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Engineering and Physical Sciences Research Council
Economic and Social Research Council
Natural Environment Research Council
Innovate UK
Medical Research Council
Met Office
Clean Air Programme
Strategic Priorities Fund
Science and Implementation Plan

# In memory of PROFESSOR MARTIN WILLIAMS

Martin was Head of the Science Policy group, Environmental Research Group at Imperial College London and former Head of the Air Quality programme at the Department for Environment, Food and Rural Affairs. Martin, an atmospheric scientist, who published on a range of air quality issues, including health effects, and spent a large part of his career formulating, promoting and co-ordinating research prorammes and policy in air pollution.

At various times he was a member of COMEAP, EPAQS and various government advisory groups on air quality. He was a member of Defra's Air Quality Expert Group (AQEG). He chaired Defra's Air Quality Modelling Steering Group and co-chaired the group revising the WHO Air Quality Guidelines for public health. He had been a former chair of the European Monitoring and Evaluation Programme (EMEP) Steering Body and the UNECE Convention on Long Range Transboundary Air Pollution. He was part of the project, one of the first in Europe, to produce evidence on real-world emissions of $NO_x$ from diesel vehicles.

Earlier in his career, he made significant contributions to UK air quality research. He established the first systematic programme to calculate UK national emission inventories; led the first research to produce on-road real-world vehicle emissions (the only group in the world doing this at the time); undertook the first identification of stratospheric $O_3$ intrusions to ground level in the UK; made the first measurements of boundary layer height in London and the rural south east; and built the first model to forecast next day UK $O_3$ concentrations.

Professor Martin Williams was one of the foremost authorities on air pollution science and its incorporation into policy – not only in the UK, but also more widely in Europe. We would also like to share a tribute from Professor Frank Kelly (Imperial College London), 'Mr Air Quality':

www.imperial.ac.uk/news/205033/obituary-professor-martin-williams/

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# EXECUTIVE SUMMARY

In the UK, poor air quality is acknowledged as the top environmental risk to public health, with air pollution in the UK responsible for ~40,000 early deaths and has a cost of ~£20bn pa to health services and businesses.[1] This challenge will require shared Government, business, research and civic responsibility to tackle.

The Clean Air programme is a £42.5m research and innovation investment supported by the UK Research and Innovation Strategic Priorities Fund. The aim is to bring together the UK's world-class research base and support high quality multi- and interdisciplinary research and innovation to develop practical solutions for today's air quality issues and equip the UK to proactively tackle future air quality challenges, in order to protect health and support clean growth.

## The Clean Air Programme

The programme is delivered through two waves; the first (£20.5m) has supported multidisciplinary research and innovation on near-term outdoor air pollution issues and the funded projects will develop short-term policy relevant outputs, support commercialisation of near-market solutions for non-exhaust transport emissions and deliver a pilot systems framework for clean air analysis.

The second wave of investment (£22m) will support new interdisciplinary research and innovation that will equip the UK to proactively tackle new and emerging air quality challenges related to changes in the types of air pollutants emitted and their importance across the indoor/outdoor interface, with regards to exposure patterns and impacts on those most at risk.

## Benefits, Outcomes and Legacy

The main benefits of the Clean Air Programme are anticipated to be improved air quality and public health and wellbeing, improved pull though across the air quality science chain and into policy, cost savings to health services and businesses, clean economic growth, and a strong UK reputation for world-leading research and innovation on air quality.

Effective communication and knowledge exchange is an integral part of the Clean Air Programme and vital to ensure that the research and innovation supported by the programme has wide benefits for knowledge, society, and the economy. Supported by the Champions, the Clean Air programme will identify those who will benefit from or make use of the research beyond the scientific community and positively impact a broad range of audiences, including: the public, UK Government, Public Sector Research Establishments, and stakeholders from healthcare systems/regulators/quality bodies, users of programme outputs, policymakers, practice, industry, and the media.

By creating new connected research to address real world issues about air pollution now and in the future, it is envisaged that the Clean Air Programme will lead to changes that will translate into improved air quality both outside and indoors.

1. Defra 2019 Clean Air Strategy https://www.gov.uk/government/publications/clean-air-strategy-2019

# THE CHALLENGE AND OUR VISION

Poor air quality is acknowledged as the top environmental risk to public health in the UK, with air pollution in the UK responsible for ~40,000 early deaths and has a cost of ~£20bn pa to health services and business.[1] For example, air pollution makes us more susceptible to respiratory infections and other illnesses. Particulate matter, nitrogen dioxide and ozone were estimated to cost UK businesses £2.7bn in productivity losses in 2012, and are projected to cost the NHS and social care systems between £5.3bn and £18.6bn by 2035.[1]

The challenge will need to be tackled with shared Government, business, research and civic responsibility. The UK has built up exceptional research, practitioner and citizen communities to address air quality challenges. However while these have been of high quality, approaches have been somewhat narrow in perspective and single discipline (e.g. epidemiology, animal models, atmospheric science). Air pollution can be regarded as a 'wicked problem'[2] in that the issues involved owe much of their persistence to their complex and interactive nature.

> "The vision of Clean Air is a coordinated strategic landscape of multidisciplinary research and innovation co-designed with users to develop robust solutions that reduce emissions, improve air quality and reduce the health impacts and risks of atmospheric pollution.

Furthermore, the UK is entering a transformative period in air pollution as transport, heating, energy, solvent use and agricultural emissions change. Most of the 'easy wins' to reduce particulate matter, volatile organic compounds, ammonia and nitrogen oxides have already been or are being implemented in the UK. Future improvements will require a step change in innovative solutions underpinned by new research to protect the health of society, whilst pursuing clean growth and increasing national productivity.

Divergent trends are anticipated over the next decade that will likely see declining outdoor air pollution emissions from the road transport sector. However other sectors, such as domestic consumption of volatile organic chemicals, will become more prominent. Such a change was shown to be possible during the recent Covid-19 pandemic when there was a dramatic fall in industry, motorised transport and beneficial effects on non-Covid-19 related mortality.[3] However, such changes in emissions will shift air quality concerns more towards secondary pollutants controlled by complex non-linear chemical and physical dependencies. Managing human exposure to the very smallest airborne particulate matter (PM1 and ultra-fine PM)[4], the complex cocktail of volatile organic compounds (VOCs)[5], and interactions with other potential exposures (such as a biological exposure), are likely to grow in health significance as concentrations of larger primary particles (e.g. PM10 and tailpipe $NO_x$) decline.

1. Defra 2019 Clean Air Strategy https://www.gov.uk/government/publications/clean-air-strategy-2019
2. Rittel, H. and Webber, M. (1973). Dilemmas in a general theory of planning. Policy Sciences, 4, 155-169
3. Chen K, Wang M, Huang C, Kinney PL, Anastas PT. Lancet Planet Health. 2020 May 13. doi: 10.1016/S2542-5196(20)30107-8.
4. Particulate matter (PM) is everything in the air that isn't a gas, a suspension of particles which are solid, liquid or somewhere in between, and can have anthropogenic and natural sources. Particulates are classified according to size, where $PM_1$ is particles of ≤1 µm diameter, and these are largely secondary PM which are formed in the air through chemical reactions of gaseous pollutants.
5. Volatile organic compounds (VOCs) are organic chemicals which evaporate in the air at room temperature and are emitted from many sources including production processes, household chemicals, solvent use and different kinds of combustion.

# BACKGROUND AND AIM

Clean Air is an integrated programme of air quality research (Figure 1), which aims to bring together the UK's world class air quality capabilities, including the health, atmospheric and behavioural/social sciences to address, and support high quality multi- and interdisciplinary research and innovation to develop practical solutions to today's air quality issues and equip the UK to proactively tackle future air quality issues, in order to protect human health and support clean growth. The programme comprises a £42.5m research and innovation investment supported through the UK Research and Innovation Strategic Priorities Fund (SPF) and is delivered across two waves of SPF funding. The UKRI Strategic Priorities Fund (SPF) has been set up to build upon the vision of a 'common research fund' set out in Sir Paul Nurse's independent review of the Research Councils. The fund will drive an increase in high-quality multi- and interdisciplinary research and innovation, ensure that UKRI's investment links up effectively with Government departments' research priorities and opportunities, and ensure that the system is able to respond to strategic priorities and opportunities.

The Clean Air programme is jointly delivered by the Natural Environment Research Council (NERC) and the Met Office, with the Economic and Social Research Council (ESRC), Engineering and Physical Sciences Research Council (EPSRC), Innovate UK, Medical Research Council (MRC), National Physical Laboratory (NPL) Science & Technology Facilities Council (STFC), Department for Environment, Food and Rural Affairs (Defra), Department for Health and Social Care (DHSC), Department for Transport (DfT), Scottish Government and Welsh Government.

### Wave 1: Analysis and Solutions

Through the first wave of investment (£20.5m), the programme has supported multi-disciplinary research and innovation to stimulate solutions for clean air through predictive understanding of future air quality challenges; a systems approach to analysis; new technologies and innovative policy and practice interventions to benefit groups of people most at risk[6]; and to improve public health and support clean growth.

6. Those most at risk may include, but are not exclusive to, individuals and groups at vulnerable stages of the life course, with established disease and/or those disadvantaged by inequalities.

This has been achieved by exploiting and building on the existing exceptional UK-based capability to drive forward research and innovation, leveraging existing UK investments and enabling a challenge-focussed multidisciplinary community to work together for the first time, to inform the implementation of the Clean Air Strategy and to develop new solutions to reduce emissions and protect public health, whilst avoiding perverse consequences.

## Wave 2: Indoor/Outdoor Interface

Through the second wave of investment (£22m), the programme aims to equip the UK to proactively tackle new and emerging air quality issues, relating to changing emissions, and the need to evaluate exposure across all outdoor and indoor environments as a continuum, and their impacts on individuals and groups most at risk.[6]

This will be achieved by building a new interdisciplinary community across the interface of the indoor/outdoor air quality emissions, exposures and health impacts. It aims to 1) deliver new knowledge that provides critical foresight on emerging air pollution challenges and associated health risks and impacts, 2) enable us to better understand and quantify human behavioural change and practices, and how to influence through communication and technology interventions in order to limit exposure routes and mitigate health risks at vulnerable stages of the life course, 3) provide consistent, evidence-based advice for stakeholders through open data and tools in order to stimulate policy and regulatory innovation, and 4) stimulate business-led innovation for sustainable products and services to protect health across the indoor/outdoor air quality interface and grow UK businesses.

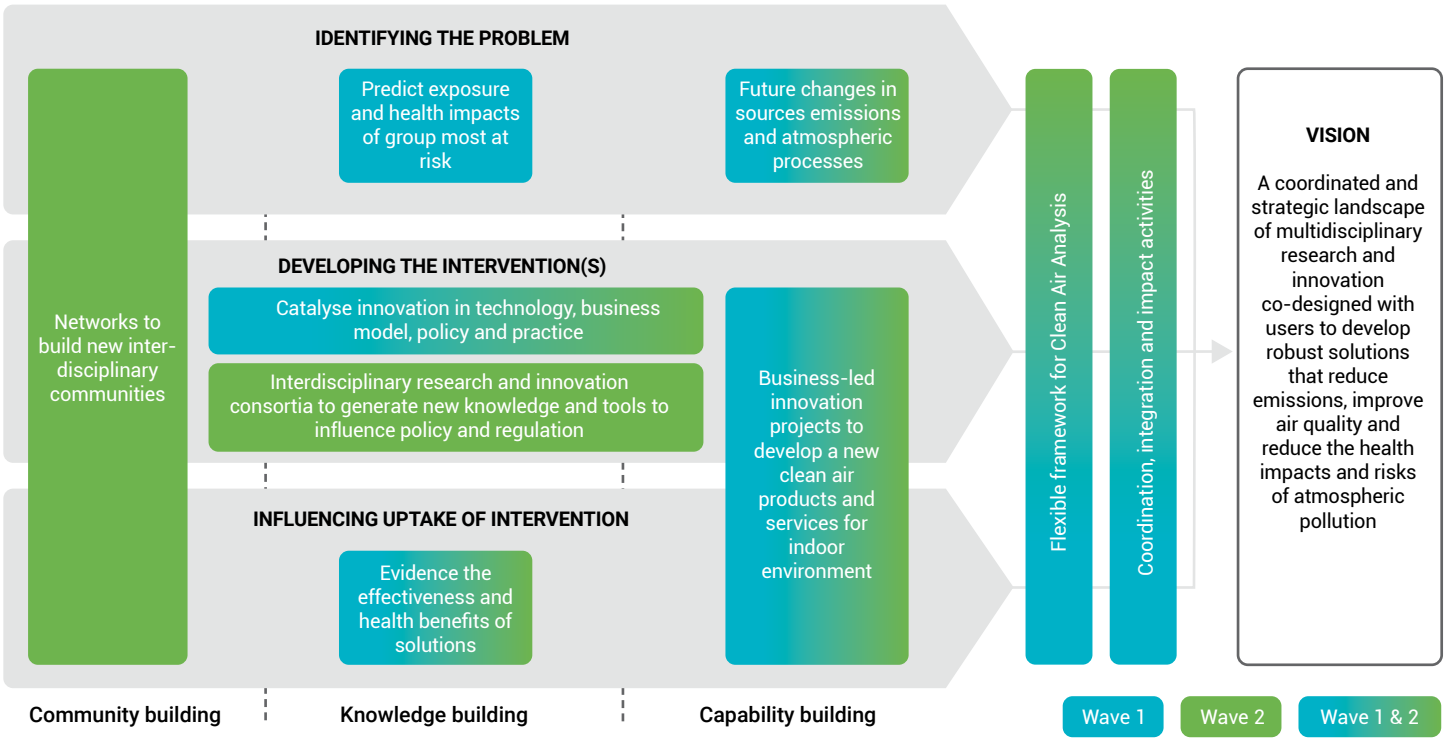



Figure 1. Overview of the Clean Air programme.

6. Those most at risk may include, but are not exclusive to, individuals and groups at vulnerable stages of the life course, with established disease and/or those disadvantaged by inequalities.

# REQUIRED OUTCOMES/BENEFITS

The main benefits of the Clean Air Programme are anticipated to be, improved air quality and public health and wellbeing, improved pull though across the air quality science chain and into policy, cost savings to health services and businesses, clean economic growth, and a strong UK reputation for world-leading research and innovation on air quality (Figure 2).

Realisation of potential benefits will be achieved through robust contributions to the evidence base of policy targets for local, national and transboundary emissions reductions, health and environmental protection and infrastructure development, stimulation of growth in relevant industry sectors, and alignment of Government, UKRI and Met Office Clean Air priorities as well as engagement with a variety of stakeholders with cleaner air as a common interest.

As well as delivering direct benefits to human health, indirect benefits of the programme will include positive impacts on the wider environment of cleaner air, including agricultural gains, beneficial effects on animals and their habitats, as well as creating a better environment for everyone to live and work in.

The specific anticipated benefits from the programme are detailed below, in terms of new knowledge generated, and impacts to society and the economy, identified through stakeholder analysis.

### Knowledge:

- Expanded and coordinated capability for solutions for Clean Air.
- New influential multi- and interdisciplinary UK research and innovation clean air community with a strong UK reputation for world-leading research and innovation on air quality.
- Improved evidence base for focussed and prioritised policy decisions on emissions reductions, health protection and infrastructure development.

### Society:

- Innovation in policy and regulation to protect public health resulting in improved public health.
- Stakeholders and the public are able to access and use clear and trusted information on air quality and health impacts.

### Economy:

- Time and resources saved by research community and stakeholders in synthesising evidence and identifying appropriate tools.
- Growth in clean air industry sector in UK and export opportunities created abroad, leading to clean growth.
- Cost savings to health services and businesses through avoided health impacts.

During programme | Post programme

| Objectives | Activities | Outputs | Outcomes | Impacts |
|---|---|---|---|---|
| What we are trying to achieve | What we are doing | So that . . . | Meaning that . . . | Contributing to . . . |
| **Multi- and interdisciplinary research community**<br>· Drive forward new multidisciplinary research and innovation<br>· Leverage existing UK investments and enable a challenge-focussed multidisciplinary community to work together for the first time<br>· Build a new influential interdisciplinary community in the area of the indoor/outdoor air quality interface, comprising academic, PSRE, business and stakeholder members across the required disciplines | **Deliver an integrated programme aligned with Government priorities**<br>· Actively engaging Government and other stakeholders to align priorities and shape research outcomes<br>· Aligning academic and PSRE research and the wider clean air community<br>· Supporting networks to build interdisciplinary partnerships | **Enhanced community**<br>UK air quality and health research community is united and expanded and delivering multi- and inter-disciplinary research to tackle complex questions | **Influential community**<br>Well regarded, influential, collaborative and sustainable UK air quality R&I community is developed; building future leaders and offering robust advice | **World leaders**<br>World class interdisciplinary indoor and outdoor air quality R&I with a strong international reputation |
| **New knowledge to influence policy, regulation and behaviour**<br>· Deliver new knowledge that: i) provides critical foresight on emerging air pollution challenges and associated health risks; and ii) enables us to better understand human behavioural change and practices, and how to influence to mitigate health risks at vulnerable stages of the life course<br>· Provide consistent, evidence-based advice for stakeholders through open source data and tools in order to stimulate policy and regulatory innovation<br>· Inform implementation of the UK's Clean Air Strategy and other relevant Government and local strategies<br>· Present information to stakeholders and public in an accessible way | **Fund multi- and interdisciplinary research**<br>Funding multi- and inter-disciplinary research to identify/inform:<br>· New air pollution challenges and associated health risks, especially at the indoor/outdoor continuum<br>· New assessment tools to improve understanding of the problem and/or evaluation of interventions<br>· Possible mitigations and interventions, including behavioral changes | **Knowledge generation**<br>· Critical foresight on emerging air pollution challenges, associated health risks and possible mitigations is available<br>· Open data and tools are developed with improved modelling capability to allow improved policy formulation/trade-offs<br>· Future research needs are identified | **Enhanced evidence base**<br>· Improved evidence base is used to inform policy decisions and targets on emissions, health protection and infrastructure development, as part of UK Gov strategy implementation<br>· Expanded and coordinated knowledge base for solutions, with greater uptake of research outcomes | **Improved public health**<br>Improved public health, especially for vulnerable groups and those with health inequalities, measured through increased QALYs(Quality-Adjusted Life Year) and DALYs (Disability-Adjusted Life Year) |
| **Innovative products and services**<br>· Develop new solutions to reduce emissions and protect public health, whilst avoiding perverse consequences<br>· Stimulate business-led innovation for sustainable products and services to protect health at the indoor/outdoor interface and grow UK businesses | **Appoint Champions**<br>To create cohesion, identify synergies, synthesise accessible outputs, and help build and promote the programme<br><br>**Fund business-led research**<br>Fund business to develop sustainable products and services to reduce emissions and protect health from indoor and outdoor sources of air pollution | **Knowledge exchange**<br>· The programme has a high and trusted profile with end-users<br>· Clear, consistent and accessible information is available for policy makers, the health sector, the public, and business<br><br>**Product development**<br>Innovative products, services, and solutions are developed and commercialised | **Informed society**<br>Better informed and empowered society with access to clear and trusted information on air quality and health impacts<br><br>**Industry growth**<br>Growth in UK 'Clean Air' industry with export opportunities, aligning with new and improved regulation | **Improved environment**<br>Cleaner air benefiting wildlife, agriculture and climate change ambitions<br><br>**Clean growth**<br>Cost savings to health services through avoided health impacts and increased GDP due to sustainable commercialisation of research and new opportunities for business |

Figure 2. SPF Clean Air programme logic model, summarising the objectives and anticipated outcomes and benefits.

# CLEAN AIR CHAMPIONS

The Champions will bring together outstanding researchers across atmospheric, medical and social science to develop practical solutions for air quality issues, and then ensure that these interdisciplinary communities are connected to the public and wider policy and business environment to maximise the impact of their research. The Champions will also look into working with other national and international stakeholders to facilitate joint-working, identifying areas of common interest and helping to ensure no duplication.

### Professor Sir Stephen Holgate

**Medical Research Council Clinical Professor of Immunopharmacology, University of Southampton**

Stephen has a research interest in the mechanisms of asthma and allergy, focusing on the roles of air pollutants, allergens and viruses in driving airway inflammation and remodelling. He was the founder chair of the Committee on the Medical Effects of Air Pollutants (COMEAP), chair of the Expert Panel on Air quality Standards (EPAQS), and was a member of the Royal Commission on Environmental Pollution (RCEP). He is Special Advisor to the Royal College of Physicians on air quality.

### Dr Jenny Baverstock

**Senior Research Fellow, University of Southampton**

Jenny has a background in clinical trials research, primary care, public health and biological systems, with experience in interdisciplinary research (e.g. coordinated the Southampton Cleaner Air Partnership). A biochemist by training, her career has spanned bench science, research management and leadership in the Research Council, University and the NHS sectors. She has been engaged in connecting science to policy, and developing and operationalising policy for science opportunities.

### Dr Gary Fuller

**Senior Lecturer at Imperial College London**

Gary led the development of the London Air Quality Network to become the largest urban network in Europe, is a member of Defra's Air Quality Expert Group and a project reviewer and steering group member for the Irish EPA. He is a member of the Medical Research Council Centre for Environment and Health and was co-opted to the Committee on Medical Effects of Air Pollution for their review of the UK air quality index. He was a co-author of Every Breath You Take, and has been a regular contributor to the Guardian newspaper.

We would also like to pay tribute to our former champion Professor Martin Williams and dedicate this report in memory of his significant contributions to clean air research.

More information about the Champions and their activities, and details for how you can get in touch with them to be involved with, and support their vision, can be found on the Clean Air website.

# WAVE 1 ACTIVITIES

The evolving nature of the air quality challenge and lack of cohesion in the research and user community is limiting both research and innovation developments and policy benefits. Consequently, stakeholders are faced with multiple evidence streams leading to inconsistent analysis and inefficient application of new science to support policy and action. To address these challenges, the programme will support a multidisciplinary portfolio of investments.

Wave 1 is focused on near-term outdoor air pollution issues and the funded projects will leverage existing long term strategic investments in order to develop short-term policy relevant outputs, support commercialisation of near-market solutions for non-exhaust transport emissions and deliver a pilot systems framework for clean air analysis.

## FUTURE CHANGES IN SOURCES EMISSIONS AND ATMOSPHERIC PROCESSES

UK emissions are changing which leaves substantial scientific uncertainty over how non-linear atmospheric processes will respond, such as how controls on farming ammonia might change exposure to fine particulate matter, or how reductions in domestic and personal volatile organic chemicals would lead to lower ambient ozone concentrations, and how human behaviours influence such emissions processes and pathways. Success would deliver proven process-based predictive capability that could quantify trends in sources and emissions, and resulting pollutant concentrations in air, indoors and out, at local, national and trans boundary scale.

### OSCA: Integrated Research Observation System for Clean Air

- Changes to transport systems, energy supplies, solvent use, methods for heating homes and agricultural systems are likely to cause profound changes in the emissions of air pollutants in the near future.
- The OSCA project will provide new capability to predict future changes in the sources, emissions and atmospheric processes responsible for air pollution, providing robust evidence for air quality policies as well as data and infrastructure for the wider Clean Air Programme. Long term measurements will be carried out at three new air quality supersites (Manchester, Birmingham, and London), and a call will be announced for the UK science teams to use the sites during intensive observation periods to augment the continuous data sets.
- The OSCA project is led by Professor Hugh Coe at the University of Manchester. The project partners are University of Manchester, University of Birmingham, Kings College London, University of Cambridge, University of York, Centre for Ecology & Hydrology, National Centre for Atmospheric Science, University of Edinburgh.

## EXPOSURE AND HEALTH IMPACTS OF GROUPS MOST AT RISK

Children, older people and those with underlying medical conditions are particularly vulnerable to air pollution. Our lack of understanding of susceptibilities and exposure routes limits our ability to protect them. The aim is to develop innovative techniques to predict exposure of groups of people most at risk and determine mechanistic pathways through which air pollution leads to adverse health impacts, examining the actions of different groups to understand how best to mitigate, manage and treat.

### DREaM: Component-Specific Air pollutant Drivers of Disease Risk in Early to Midlife: a pathway approach

- High pollutant concentrations are linked to a range of long-term adverse health effects, and it is thought that as well as aggravating symptoms, air pollution may contribute to the development of disease.
- The DREaM project aims to identify the ways in which the components in the air pollution mix affect people's vulnerability to cardiovascular disease and the causal mechanisms behind this, by examining DNA modifications in key genes associated with air pollution. The findings will help to develop targeted mitigation actions and communication strategies to help people understand the health risks.
- The DREaM project is led by Dr Ian Mudway at King's College London. The project partners are King's College London, Imperial College London, Durham University and University of Cambridge.

### APEx: An Air Pollution Exposure model to integrate protection of vulnerable groups into the UK Clean Air Programme

- Current methods for assessing the impact of clean air policies are entirely based on outdoor air quality, without considering human behaviours or susceptibility.
- The APEx project will place people at the centre of the problem by creating an exposure model that more accurately reflects the air that people breathe as they interact with the city. The tool will be used to instigate new solutions to protect the health of vulnerable groups, allow the refinement of existing solutions to increase impact and reduce unintended consequences.
- The APEx project is led by Dr Ben Barratt at King's College London. The project partners are King's College London, University of Reading, University of Edinburgh, Grantham Research Institute on Climate Change, University of Birmingham, and University College London.

## QUANT: Quantification of Utility of Atmospheric Network Technologies

- Low-cost air pollution sensors could play a vital role in improving air quality, but a deeper understanding of their performance is required to realise their full potential.
- The QUANT project will directly address this challenge through the delivery of a real-world open and traceable assessment of low-cost sensors and sensor networks, including calibration methods, and provide key information on the use of low-cost sensors for tackling air pollution in the UK. The project will also enhance the value of low-cost sensor data for specific UK air quality challenges through the development of novel methods that use the unique strengths of these devices to extract new information on key pollutants.
- The QUANT project is led by Dr Peter Edwards at the University of York, National Centre for Atmospheric Science. The project partners are University of York, National Centre for Atmospheric Science, Cranfield University, University of Birmingham, Centre for Ecology & Hydrology, University of Cambridge.

## DIMEX-UK: Data integration model for exposure modelling

- Understanding exposure at the individual and across populations is key in determining the health burden of air pollution and also in driving health based policy. Most current methods for assessing exposures to air pollution tend to focus on a large areas, whether citywide, regionally or even nationally. However, to fully understand the effects of air pollution on human health, there is a need to narrow this focus down to the individual level to both measure how pollution impacts each person directly, but also to measure the effectiveness of intervention actions.
- By developing a framework in which data on air pollution can be combined with human activity and health data, the DIMEX-UK project will make the most of the data that is available to examine the health impacts of air pollution. The personal exposure modelling framework will allow variations in exposures between different populations to be quantified, and for exposure patterns over space and time to be assessed. The aim of the project is to develop a modelling framework to integrate ambient and indoor concentrations with human activity to estimate personal exposures to air pollution for use in future health impact analysis and other applications.
- The DIMEX-UK project is led by Professor Gavin Shaddick at the University of Exeter. The project partner is the University of Manchester.

## UK 15 Year Air Quality Re-analysis

- Air quality exposure assessments are typically performed using temporally or spatially limited modelling or measurement data. This places numerous limitations on health impact assessments. Government policy, interventions and many other actions are by necessity based on wider population data and are also applied to broad cross sections of that population.
- The UK 15 Year Air Quality Re-analysis will build on the Met Office national air quality forecast. The modelling infrastructure created to deliver the best possible forecast is also ideally suited to generate a reanalysis of the past in which observational data from the past is used to constrain the model providing a greatly improved recreation of the past reality across the entire modelling domain. This will provide data for those looking to generate health impact studies, that usually require a generous timescale with which to tease out the health impact signals.
- The UK 15 Year Air Quality re-analysis is led by Dr Eleanor Smith at the Met Office.

## Catalyse innovation in technology, business model, policy and practice.

Clean air is a shared responsibility across market sectors and national and local government, however incentives for innovation are limited. The aim is to catalyse innovation in new and disruptive technologies, create new or reformulated products, guide changes to business models, Government policies and practice that will provide actionable solutions to the twin challenges of improving air quality and decarbonisation, and help grow UK business competitiveness.

Six feasibility studies were funded of which three projects were supported to full stage.

Projects supported to feasibility were:


### ENSO: Sustainable, Low-Emission Tyres for Improved Air Quality

- By inventing a new generation of efficient, durable and sustainable tyres for electric vehicles, this project aimed not only to disrupt the £200bn global tyre industry but to address both of the principal tyre PM emission environmental impact categories, i.e. the impact of tyre wear on local air quality and as a source of micro-plastics.
- The ENSO project was led by Enso Tyres.

### Food Transport Refrigeration with Engine Exhaust and Metal Hydride Reactors

- The standard cooling cycle for refrigerated transport is the Vapour Compression System (VCS). Working fluids are traditionally hydrofluorocarbons (HFC) with relatively high Global Warming Potential (GWP); it is electrically powered by the vehicle's alternator or by a diesel genset on the trailer. Both, especially the latter, significantly increase fuel consumption, CO, $NO_x$, PM and noise emissions. Higher fuel costs, anticipated reductions in tax rebates on 'red' diesel used in gensets and stricter emissions regulations, particularly in urban areas, drive the need for more efficient and lower emissions systems.
- This feasibility study, also known as ExHAUst-heat driven cooLIng for refrigERated tranSport (HAULIERS), developed a new refrigeration technology, driven largely by the heat in the vehicle engine's exhaust gases. It combines desorption and absorption of hydrogen (H2) in two pairs of metal hydride reactors, each pair with a hot and a cold reactor. Compared to the VCS, the Metal Hydride System (MHS) will eliminate the trailer's genset and its associated fuel consumption and CO, $NO_x$, PM and noise emissions, using a low GWP working fluid (H2), have fewer moving parts and lower maintenance costs, and be lighter and smaller. H2 is stable at high temperature, non-toxic, cheap, inert to materials of construction and can be handled safely.
- The Food Transport Refrigeration with Engine Exhaust and Metal Hydride Reactors project was led by the University of South Wales.

### SHIELD: Series Hybrid Intelligent Electric Loader Drive

- Front loader powertrains have extreme performance requirements due to their demanding usage cases in the construction and mining industries. Whilst their typical peak- and mean-power ratings are similar to trucks/coaches the combination of low-speed/high-torque 'grading' and high-speed 'load and carry' operating modes demands a unique tractive-effort curve. The aim of the SHIELD project was to generate a single-speed series hybrid powertrain designed for front loader construction machines.
- The SHIELD project was led by EDrive Engineering.

Projects supported to full stage are:

## Auto-Align: Reduction of tyre and road wear through wheel alignment monitoring

- Particulate emissions resulting from tyre and road wear, along with other non-exhaust emissions from brakes, have an equal contribution to total vehicle atmospheric emissions as exhaust fumes, but attract substantially lower levels of attention and investment. Wheel misalignment significantly increases tyre and road wear, releasing harmful particulates into the air, as well as adding to a vehicle's fuel consumption.
- Auto-Align is a development project that creates a monitoring system to enable commercial vehicle operators to reduce these emissions by continuously monitors wheel alignment in trucks and trailers. Auto-Align is designed to detect misalignment as it happens, (i.e when a curb is clipped) so that it can be corrected before it has an effect on tyre wear. Through this real-time detection and correction, the particulate emissions related to tyre and road wear will be significantly reduced, leading to cleaner, safer air around roads and in urban areas.
- The Auto-Align project is led by RL Capital Ltd.

## CAGE: Clean Air Gas Engine

- The inherent low emission benefits of gas fuels are well documented with natural advantages in output of $NO_x$, and harmful particulates when compared with diesel engines. However, diesel engines have perceived advantages in ease of refuelling with low cost fuel, and fuel efficiency when compared to other engine types, making them very attractive to the construction sector.
- The CAGE project fully addresses these issues to offer a cost competitive, ultra low emission gas engine product with easy refuelling and competitive fuel costs. The project applies OakTec's IP in low emission gas engine combustion and control to Jaguar LandRover's (JLR) state of the art Ingenium automotive engine platform, and optimises its performance to suit a range of industrial applications used in the construction industry.
- The CAGE project brings together the gas engine development expertise of OakTec with leading industrial partners including Autocraft Drivetrain Solutions. With further support from Calor/SHV Energy, who will provide innovative bioLPG fuelling solutions, industrial engine supplier EP Barrus, and Kings College London (KCL) to assess and monitor air quality benefits, the project builds on five years dedicated research into efficient, low emission industrial gas engines by OakTec.
- The CAGE project is led by Oaktec.

## Cool Run: Hubl's solution to multi-temperature last mile delivery

- The challenges related to multi-temperature food deliveries in urban areas are significant; mobile refrigeration system related, poor vehicle payloads and impact on drivetrain selection. Demand for urban deliveries is growing expediently due to the demand for grocery home delivery, convenience store fulfilment and the booming restaurant and foodservice market. These trends are increasing in a less efficient model of food distribution as individual delivery unit sizes declines.
- These trends and associated issues represent a significant market opportunity which the Cool Run system addresses. The Cool Run system optimises the handling of food through a novel insulated pod system, which controls the temperature of individual unit loads. The system reduces vehicle cold air losses through door openings and retains the refrigerated air during multiple drops on the last mile delivery run. The pod system maintains the product at optimal temperatures so preventing thermal gain and product going above the legal temperature requirements. The system provides a generic solution for both home and commercial deliveries.
- The Cool Run project is led by Hubl.

## Flexible Framework for Clean Air Analysis

There is an inter-linked chain which connect emissions, atmospheric processes, air quality, its impacts and policy action (figure 3). The links and feedbacks are multidisciplinary and highly inter-dependent. A systems analysis approach is therefore required to connect the data and modelling elements in the chain towards a coherent national capability for clean air analysis. This scientific analysis framework will enable research and ensure it is balanced across the chain, while enhancing traceability, scientific and economic analysis and pull though into policy.

- **Support a virtual community hub** that networks multidisciplinary communities.
- **Develop and initiate the systems analysis framework** by establishing requirements, a software architecture and implementation plan.
- **Deliver key components of the framework** in the areas of meteorology, air quality modelling, open data standards and sharing protocols.

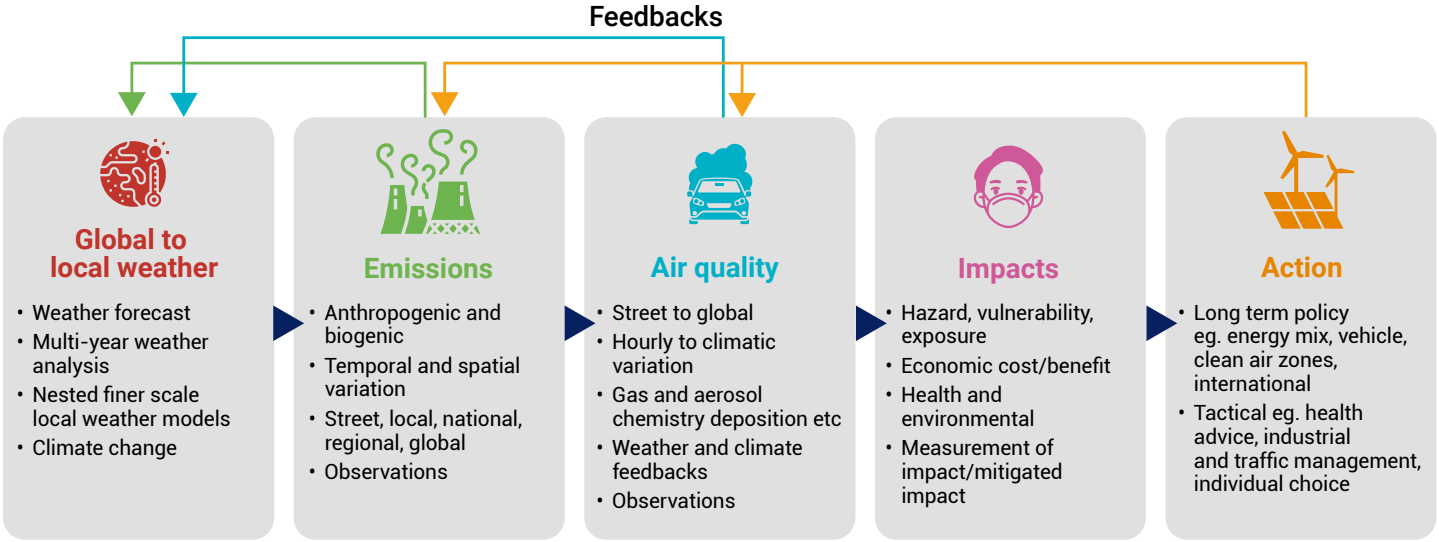



Figure 3. Schematic of air quality 'system' and concept behind analysis framework.

Air pollutants $SO_2$, NO2, $PM_{10}$, $PM_{2.5}$, NMVOCs, $SO_2$, $NH_3$, CO

## DUKEMS: Developing a UK Community Emission Modelling System

- Emissions and modelling are vital parts of air quality understanding and policy. The focus of this work is to support and enable robust scientific research and sound decision making through a consistent approach for providing emissions data at a range of geographical scales for a wide range of uses.
- The DUKEMS project will deliver a framework and tools designed to be operational long term in supporting the atmospheric modelling community by providing a flexible, user friendly system to deliver emission input data for modelling in a transparent, traceable and reproducible manner. In this context, the focus of the proposed work is not on blue-skies discovery science, but primarily on supporting and enabling science.
- The proposed work will primarily deliver a system with a focus on priority air pollutants ($SO_2$, NO2, $PM_{10}$, $PM_{2.5}$, NMVOCs, $SO_2$, $NH_3$, CO), while utilising existing activities (in-kind) to demonstrate the integration of $CH_4$, $CO_2$ and $N_2O$ emissions as far as feasible within the time scales and funding envelope.
- The DUKEMS project is led by Dr Stefan Reis at the UK Centre for Ecology and Hydrology. The project partners are Ricardo Energy and Environment, University of Birmingham, University of Manchester, Rothamsted Research, University of York, King's College London, Aether, and Imperial College London.

## Future air quality forecast system for the UK

- Although there is an abundance of regional scale air quality models operating with grid lengths typically at 10km, the same cannot be said of 'complex' models operating at higher resolution of around a kilometre.
- The future air quality forecast system for the UK project will develop a ~km resolution air quality model covering the whole of the UK along with enhanced post processing for further local represnetivity. This will align with and benefit from the Met Office operational UK numerical weather prediction model. Other benefits include improved: representation of atmospheric processes; use of emissions datasets; representation pollutant concentration gradients in the rural and urban background environment. This will be used to produce the Defra UK air quality forecast service and also provide improved outputs to support policy and other modelers such as those working at street scale and on health impacts.
- The Future air quality forecast system for the UK is led by Dr Benjamin Drummond at the Met Office.

## High resolution meteorological and aerosol modelling for air quality

- Transport emissions and how they mix with other pollutants within the urban environment plays a key role in air quality as it influences factors such as reactions and residence time.
- The High resolution meteorological and aerosol modelling for air quality project is focused on the challenge of representing the complex diversity of the urban environment on many scales, down to the smallest street scales, in atmospheric models. This work will consider the representation of turbulence and other processes in very high-resolution atmospheric models and also the development of methods to represent the urban surface. In addition, this project will investigate and improve aerosol modelling in these high resolution meteorological-aerosol modelling systems.
- The High resolution meteorological and aerosol modelling for air quality is led by Dr Humphrey Lean and Dr Adrian Hill at the Met Office.


## MAQS-Health: Multi Model Air Quality System for Health Research

- Air quality various very significantly on very small scales i.e. along and between neighbouring streets. Species arise from local and far away sources. MAQS-Health will bridge these scales and push forward the linking of regional and street scale modelling.
- The Urban Outdoor Air Quality Modelling project will offer an open flexible system which seamlessly couples state-of-the-art regional and urban air quality models thereby integrating processes across national and local scales. Users of the system will have a choice of models: the regional models considered in the coupled system will be CMAQ, EMEP4UK, WRF-Chem and AQUM/UKCA, whilst the urban models will be the urban air quality model ADMS-Urban and a fast, open version of ADMS focussed on road traffic pollution developed as part of this project. In addition, the open system will be designed so that it may be modified to link other models as required, both regional and urban/local. An open verification system will enable verification of urban-scale air quality predictions.
- The Urban Outdoor Air Quality Modelling project is led by Dr David Carruthers at Cambridge Environmental Research Consultants. The project partners are University of Edinburgh, University of Lancaster, University of Birmingham, University of Hertfordshire.

## Lower Troposphere and Boundary Layer Measurements

- While aerosol and gaseous pollutants in the UK are generally well-observed at the surface, and column-averaged information is increasingly available from satellite observations, there remains limited data on the vertical distribution of key pollutants in the UK boundary layer. More measurement data is needed across the lower troposphere and boundary layer to support air quality model evaluation and development.
- This Lower Troposphere and Boundary Layer Measurements work leverages existing Met Office contracted airborne capability. This resource allows SPF Clean Air access to enough flying hours to mount a yearlong measurement campaign. The duration as well as the vertical spatial domain will result in a unique additional data set of aspects of UK air quality. The data and analysis code will all be freely shared with the research community.
- The Lower Troposphere and Boundary Layer Measurements work is led by Joss Kent at the Met Office.

### Clean Air Framework

- Air quality is a highly multi-disciplinary field with many different data sets and users. Current data is often very disparate and can be hard to find and work with. Analysis approaches used in the community are also very varied making comparison between studies often hard. This work will aim to draw and link elements of this together to provide shared common resource and for more transparency.
- The concept of a Framework and/or systems approach to air quality study and analysis has many potential benefits. Air quality is scientifically multi-disciplinary; spatially and temporally multi-scale; cross cutting in terms of policy and government; and multi-faceted in terms of causes/sources and impacts. There are however common requirements, dependencies and interconnections that lend themselves to a certain level of shared science, 'infrastructure', data and tools. There exist examples of shared resource, but these also each require individual approaches/effort and/or may not be perfectly matched to the use to which they are being put. Community members' knowledge of these resources varies as does our shared understanding of what each are using and the limitations and uncertainties of inputs and our outputs. The Clean Air Framework activity will seek to develop a community led and maintained resource that will aim to tackle a range of these challenges.
- The Clean Air Framework will be delivered by the Met Office (Noel Nelson and Dr Rachel McInnes) in partnership with the air quality community.

## Evidence the effectiveness and health benefits of solutions

The aim of this work package is to develop new and improved techniques to explore the wider consequences of policies relating to air quality. This includes the development of tools and guidance to enable greater consideration of unintended and unanticipated consequences of policies relating to air quality, which in turn will enable rethinking and improvement of prospective policy options at the appraisal stage. This work package aims to help underpin a future broader analysis framework that will allow policy makers to more fully understand and apply evidence on the economic cost, effectiveness, societal acceptance and adoption of clean air solutions.

### ANTICIPATE: Actively anticipating the unintended consequences on air quality of future public policies

- UK public policies can have significant environmental, economic, social and political consequences over both near and distant timescales, but the full range of impacts are not always thoroughly considered at the appraisal stage.
- The ANTICIPATE project will improve awareness of the positive and negative consequences outside the core areas of intended impact, working on four policies selected from the UK Industrial Strategy, Clean Growth Strategy, 25 Year Environment Plan and the NHS Long Term Plan. Expert workshops will explore the policy proposals and their potential impacts on air quality in depth, identifying previously unremarked or under-emphasised implications. An evaluation of the effectiveness of this process will be used to develop recommendations on how to identify the unanticipated consequences of future public policies at the design stage thus contribute to more robust and resilient policy making.
- The ANTICIPATE project is led by Professor Nigel Gilbert at the University of Surrey. The project partners are University of Surrey, University College London, University of Birmingham, University of York, National Centre for Atmospheric Science.

# WAVE 2: INDOOR/OUTDOOR INTERFACE

Human exposure to air pollution occurs not just outdoors, but also indoors (at home, at school and in workplaces, whilst travelling, and during leisure activities). As current measures to improve ambient air quality take effect and concentrations of larger primary particles decline, managing human exposure to the very smallest primary and secondary airborne particulate matter and the complex cocktail of volatile organic compounds (VOCs) that remain is likely to grow in health significance. We spend over 85% of our time indoors and yet we understand very little the effects of the indoor 'breathed environment'. Domestic chemicals including household cleaning and domestic care products are an important source of VOCs[7], and the proportion of VOC emissions derived from consumer products is growing[8], which, together with the trend towards more energy efficient sealed buildings, will increase importance of indoor exposures and it will no longer be effective to attempt to manage public health impacts solely through controlling outdoor sources. Indoor environments are very heterogeneous with interacting factors such as temperature, moisture, indoor chemical and biological pollutants, which are hard to regulate. This will mean that many reductions in emissions and exposure indoors will largely need to be delivered through changes in behaviour, product standards, and better urban planning and design of our indoor spaces. The scientific, technical, behavioural and policy approaches used to assess and manage exposure to air pollution need radical changes to reflect this indoor/outdoor continuum of exposure and avoid unintended consequences of these drivers for change.

> "We spend over 85% of our time indoors and yet we understand little on the effects of the indoor 'breathed environment'.

Wave 2 activities will aim to address challenges arising due to new and emerging air quality issues relating to changing emissions, and the need to evaluate exposure across outdoor and indoor environments as a continuum, and their impacts on groups of people most at risk.

In meeting the aims of SPF Clean Air Wave 2 sets out five multi-disciplinary work packages.

### Networks to build new interdisciplinary communities

The indoor air quality research and stakeholder community is even more diverse than the outdoor air pollution community, and has not previously been the focus for coordinated UKRI-NERC and Met Office support. Furthermore, the two communities have had little opportunity for joint working. Understanding the indoor/outdoor air quality interface remains a frontier research challenge where interdisciplinary approaches and cross-disciplinary working is greatly needed.

The objective is to fund a cohort of networks that will help build a new influential UK interdisciplinary community in the area of new pollutants and the indoor/outdoor air quality interface, comprising academics, Public Sector Research Establishment (PSRE) researchers, and relevant stakeholders including from across healthcare, policy, practice, industry, 3rd sector and the publics, as appropriate, across the required disciplines.

7. Defra, 'Clean Air Strategy 2019' (2019), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770715/clean-air-strategy-2019.pdf
8. McDonald et al, 2018. Volatile chemical products emerging as largest petrochemical source of urban organic emissions. *Science*, 359(6377), pp.760-764. Lewis, A., 2018. The changing face of urban air pollution. Science, 359(6377), pp.744-745.

The anticipated outcome of the UKRI led call and the Met Office targeted network is a new coordinated self-sustaining UK community, positioned ready to drive forward world-leading interdisciplinary clean air research and innovation across the indoor/outdoor air quality interface.

### Air Pollution Solutions for Vulnerable Groups (CleanAir4V) Challenge that the network addresses

- The aim of CleanAir4V is to develop innovative and cost-effective behaviour and technology interventions to reduce further air pollution exposure and improve health of vulnerable groups and implement these interventions through policy advice, planning and business innovation.
- The CleanAir4V project is led by Dr Christian Pfrang at the University of Birmingham.

### Breathing City: Future Urban Ventilation Network

- The aim of Breathing City is to define a new integrated health evidenced approach to urban building design and technology innovation for vulnerable groups, by understanding how airflows transport pollutants in indoor and urban environments.
- The Breathing City project is led by Professor Catherine Noakes at the University of Leeds.

### Indoor/outdoor Bioaerosols Interface and Relationships Network – BioAirNet

- The aim of BioAirNet is to act as the leading voice for the UK BioPM science community by taking a transdisciplinary approach to understand the complexity and connectivity among people, BioPM exposure and the indoor-outdoor continuum.
- The BioAirNet project is led by Professor Frederic Coulon at Cranfield University.

### Optimising air quality and health benefits associated with a low-emission transport and mobility revolution in the UK

- The aim of the TRANSITION network is to identify, prioritise and tackle indoor and outdoor air quality challenges linked to the UK low emission mobility revolution, bringing together academics, researchers, policymakers, business, civil society and the wider general public.
- The TRANSITION network is led by Dr Suzanne Bartington at the University of Birmingham.

### Tackling Air Pollution at School

- The aim of Tackling Air Pollution at School is to bring together interdisciplinary expertise to develop the research base to design and operate healthy schools in the environment of the future.
- The TAPAS project is led by Professor Paul Linden at the University of Cambridge.

### The health and equity impacts of climate change mitigation measures on indoor and outdoor air pollution exposure (HEICCAM)

- The aim of HEICCAM is to strengthen evidence to optimise the health and equity impacts of changes in air pollution at the indoor/outdoor interface as we transition to a low carbon future.
- The HEICCAM project is led by Professor Ruth Doherty at the University of Edinburgh.

### Clean air metrology network

- The aim of the metrology Network is to address the metrology needs of the Clean Air programme and hence the wider air quality community.
- The metrology network is led by Dr Tom Gardiner at the National Physical Laboratory (NPL).

## Interdisciplinary research and innovation consortia to generate new knowledge and tools to influence policy and regulation

Trends expected over the next decade will bring about a different range of air quality challenges to the ones we are facing today. Decarbonisation and the drive to net zero suggest future scenarios where road traffic pollution from exhaust emissions is reduced, new buildings become increasingly sealed for energy efficiency, and people spend more time indoors as they work and study at home using technology to stay connected. These trends will have an impact across the indoor/outdoor interface by affecting both indoor and outdoor air quality, how indoor air pollution affects outdoor air quality and vice versa, and how people experience air quality as they move between indoor and outdoor spaces throughout their day. These trends will have an impact across the indoor/outdoor interface by affecting both indoor and outdoor air quality, how indoor air pollution affects outdoor air quality and vice versa, and how people experience air quality as they move between indoor and outdoor spaces throughout their days.

This will require new knowledge and critical foresight on emerging air pollution challenges, associated health risks, new technologies, human behavioural changes, and better capability to analyse large data sets to limit exposure routes and mitigate health risks for groups of people most at risk.

The consortia will deliver new knowledge, insight, capability and technology to enable us to understand and answer the critical emerging air quality challenges and the associated health impacts facing the UK population. They will span the necessary wide range of disciplines, bringing together researchers, technologists and policy experts from fields spanning the physical, chemical, modelling, measurement, data, health, innovation, biological, social, economic and political sciences.

Built collaboratively across UKRI and PSRE led programmes they will deliver:

### Knowledge that provides critical foresight on emerging air pollution challenges and associated health risks and impacts, including to:

- deliver new knowledge and understanding of the air pollution that occurs in differing types of indoor environments which are likely as our society decarbonises, and how this influences outdoor air pollution and vice versa. This may result in the characterisation of a range of indoor microenvironments or super-emitters where pre-emptive action to reduce emissions could be targeted such as behavioural changes and product standards. This new knowledge will take account of practices and inequalities across socio-demographic groups. For example, poor-quality housing stock or impact of fuel use through cooking, cleaning, wood burning etc.

- deliver new knowledge and understanding, beyond identifying pollutant hazards, of human exposure to pollutants, of the relative toxicological properties including the formation and toxicity of secondary pollutants, of biomarkers and potential health impacts of emissions and exposures across the indoor/outdoor interface in the context of future scenarios, such as future new mixes of air pollution. This could include hypothesis driven, mechanistic studies using appropriate model systems (in vivo/in vitro/in silico). This new knowledge will take account of the varying exposures at the individual level through exploring differences in behaviour, interactions, and practices in different settings, and explore how this can be integrated in exposure models, while identifying individuals and groups who are most vulnerable to exposure; and
- deliver new knowledge and understanding of the role that airborne biological materials, e.g. fungi, bacteria, viruses, and pollens, and their interactions with particulate and gaseous air pollutants play in exacerbating negative health outcomes. There remain broad questions around the role of airborne microbes and allergens in affecting air quality and the role of air pollution in increasing airborne microbes and allergen related health impacts.

**Understanding and quantifying human behavioural change and practices, and developing and assessing of behavioural and technological interventions, that limit exposure routes and mitigate negative health impacts of those most at risk, including to:**

- deliver new impact driven knowledge and understanding of the human behaviours and practices that lead to emissions and exposures to air pollution across the indoor/outdoor interface, and how these human behaviours may be changed at the individual and societal level to reduce these emissions and exposures and improve health outcomes. This may include prevention-related research, exploring levels of awareness of, and attitudes to indoor and outdoor air quality and its health impacts as well as analysing economic and health benefits of new and existing interventions (both technological and behavioural). This new knowledge will inform the development of various types of interventions to raise awareness, inform the general public, and influence behaviour and practices that can protect those most at risk from exposure; and
- identify and test new technology and interventions for future scenarios of the urban and built environment which prevent the negative health impacts on people of indoor/outdoor air pollution, whilst also identifying opportunities for these solutions to have co-benefits such as reducing greenhouse gas emissions and promoting active travel. Furthermore, to conduct economic analysis and work with city planners, manufacturers of furnishings and fittings, and the construction industry to embed these new technologies and interventions; and make strong arguments for change during the post-pandemic economic recovery and in the future.

**Capability to better synthesise and analyse the diverse big data challenge facing air quality to:**

- deliver new air quality knowledge and capability by drawing together the data, observations, models and analysis from across the indoor and outdoor environments. Capabilities based on a systems approach, linking across the indoor/outdoor interface will be needed. Data exchange and usability is critical in this highly multi-disciplinary and diverse indoor/outdoor community and so work in this area will also need to tackle challenging data and communication issues.

- deliver new emission, modelling and analysis capability across the indoor/outdoor interface necessary to deliver the evidence needs of future policy. Our emerging understanding of future air quality challenges requires improved and new tools able to use and deliver a wider range of air quality measured and modelled data. This will need to span the indoor/outdoor interface and extend across the urban and transboundary scales if they are to support entire human and environmental impact assessment.

Consortia will be commissioned through a series of calls from both UKRI and PSRE.

The consortia will work alongside the PSRE-led further development of the Clean Air Analysis Framework. Building on the Wave 1 Framework this will provide a platform for consistent, evidence-based analysis and advice for stakeholders. It will: 1) support research and policy relevant work across indoor and outdoor air quality areas; 2) Aid discoverability, and ease the use, of data, tools and models; 3) be an open structure that improves transparency and traceability; 4) be scalable, flexible and portable; and 5) support understanding of uncertainties and testing and evaluation.

### Business-led innovation projects to develop new clean air products and services for the indoor environment

Business-led innovation in two priority areas will draw on the research findings of the wave 1 programme and complement ongoing innovation in the Transforming Construction Industrial Strategy Challenge Fund programme and relevant Catapults. Priority will be given to innovations which reduce domestic emissions, new products with global reach, and services directed at improved indoor air quality.

Two innovation Small Business Research Initiative (SBRI) competitions are underway to support the development of new products and services in the area of;

- monitoring of indoor air pollution in the domestic environment
- mitigation and removal of pollutants in the domestic environment

SBRI competitions are pre-commercial procurements, which support organisations to undertake the R&D necessary to develop and test new products and services that will address a specified unmet need. The SBRI process is structured in to phases which select the most successful projects from the previous phase to progress to the next. Both of these competitions comprise two phases;

- Phase 1: Feasibility
- Phase 2: Prototyping and testing

The first competition (*SBRI: monitor and visualise domestic pollution to safeguard health*) concluded in May 2020. Five projects were selected to start feasibility studies in September 2020. Of these, the two most promising feasibility studies will be funded to undertake detailed prototyping and testing work. The selection process is currently underway with the second phase projects expected to start by May 2021.

The second competition (*SBRI Removing air pollutants from homes to safeguard health*), focusing on bringing forward innovative products to selectively remove pollutants from the domestic environment, launched for phase 1 in November 2020. There were 132 applications for this funding and the process to select the six projects that will undertake feasibility studies is now underway with projects expected to launch in May 2021. The most promising projects from the feasibility phase will progress to phase 2.

# KNOWLEDGE EXCHANGE AND COMMUNICATION

Effective communication and knowledge exchange is an integral part of the Clean Air Programme and vital to ensure that the research and innovation supported by the programme has wide benefits for knowledge, society, and the economy.

Clean Air aims to engage, reach and positively impact a broad range of audiences, including: the public, UK Government (including BEIS, parliamentarians, local authorities), research scientists and academics, Public Sector Research Establishments, researchers, and stakeholders from healthcare systems/regulators/quality bodies, users of programme outputs, policymakers, practice, industry, and the media.

Supported by the Champions, the Clean Air projects will identify those who will benefit from or make use of the research beyond the scientific community, how they might benefit or make use of the research, and methods for disseminating data, knowledge and skills in the most useful and effective manner. The appointment of regional champions will aid this further by making sure there is more joined up thinking with local governments and business.

The Champions will be working closely with the NGO Global Action Plan (a charity working for a green and thriving planet – https://www.globalactionplan.org.uk/) advise on communications with key stakeholders and the public at large, supporting the programme to develop. Global Action Plan[9] (GAP) have a successful track record in supporting the public and private institutions to understand the latest research findings such as through their Clean Air Day, Business for Clean Air[10], and the Clean Air for Schools Framework[11]. The Champions will work with GAP to enhance the uptake of Clean Air interventions through GAP which support specific professions to reduce air pollution where those professions have a good opportunity to reduce emissions (for example vehicle fleet managers and hospital executives).

Though the Champions role is currently largely national, connections and communications are being explored with a number of countries (for example Australia and Japan) or organisations with work in other countries, such as advising the MRC Lifecourse Epidemiology Unit (LEU) on its work on household smoke in an Ethiopian community.

Clean Air has a strong ambition in knowledge exchange and communications and has already held a range of activities to facilitate and encourage dialogue with a wide range of stakeholders. Events have included scoping workshops, kick-off meetings, project orientated events, and local community events. Clean Air will continue to host and expand the range of activities for the community to be involved with the programme.

To find out more, visit our website, Twitter and Instagram for further information about the programme, our ongoing activities, and how you can stay in touch with Clean Air.

9. https://www.globalactionplan.org.uk/
10. https://www.globalactionplan.org.uk/business-for-clean-air
11. https://www.globalactionplan.org.uk/clean-air/clean-air-for-schools-framework

# LEGACY

By creating new connected research to address real world issues about air pollution now and into the future, it is envisaged that the Clean Air Programme will lead to changes that translate into improved air quality both outside and indoors. To believe that major changes can be achieved during the 6 years of the Programme is unrealistic, but what is hoped is that the community, industry and policy landscape will have changed sufficiently to realise the Government's intentions as laid out in policy documents such as The Clean Air Strategy 2019[12], The Road to Zero[13], and A Green Future: Our 25 Year Plan to Improve the Environment[14]. With this in mind, a Clean Air Research Futures Group (CARFG) will be established to inform and drive the air quality agenda over the longer term by providing a horizon-scanning function for the air quality community.

The major legacy expected from this programme is:

- A UK air quality and health research community which is united and expanded, able to deliver multi- and inter-disciplinary research to tackle complex questions and innovation to develop robust solutions and to improve air quality beyond the lifetime of the programme.
- Improved awareness and reach of air quality with health professionals and the public.
- Comprehensive air pollution measurement datasets, enhanced integrated modelling capabilities, and improved health assessments that provide a national capability for future research.
- Improved evidence base to inform policy decisions and targets on emissions, health protection and infrastructure development, to realise the Government's ambitions for air quality as laid out in the 25 Year Environment Plan.

12. https://www.gov.uk/government/publications/clean-air-strategy-2019
13. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739460/road-to-zero.pdf
14. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf

In addition to the objectives outlined above (and in Figure 2), the programme will work towards the following areas of legacy:

### Training the next generation of Clean Air researchers

The Clean Air programme provides an opportunity for early career researchers to work in a challenge-focussed and interdisciplinary setting, offering them contacts across academic disciplines such as public-sector research establishments, Government and industry. While the Clean Air SPF does not provide funding for postgraduate training directly, the intensive observing periods are open to wide participation and the Consortia in particular provides substantial awards, alongside with studentships from UKRI Doctoral Training partnerships and other schemes that may be aligned. The Met Office has already seen an increase in requests for CASE studentships during the lifetime of the programme.

### Building stakeholder capacity to achieve Clean Air

The Champions have produced a roadmap with 10 fields where multi-stakeholder action is needed to build capacity to achieve Clean Air. These fields include the need for connected data science between atmospheric and health sciences, improved communication tools for different stakeholders including the public, industries and patients, and increased ownership of the air quality agenda by the health professions. The roadmap will provide guidance on widening the work to engage a broader range of stakeholders and promote the sustainability of the Clean Air activities beyond the funded period.

> “Improving air quality can also helps mitigate against climate change.

### Sustained funding for Clean Air research, innovation and implementation

It is anticipated that the Clean Air SPF will act as a catalyst for Clean Air research and innovation and form the basis of a growing funding relationship widening to include input from other organisations such as NIHR, the Medical Charities, Professional Bodies and Industry. It will be especially important to engage the Government Departments, Devolved Administrations and Executive Agencies responsible for delivering air quality-related activities to encourage a joined up ministerial approach to deliver workable solutions. Involvement of City Mayors and local government will also be essential to encourage take-up of research findings by regional and local communities and ensure in these settings air quality moves up the priority agenda in town and country planning. Citizen science has an important role to play in creating the necessary local evidence of importance in driving down air pollution and improving the built environment.

### A green recovery

Poor air quality and climate change are interlinked, with many air pollutants being ‘climatically active’, such that improving air quality also helps mitigate against climate change. However, some climate mitigating solutions do not always have a positive effect on reducing air pollution. The benefits of adopting an integrated approach, looking at solutions that reduce both, are large from a financial, environmental and timescale perspective. Part of the legacy of this programme should be to highlight the need for air pollution to be a part of the conversation into the green recovery and targets of reducing the impact of climate change, and net zero ambitions. Such that climate mitigation solutions also benefit air pollution.

The recent events of the coronavirus (COVID-19) pandemic have highlighted the importance of the natural environment for our physical and mental health, but also the impact our day to day lives have on the environment around us. Air quality around the world saw major improvements as lockdowns came into force, largely due to a reduction in factory and road traffic emissions of carbon dioxide ($CO_2$), nitrogen oxides ($NO_x$) and related ozone ($O_3$) formation, and particulate matter (PM). In some European cities, for example, a reduction of ~50%, and up to 70% in some cases in nitrogen oxides ($NO_x$), a pollutant typically emitted from traffic, compared to pre-lockdown values[15].

These rapid changes in emissions gave insights into the sensitivity of air pollution exposure to source changes and an unprecedented opportunity to witness how policies relating to transport (the way people work, study and consume) could be capitalised upon in a green recovery. With government incentives to 'Build, Build, Build' to aid in our economic recovery, in the words of Emma Howard Boyd (Chair of the Environment Agency), can we achieve this in a way that lets people 'Breath, Breath, Breath'[16]?

15. https://www.euro.who.int/en/health-topics/environment-and-health/air-quality/news/news/2020/9/a-new-international-day-to-celebrate-clean-air-and-a-sustainable-recovery-from-covid-19
16. https://www.gov.uk/government/publications/state-of-the-environment/state-of-the-environment-health-people-and-the-environment

# PROGRAMME GOVERNANCE

The governance of the UK Clean Air programme encompasses a number of different bodies which undertake different roles.

## Programme Board

The Programme Board is responsible for providing the strategic direction for the programme, the delivery of the programme's objectives and is the ultimate decision-making authority for the programme. It comprises the programme's delivery partners as follows:

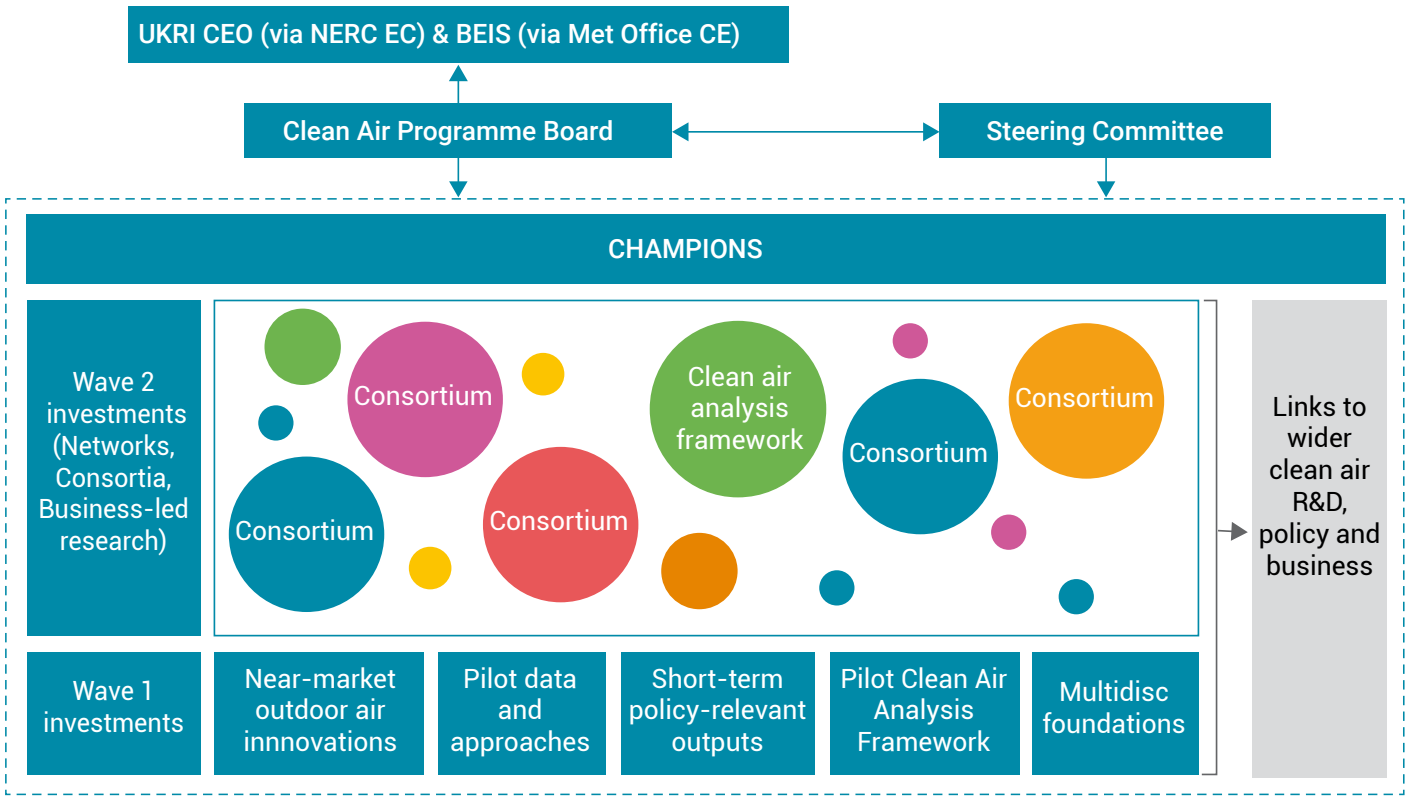
- UKRI-NERC (co-Chair)
- Met Office (co-Chair)
- UKRI-EPSRC
- UKRI-ESRC
- UKRI-Innovate UK
- UKRI-MRC
- Defra
- National Physical Laboratory

## Steering Committee

The Steering Committee provides strategic advice to the Programme Board in support of the programme's objectives. Its membership is detailed on the SPF Clean Air website.

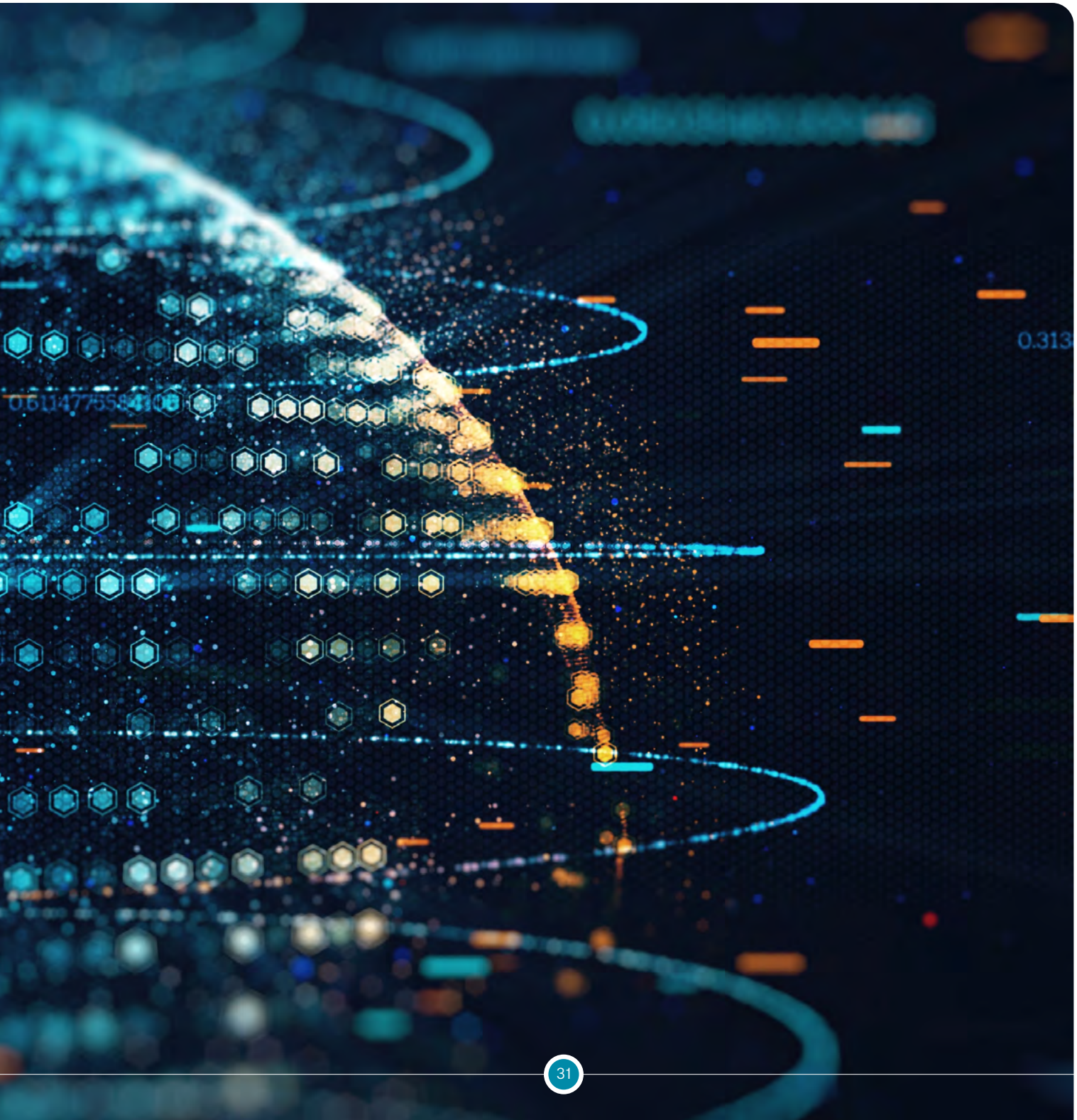
## Secretariat

The Secretary, based at the NERC Head Office, provides administrative support to the Programme Board and Steering Committee.



# DATA MANAGEMENT

The Clean Air Programme will be using the UKRI data policy. UKRI supports the principles in the Concordat on Open Research Data (PDF, 178KB) that recognise that research data should wherever possible be made openly available for use by others in a manner consistent with relevant legal, ethical, disciplinary and regulatory frameworks and norms, with due regard to the cost involved. The Concordat was developed by a UK multi-stakeholder group to provide expectations of best practice reflecting the needs of the research community.












October 2021