient PM$_{2.5}$ concentrations in 2019.
- We also use emission projections for 2030 to assess the efficacy of legally binding and best available measures for reducing precursor emissions of PM$_{2.5}$.
- Modelled PM$_{2.5}$ is validated against the UK surface monitoring network (Kelly et al., 2023).
- 79% UK exceeds WHO PM$_{2.5}$ guideline.

Modelled annual mean PM$_{2.5}$ for 2019

WHO guideline

PM$_{2.5}$ [µg m^{-3}] 0 3 6 9 12
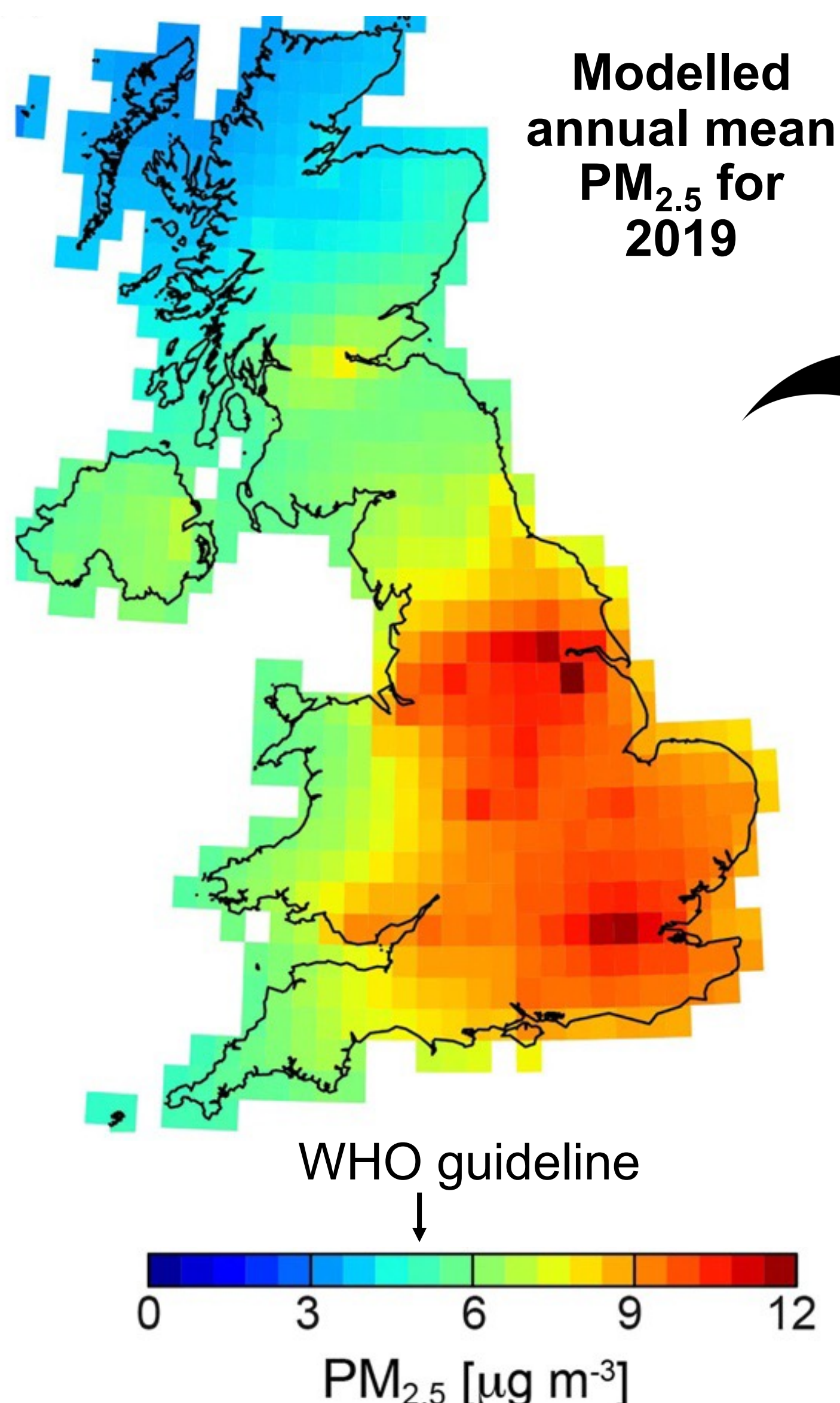
2.2. Relative risk (RR) from updated exposure-harm relationships

- We use the hybrid health risk assessment model combining **Fusion** (combines best of 3 well-established curves) and **eSCHIF** (Canadian cohort, provides RR at low PM$_{2.5}$) with transition at their intersection (Fusion > 9.8 µg m^{-3} and eSCHIF for 2.5-9.8 µg m^{-3}) *[Approach motivated by Weichenthal et al. (2022)]*
- Updated RR above 1.06 (PHE) and 1.08 (Macintyre et al., 2023) at 10 µg m^{-3} previously used for the UK

Legend: eSCHIF (Brauer et al., 2022); Fusion (Burnett et al., 2022); Hybrid (this study); GEMM (Burnett et al., 2018); PHE (2014) (Gowers et al., 2014); Macintyre et al. (2023)

eSCHIF/Fusion intersect

WHO guideline

Relative risk is the ratio of probability of premature mortality in population exposed to PM$_{2.5}$ to probability of premature mortality in an unexposed population

Relative Risk* (y-axis 1.00–1.15); PM$_{2.5}$ [µg m^{-3}] (x-axis 0–10)

2.3. Estimate Population Attributable Fraction (PAF)

PAF is proportion of premature mortality attributed to long-term exposure to PM$_{2.5}$

$$PAF = 1 - \frac{1}{RR}$$

Standard approach as in Vohra et al. (2021), Burnett et al. (2018)

2.4. Calculate premature deaths

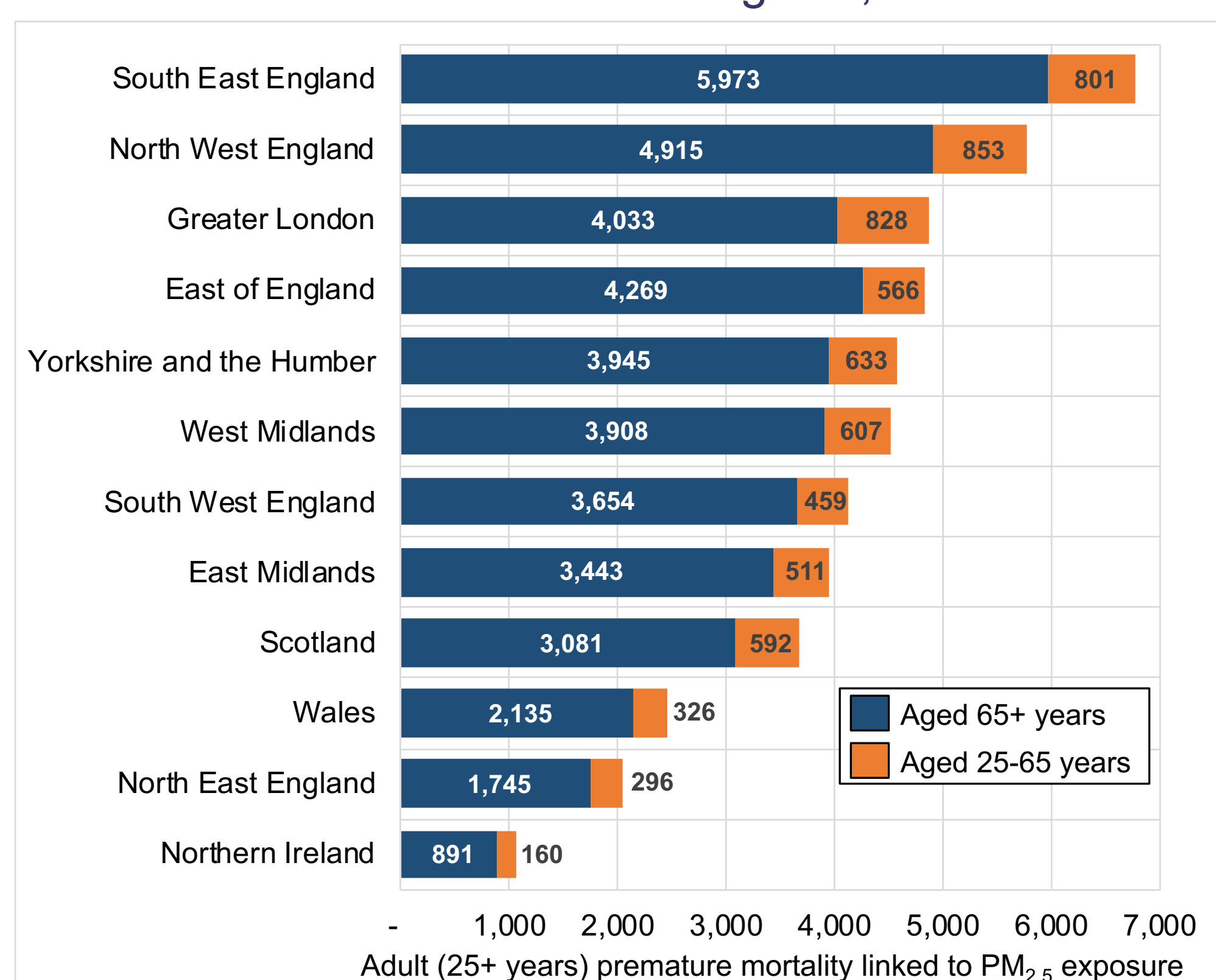Premature death is estimated using PAF, adult population (Pop) from WorldPop and baseline mortality rates (BMR) from ONS

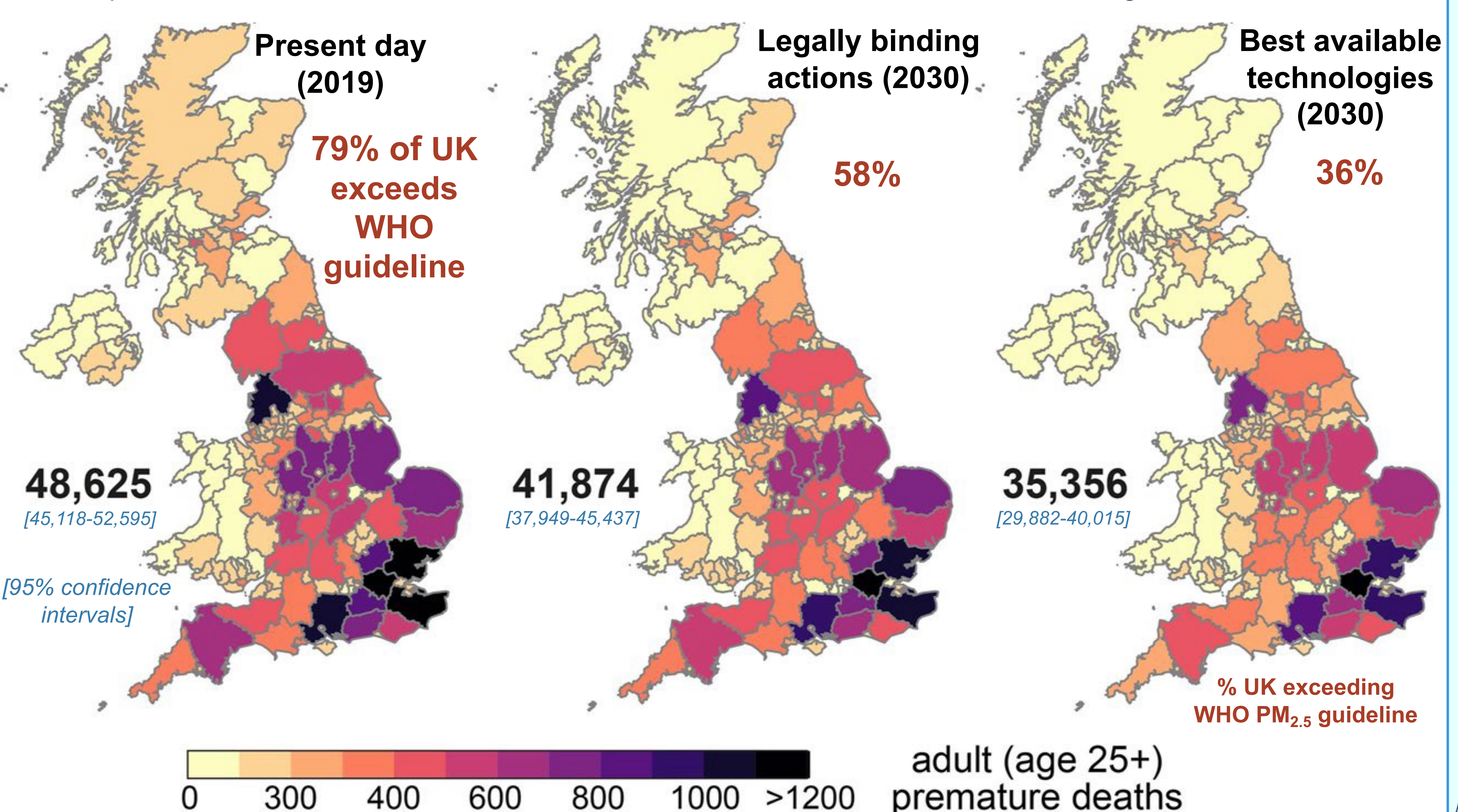$$PM_{2.5}\text{-attributable mortality} = PAF \times Pop \times BMR$$

3. Results   Severe health burden of PM$_{2.5}$ pollution persists in the UK despite adopting best available technologies

1. We estimate 48,625 adult premature mortality attributable to exposure to ambient PM$_{2.5}$ in the UK in 2019; 15,000-20,000 more than estimates using outdated health-risk assessment models.
2. The elderly (65+ years) account for most (86%) UK deaths. 89% in South West England, 83% in London.

Region	Aged 65+ years	Aged 25-65 years
South East England	5,973	801
North West England	4,915	853
Greater London	4,033	828
East of England	4,269	566
Yorkshire and the Humber	3,945	633
West Midlands	3,908	607
South West England	3,654	459
East Midlands	3,443	511
Scotland	3,081	592
Wales	2,135	326
North East England	1,745	296
Northern Ireland	891	160

Adult (25+ years) premature mortality linked to PM$_{2.5}$ exposure (x-axis: -, 1,000, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000)

3. All adult (25+ years) premature mortality in Greater London exceeds that in Scotland, Wales and Northern Ireland.

4. Decline in precursor emissions of PM$_{2.5}$ by adopting currently legislated measures results in 41,874 premature deaths by 2030 or 6,751 avoided early deaths. By adopting best available technologies, these total 35,356 premature deaths or 13,269 avoided deaths, twice that achieved with current legislation.

Present day (2019) — 79% of UK exceeds WHO guideline — 48,625 *[45,118-52,595]* *[95% confidence intervals]*

Legally binding actions (2030) — 58% — 41,874 *[37,949-45,437]*

Best available technologies (2030) — 36% — 35,356 *[29,882-40,015]*

% UK exceeding WHO PM$_{2.5}$ guideline

adult (age 25+) premature deaths — 0 300 400 600 800 1000 >1200

4. Key findings

➤ PM$_{2.5}$ is more hazardous to UK adults than previously reported
➤ Elderly population is most affected (83-89%) by PM$_{2.5}$ pollution across the UK
➤ A supralinear exposure-response curve also suggests there are substantial public health gains in targeting dominant source contributors to PM$_{2.5}$, in particular the unregulated agricultural sector. This is likely to be offset by the increase in an aging population by 2030.

Check out Marais et al. (2023) for more details

References

1) Braur et al., url:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9556709/pdf/hei-2022-212.pdf, 2022.
2) Burnett et al., doi:10.1073/pnas.1803222115, 2018.
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4) Gowers et al., url:https://www.gov.uk/government/publications/estimating-local-mortality-burdens-associated-with-particulate-air-pollution, 2014.
5) Kelly et al., doi:10.1016/j.cacint.2023.100100, 2023.
6) Macintyre et al., doi:10.1016/j.envint.2023.107862, 2023.
7) Marais et al., doi:10.1029/2023GH000910, 2023.
8) Vohra et al., doi:10.1016/j.envres.2021.110754, 2021.
9) Weichenthal et al., doi:10.1126/sciadv.abo3381, 2023.

Interactive Dashboard

X (formerly Twitter): @kohra_thefog