Written evidence submitted by Prof. Alastair Lewis on behalf of the National Centre for Atmospheric Science (NCAS).

About NCAS

The National Centre for Atmospheric Science is one of the Natural Environment Research Council's (NERC) established research centres. The Centre increases knowledge of key environmental issues including climate change, weather processes and atmospheric composition including air quality.

Declaration of interests.

NCAS derives the majority of its research funding from UKRI in addition to receiving grants and contracts from government departments and commercial sources. Prof Alastair Lewis is an employee of the University of York and is currently: Chair of the Defra Air Quality Expert Group (AQEG), Chair of the Department for Transport Science Advisory Council and a member of the Environmental Sustainability Panel of the Civil Aviation Authority.

What evidence exists of the extent of air pollution directly or indirectly impacting health of individuals or communities in England?

1. Exposure to air pollution remains the largest modifiable environmental risk to global public health. In the UK anthropogenic air pollution is associated with causing and/or exacerbating multiple disorders such as respiratory and cardiovascular diseases and is estimated to lead to around 30,000 deaths every year. The mechanisms that cause harm are multiple; exposure to air pollution can led to immediate effects, for example inducing asthma, or harms that accumulate through long-term (years to decades) exposure, such as increased cancer risk and dementia.

2. Ill health and deaths associated with air pollution are very rarely directly attributed to pollution in NHS admissions or treatment data or on death certificates. A useful analogy is to imagine the health impacts of poor air quality manifesting in a similar manner to those from poor diet, smoking or physical inactivity. These are also causes of major harm to public health that unequivocally led to reduction in life expectancy but, like air pollution, are typically not named specifically as causes of death.
3. Individuals and communities are affected by air pollution in different ways. Those living in the north and west of the UK experience on average better air quality than the south and east of the country, arising because of population density, distance from mainland Europe (which is a source of pollution) and weather conditions (wetter and windier weather is good for air quality). City-dwellers experience more pollution than those in the countryside.
4. There are some substantial disparities in air pollution based on deprivation and ethnicity. The most deprived communities in the UK experience, on average, higher emissions of pollution (both NO_x and $PM_{2.5}$) in their local environment than the least deprived[1]. Once deprivation effects are accounted for there is then a further enhanced disparity, and exposure to higher emissions, in communities that have substantial non-white populations.
5. Within communities the effects of air pollution are variable. Individuals with underlying health conditions for example COPD, heart disease, asthma, may be more acutely impacted than the wider population. However, air pollution has effects beyond those with pre-existing health conditions. Significant harm arises from the accumulation of exposure over many years, so whilst individuals may feel no immediate effects, like smoking, damages build over a life course. The effects of exposure to persistent air pollution are likely particularly significant in the young during physical development.

What evidence exists to demonstrate the impact of the Ultra Low Emission Zone in London, and other Clean Air Zones nationwide, on reducing public health risks or improving health outcomes within areas where they have been introduced?

6. Nitrogen dioxide (NO_2) is a relatively short-lived primary pollutant (lifetime ~ 2 hours) with highest concentrations historically at the roadside due to transport combustion emissions. The concentration at any given location is determined predominantly by local emissions and measures such as ULEZ have been used to moderate roadside concentrations. Since interventions of this kind discriminate by

[1] Chapter 3: How air pollution is changing. (Figure 5, p60), Chief Medical Officers Annual Report, 2022.

vehicle tailpipe emission standards, they are most effective at reducing tailpipe pollutants. Importantly for $PM_{2.5}$ the majority of emissions from vehicles now arise from friction and abrasion, the wear of tyres on the road and from brakes. These emissions continue to occur even with electrified vehicles.

7. ULEZ and CAZ approaches can be effective public health interventions for managing NO_2 pollution. However as newer and cleaner vehicles, including BEVs, enter the transport fleet their efficacy will decline over time - if they remain based on tailpipe emission standards. By around 2030 NO_x emissions from road transport will be roughly equal to NO_x from natural gas combustion used for space heating at a national scale[2]. In central London burning natural gas now contributes as much to NO_2 pollution as transport[3,4]. Future city-scale interventions will therefore need to look beyond traffic management to reduce urban NO_2 lower.

8. Domestic combustion (particularly wood burning) is currently the largest source of $PM_{2.5}$ in cities. Whilst ULEZ has some impacts in reducing concentrations by excluding vehicles with high tailpipe emissions the effects are smaller than for NO_x. Most $PM_{2.5}$ that is now released from road transport is non-exhaust. Modal shift away from cars and towards active travel and public transport all help reduce non-exhaust $PM_{2.5}$.

Are the current national targets for outdoor air pollution ambitious and wide-ranging enough to provide adequate protection for public health and the environment in a) rural and b) urban areas?

9. **$PM_{2.5}$**: The WHO (2021) guidelines identified that harms from exposure to $PM_{2.5}$ occur at annual average concentrations above 5 $\mu g\ m^{-3}$, a value that is lower than the interim and long-term targets set in the Environment Act (2021). Whether the Environment Act target is 'adequate' raises a more philosophical question about whether targets should be always be practically achievable or whether they should represent optimal end-points irrespective of practicality. If a target must be achievable then an annual average 10 $\mu g\ m^{-3}$ for outdoor $PM_{2.5}$ is arguably about the most ambitious limit value that could be set, if it is to be achieved across England as a whole.

10. The southeast of England is exposed to the import of pollution from continental Europe, added to which is $PM_{2.5}$ arising from natural sources such as soil dust, biogenic emissions, wildfires and so on. These external contributions likely lead to a 'baseline' in the southeast of as much as 5 $\mu g\ m^{-3}$. This is the concentration of $PM_{2.5}$ before any national emissions occur. Added to this are $PM_{2.5}$ from sources that will always be difficult if not impossible to ever abate fully – e.g. from cooking and friction. Given a pre-existing background and irreducible emissions in $PM_{2.5}$ it makes the challenge of bringing central London under 10 $\mu g\ m^{-3}$ particularly formidable, even with ambitious measures. In contrast many rural areas towards the north and west could achieve $PM_{2.5}$ below 5 $\mu g\ m^{-3}$.

11. **NO_2**: WHO (2021) introduced significantly lower annual average guidelines for NO_2 (now 10 $\mu g\ m^{-3}$ annual average). This creates a significant divergence between WHO and current UK standards (currently 40 $\mu g\ m^{-3}$). Nitrogen dioxide concentrations are 'controllable' from a national and local perspective since there is only limited transboundary movement of NO_2 from mainland Europe and low natural emissions. Unlike $PM_{2.5}$, the 'baseline' for NO_2 is not a constraining factor and in principle NO_2 could be brought to very levels if all combustion systems were removed.

12. The delivery of a net zero greenhouse gas budget is likely to see many combustion processes that currently emit NO_2 removed and electrified, so more ambitious NO_2 standards in the UK would be readily achievable in the medium to long-term. The adoption of more ambitious targets for NO_2 might prove influential in ensuring that net zero pathways steer away from combustion of low carbon fuels, which may create health harms, and towards electrification options that do not. For example, influencing decisions prioritising hydrogen for use in fuel cells (where no NO_x is emitted) vs hydrogen in internal combustion engines or gas boilers (where it is emitted).

13. There is some evidence that disproportionate health harms arise from a subset of airborne particles, and that metrics beyond $PM_{2.5}$ might be more reliable air quality indicators. This is highlighted in the WHO (2021) guidelines; ultrafine particles (those smaller than 1 μm), black carbon, and particle

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[2] Annex IV: Projected Emissions Data: https://naei.beis.gov.uk/data/

[3] https://data.london.gov.uk/dataset/laei-2019---borough-air-quality-data-for-llaqm

[4] Cliff, S.J et al. Pandemic restrictions in 2020 highlight the significance of non-road NO_x sources in central London, Atmospheric Chemistry and Physics, 23, 2315-2330. https://acp.copernicus.org/articles/23/2315/2023/

number are cited. There is some limited monitoring in UK national networks and at research supersites, but it is not yet clear what values would be appropriate to use as air quality targets.

Are measures currently in place, and those proposed in the revised Air Quality Strategy for England, sufficient to achieve national targets?

14. There is considerable uncertainty in estimating when England might meet full attainment of a 10 μg m^{-3} limit for $PM_{2.5}$ because it is extremely difficult to model with accuracy so far into the future. Forecasting $PM_{2.5}$ is dependent on projections of primary emissions as well as secondary pollutants (such as NO_x, SO_2, VOCs and NH_3) and their non-linear conversion into secondary $PM_{2.5}$. Models must make estimates of how emissions will evolve in near-neighbour countries and there are climate and meteorological effects. The difference between a 'good' and 'bad' weather year[5] can change annual average $PM_{2.5}$ by around 1 μg m^{-3}. Despite this uncertainty it does seem reasonable to anticipate that attainment could be achieved in the mid to later 2030s with existing measures.

15. There has been considerable debate around whether the statutory attainment date of a 10 μg m^{-3} annual average for $PM_{2.5}$ should be 2040 (in Statutory Instrument, Environmental Targets (Fine Particulate Matter) (England), 2023) or earlier, say 2035 or 2030. Different modelling studies are often citied in support of different positions. The uncertainties in those models are rarely reported but they are very significant and indeed often overlap. Models provide a vital policy guide to the relative size of effects of individual measures, but they are frequently attributed with predictive skill that is not scientifically merited.

16. Current measures are likely to be sufficient to meet NO_2 limits of 40 μg m^{-3} England-wide in the next few years. Ongoing exceedances are caused partly by older Euro 4 and 5 diesel vehicles. Over time they are retiring and being replaced with cleaner ICE vehicles (Euro6d) or replaced with hybrid/battery electric alternatives. Expected reductions in road transport emissions should be sufficient to meet existing NO_2 targets, however, if a more ambitious target was adopted, closer to WHO 2021 guidelines, then further measures would be needed, particularly to reduce NO_x emissions from natural gas combustion in homes and commercial premises in cities.

17. Attainment of ozone targets is dependent on the wider chemical climate and hemispheric trends in methane and NO_x. Ozone air quality strategies are now co-dependant on climate policy. Agreed future National Emission Ceilings across CLRTAP signatories that further reduce NO_x and VOCs will be beneficial and reduce ozone, however because its formation is highly non-linear reductions in precursors can sometimes have only small effects on the amount of ozone produced. The benefits from NO_x and VOC reductions can potentially be outweighed by increases in global methane.

18. Ozone has been primarily a rural pollutant affecting people, ecosystems and reducing crop yields. However, as NO_x emissions in cities reduce ozone will be become more visible as urban pollutant. This occurs because close to NO_x sources ozone is suppressed through a short-lived reaction with NO. As NO emissions reduce (which is crucial to reduce urban NO_2) ozone suppression is diminished. The benefits however of reducing NO_2 almost certainly outweigh the negative effects of increased urban ozone concentrations. Reductions in PM can also cause ozone to rise, since the surface of particulate matter can act as a sink that destroys ozone[6].

19. Attainment of ambient air quality standards for all other pollutants named in the Air Quality (England) Regulations (2000, amended 2002) appears likely with current measures. This includes: PM_{10}, sulfur dioxide, carbon monoxide, benzene, 1,3 butadiene, PAHs, and lead.

What are major barriers and challenges to achieving national targets on air quality?

20. **$PM_{2.5}$**. The overarching challenge is that the most directly abated primary emission sources, particularly vehicle tailpipe and point sources from energy and industry, have already been addressed. Some of remaining sources will always be difficult to fully abate, for example from cooking or from road and tyre wear. Delivering improvements in $PM_{2.5}$ will lean heavily on reducing domestic combustion (the largest urban source of PM) and a driver of significant air pollution disparities. Solid fuel combustion in homes has suffered from poor enforcement of existing

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[5] Modelling of future $PM_{2.5}$ in support of the Defra air quality target setting process. https://uk-air.defra.gov.uk/library/reports?report_id=1023

[6] Ivatt, P.D., Evans, M.J., Lewis, A.C. Suppression of surface ozone by an aerosol-inhibited photochemical regime. Nature geoscience, 15, 536-540, 2022. https://www.nature.com/articles/s41561-022-00972-9

regulation and some reluctance for voluntary cessation from the public. It remains essential that progress is made on reducing agricultural emissions of ammonia since it reacts in air creating $PM_{2.5}$. Many technical options exist but progress has been persistently poor for decades.

21. **NO_2**: The pace of change in road transport NO_x is rapid and going in the right direction. Meeting existing national targets seems highly likely in the near future. Progress and action on reducing NO_x emissions from space heating has not been a priority and there are no new interventions planned, beyond standards set by the Eco-design Directive. Reducing NO_x from homes and businesses in the future will be tied closely to buildings decarbonisation where progress is also slow. Some decarbonisation strategies, such as burning hydrogen as a replacement for natural gas, would lead to the retention of a substantial NO_x source in cities. This would be unlikely to impact on attainment of current targets for NO_2 but would limit progress towards WHO guideline values, which are lower.

Does the Government provide sufficient funding and devolved powers to local authorities in England to improve local air quality? If not, what additional funding or devolved powers are required?

22. Passing powers and funding to local authorities is most effective for the management of NO_2 since that can be significantly influenced by local actions. Whilst most LA interventions are based on transport, they may have an increasingly impactful role supporting schemes to reduce emissions from space heating, for example support for district heating, electrification, solar and so on. $PM_{2.5}$ is less controllable at a LA level and interventions around transport management have more muted effects, simply because transport is not the major driver of urban $PM_{2.5}$ concentrations. There is a clear role for LAs in supporting reductions in the combustion of solid fuel in urban centres. Powers to limit solid fuel burning exist however exercise of those powers is rare, potentially due lack of appetite for enforcement (it can be a difficult offence to evidence) or limitations in resource.

What are the long-term health impacts of indoor air pollution?

23. Indoor and outdoor air pollution have many common features; it is often the same pollutants found in both places and therefore the same harms arise. Indoor air holds other pollutants that are rarely a problem outdoors. Carbon monoxide is no longer a pollutant of concern outdoors, but it can reach high concentrations in homes with poorly maintained gas appliances and still leads to fatalities. Radon gas can accumulate as an indoor pollutant from the ground under homes; bioaerosols can reach harmful concentrations indoor arising from moulds and damp. The diversity and sources of indoor air pollutants have been reviewed recently by the Defra Air Quality Expert Group[7].

24. Long-term impacts and trends related to indoor air pollution in the UK are difficult to judge. Some factors that influence indoor air have improved, for example fewer solvents (VOCs) are released from paints and buildings products, there is less indoor NO_x from gas combustion, and overall fewer UK homes have mould and damp problems. Conversely, there is more wood burning, increased release of VOCs from personal care products and energy efficiency has improved, which can sometimes reduce ventilation and trap pollution indoors[8]. The effects on individuals from exposure to indoor air are extremely dependant therefore on housing quality and individual lifestyle factors, as well as being influenced by the quality of outdoor air that ventilates homes.

25. As outdoor air quality in the UK improves an increasing fraction of exposure to pollution will occur in indoor settings, including homes but also schools, transport hubs, workplaces and other spaces such as shops and hospitals. Better experimental evidence of the current state of UK indoor air would be very valuable since it may well be that greater gains in public health might be achieved by directing limited air quality resources towards reducing indoor sources.

What steps can the Government take to improve indoor air quality?

26. Indoor air quality is a truly cross-government issue and no department has responsibly for all indoor spaces. There are however many aspects of indoor air pollution that are closely associated with the quality of homes, a DLUHC-led issue. Eliminating damp and moulds from homes is vital if tragic cases such as Awaab Ishak are to be avoided in the future. Building standards are critical in ensuring that energy efficient homes are properly ventilated and not places where pollution can accumulate.

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[7] Indoor Air Quality, Defra Air Quality Expert Group, 2022. https://uk-air.defra.gov.uk/library/reports.php?report_id=1101

[8] Hidden harms of indoor air pollution—five steps to expose them. A.C Lewis, D Jenkins, C.J.M Whitty Nature 614 (7947), 220-223, 2023.

27. Managing and reducing indoor emissions is multifaceted since so many aspects of a modern life give rise to indoor pollution. Communication is essential; the simple act of routinely using an extractor hood when cooking significantly reduces pollution indoors, as does swapping from a gas to an electric hub/oven. Growth in use of VOC containing products is driven by lifestyle choices, but there is little awareness that this is a source of pollution indoors. The Defra Clean Air Strategy (2019) suggested product labelling to guide consumer choices, and this could well be an effective policy. There are some household products where reformulation could bring benefits. The largest source of VOC emissions indoors is from the use of aerosol sprays and these release more VOCs into the air than the entire UK road transport fleet. Requiring a change of propellant gases from butane and propane to nitrogen, CO_2 or air would benefit both indoor and outdoor air.

28. Attempting to regulate or enforce indoor air quality standards in individual homes may not be feasible or indeed desirable. However more rigorous minimum standards likely could be set in a manner analogous to outdoor air for public spaces such as schools, hospitals and transport hubs. There may also be a place for the promotion and adoption of voluntary standards for indoor air in commercial premises such as supermarkets, cinemas and so on.

What are the differential impacts, geographically, and across socioeconomic groups, of poor outdoor and indoor air quality? Are measures to address poor air quality appropriately targeted?

29. Little is known about the distribution of indoor air pollution across the UK since no routine measurements are made. For some indoor pollutants is seems likely that those living in the poorest quality accommodation may be most impacted, for example by bioaerosols from mould. However, the position may be more complex than for outdoor pollution –the most energy efficient and modern of homes can suffer most from poor ventilation and this may have no link to deprivation. Use of chemical products, cooking habits and many other factors may also drive differential in exposure across different communities and age groups, but without data and monitoring it is impossible to confidently answer this question.

30. For impacts across socioeconomic groups arising from outdoor air, see earlier responses in Paragraphs 3,4, and 5.

How well is the Government coordinating measures between national and local actors to improve air quality, both outdoors and indoors?

31. This question is answered from the perspective of coordination of activity of relevance to the science and evidence community.

    There have been steady improvements in the connections between government (particularly Defra), research providers and UKRI, and this has led to recent large-scale research initiatives that are designed to span discovery science and evidence for decision-making, regulation and policy. These now increasingly involve collaborations with local bodies and transport providers. A helpful development has been cross-UKRI engagement for research in air pollution science supporting better working at the interface between natural sciences, health sciences and engineering. Longstanding issues associated with indoor air research are starting to be resolved – it previously appeared to fall outside of the remits of all the Councils within UKRI.

32. Measurement and observations are critical to inform decision-making and communication on air pollution issues and there remain some disconnections between government departments, local authorities, research providers and UKRI over who is responsible for ensuring these are in place and delivering data for all stakeholders.

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