The impact of ‘net-zero’ household energy interventions on indoor air quality, health and wellbeing.

This protocol has regard for the Health Research Authority guidance (Version 1.2 March 2016)

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Version 1.1

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STUDY SPONSOR

Northumbria University

SIGNATURE PAGE

The undersigned confirm that the following protocol has been agreed and accepted and that the co-Principal Investigators agree to conduct the study in compliance with the approved protocol and any subsequent amendments.

We also confirm that we will make the findings of the study publicly available through publication or other dissemination tools without any unnecessary delay and that an honest accurate and transparent account of the research will be given; and that any discrepancies from the research as planned in this protocol will be explained.

Co-Principal Investigator:

Signature: ..... Date: 03_12_2025

Name: Jane A Entwistle

Co-Principal Investigator:

Signature: ..... Date: 03_12_2025

Name: Richard McNally

KEY RESEARCH CONTACTS

Co-Principal Investigators	Prof. Jane A Entwistle Department of Geography and Environmental Sciences, Engineering and Environment, Sutherland Building, Northumbria University, Newcastle upon Tyne, NE1 8ST, United Kingdom E: Jane.entwistle@northumbria.ac.uk T: +44 (0)191 227 3017 Dr Richard McNally Population Health Sciences Institute, Faculty of Medical Sciences, Newcastle University, NE1 4LP, United Kingdom. E: Richard.mcnally@newcastle.ac.uk T: +44 (0) 191 282 4724
Research Co-ordinators	Dr Michael Deary Department of Geography and Environmental Sciences Engineering and Environment, Ellison Building, Northumbria University, Newcastle upon Tyne, NE1 8ST, United Kingdom E: michael.deary@northumbria.ac.uk T: +44 (0)191 227 3593 Dr Lindsay Bramwell Department of Geography and Environmental Sciences Engineering and Environment, Ellison Building, Northumbria University, Newcastle upon Tyne, NE1 8ST, United Kingdom E: Lindsay.bramwell@northumbria.ac.uk T: +44 (0)191 227 3768
Funder(s)	National Institute for Health and Care Research (NIHR) Public Health Research (PHR) Programme
Other members of the Research Team	Prof. Luke Vale Department of Health Services Research and Policy, London School of Hygiene and Tropical Medicine. 15-17 Tavistock Place, Kings Cross, London. WC1H 9SH, United Kingdom. E: luke.vale@lshtm.ac.uk T: +44 (0)20 7636 8636 Mr Colin White (Housing Renewal Intervention lead) Senior Housing Renewal Officer Fairer Housing Unit Civic Centre Newcastle upon Tyne NE1 8QN E: colin.white@newcastle.gov.uk Dr Kay Rogage Department of Computing and Information Sciences

	Engineering and Environment, Ellison Building, Northumbria University, Newcastle upon Tyne, NE1 8ST, United Kingdom E: k.rogage@northumbria.ac.uk Prof. Anil Namdeo Department of Geography and Environmental Sciences Engineering and Environment, Ellison Building, Northumbria University, Newcastle upon Tyne, NE1 8ST, United Kingdom E: anil.namdeo@northumbria.ac.uk T: +44 (0)191 227 4155 Dr Tarek Ahmed (Architect, Building performance) Department of Architecture and Built Environment Engineering and Environment, Sutherland Building, Northumbria University, Newcastle upon Tyne, NE1 8ST, United Kingdom E: tarek2.ahmed@northumbria.ac.uk T: +44 (0)191 349 5278 Dr Andy Dengel and Mr Stuart Upton Building Research Establishment (BRE), Bucknalls Lane, Watford Herts, WD25 9XX E: enquiries@bregroup.com T: +44 (0)330 173 8353
Committees	Independent Project Advisory Board (IPAB) See Appendix 1 Data Monitoring and Ethics Committee (DMEC) See Appendix 1 Community Steering Group (CSG) See Appendix 1

i. LIST of CONTENTS

ii. LIST OF ABBREVIATIONS

AQ	Air Quality
CCA	Cost Consequence Analysis
CSG	Community Steering Group
DAMP	Data Access Management Plan
DEC	Domestic Energy Consumption
DMP	Data Management Plan
IPAB	Independent Project Advisory Board
IAQ	Indoor Air Quality
ICF	Informed Consent Form
NCC	Newcastle City Council
NU	Northumbria University
Obj	Objective
PI	Principal Investigator
PIL	Participant Information Leaflet
PMB	Project Management Board
PM_{xx}	Particulate Matter (size fraction)
PPIE	Patient and/or Public Interaction and Engagement
QA	Quality Assurance
QC	Quality Control
REC	Research Ethics Committee
SI	Supplementary Information
SOP	Standard Operating Procedure
SROI	Social Return on Investment

iii. RESEARCH SUMMARY

Internal ref. no. (or short title)	In2Air	
Project Start Date	1st October, 2024	
Study Design	non-randomized natural experiment	
Study Participants	Human participants in social housing in Tyne and Wear, UK	
Planned Sample Size	Participants in 90 study homes and 90 control homes	
Intervention	Informed by the Newcastle Citywide Decarbonisation Delivery Plan, the optimal intervention for each building typology has been designed to reduce the heating consumption in social housing focussing on fabric improvement measures. The planned interventions include a mix of: new windows, [wall/loft/underfloor] insulation, new front doors.	
Follow up duration	Approx. 12 months after intervention (matching month/season of pre-intervention baseline monitoring with post-retrofit monitoring).	
Planned Data-collection Period	Air-quality monitored for a minimum of 3 weeks (21 days) pre-intervention (baseline) and again post-intervention. Participant surveys undertaken at the start and end of each air quality monitoring period.	
Data outcome type	**Objectives**	**Outcome Measures**
Primary	Deployment of low-cost monitors to measure matched indoor and outdoor air conditions for > 3 weeks duration before homes are retrofitted and again post-retrofitting. The monitored parameters: $PM_{2.5}$ via a laser light scattering and particle count approach; CO_2; temperature and relative humidity. All sensors are combined within a single monitor unit. To reduce the burden on the participants and contain study costs, one combined indoor monitor will be placed in the living room of each home, and one outside the property, where feasible (so we can correct for relevant external factors). Monitors set to record at a minimum of 3-minute intervals.	Indoor concentration of $PM_{2.5}$
Secondary		Indoor concentration of CO_2, temperature and relative humidity
Secondary	Multiple approaches and data sources to quantify, assess and monitor domestic energy consumption (DEC), before and after retrofit: 1) a walk-through Level 1 Energy Audit to identify the principal household energy uses (all homes in the study cohort), 2) up to 12-months electricity and/or gas bills reviewed for each home to understand energy usage patterns and seasonal variation (all homes in the study cohort),	energy consumption in homes

	3) higher resolution data will be extracted and used for the analysis if the home has a smart meter installed	
Secondary	Use of modified standard questionnaire instruments to collect baseline and post-retrofit data on i) home characteristics (e.g. Likert scale questions on thermal comfort within the building, prevalence of condensation, damp, mould) and activities/behaviours that influence indoor AQ, and ii) occupier characteristics (e.g. age, gender) and self-reported health and wellbeing collected for all adults in each household (SF-36v2, ICECAP-A, and Use of Health and Care Services survey).	general health and wellbeing metrics
Secondary	Social return on investment derived using data on primary and secondary outcomes described above	Health Economic

iv. FUNDING AND SUPPORT IN KIND

FUNDER(S)	**FINANCIAL AND NON FINANCIAL SUPPORT GIVEN**
National Institute for Health and Care Research (NIHR) Public Health Research (PHR) Programme	36 months financial funding under Call Title: 23/22 PHR Programme Researcher-led
Newcastle City Council (NCC)	Staff time.

In addition, relevent expertise is also provided by members of the various study committees (see Appendix 1)

v. ROLE OF SPONSOR

Northumbria University assumes overall responsibility for the initiation and management of the research. Ethical approval is with Northumbria University Research Ethics Committee (REC) and no members of the research team sit on REC to ensure independence.

vi. ROLES AND RESPONSIBILITIES OF MANAGEMENT COMMITEES & GROUPS

Project Management Board

A monthly **Project Management Board** (PMB), comprising the entire multidisciplinary research team, are responsible for the research design, conduct, data analysis and interpretation, manuscript writing, and dissemination of results. The PMB will provide strategic oversight and decision-making and monitor progress towards milestones. Information on the Board can be found in Appendix 1.

Project Operation Team

Day-to-day project operation and management will be through a **Project Operation Team**, with weekly meetings of the two PIs, the Council partner and the Senior Researcher(s) to ensure all practical details of the research delivery are progressing and working well and everyone within the research team understands them. Other members of the research team invited as relevant.

Independent Project Advisory Board (IPAB)

The IPAB (or Steering Board) will meet twice a year to provide advice to the investigators on all aspects of the study and in particular to consider the study's progress, adherence to the protocol and project ethics, and to consider new information of relevance to the research question and agree proposals for substantial protocol amendments. IPAB membership can be found can be found in Appendix 1.

Data Monitoring and Ethics Committee (DMEC)

The DMEC will meet annually to provide oversight of any primary data collected from participants, including qualitative data and to make recommendations to the IPAB on whether there are any ethical or safety reasons why the study should not continue (such as where the safety, rights and well-being of the study participants is in question). DMEC membership can be found can be found in Appendix 1.

Community Steering Group (CSG)

The Community Steering Group (CSG), including residents in the study location, is chaired by the project PPIE lead. The CSG provides advice on community engagement (newsletter drops, Facebook group, local engagement events), organises local meetings and confirms preferred shared communication platform for the group. A CSG member will join the IPAB. Information on CSG membership can be found can be found in Appendix 1.

vii. PROTOCOL CONTRIBUTORS

Contributor	Affiliation	Relevant expertise
Prof Jane A Entwistle	Northumbria University	Indoor Air Quality monitoring, PPIE
Dr Richard McNally	Newcastle University	Statistics
Dr Michael Deary	Northumbria University	Air Quality Monitoring
Dr Lindsay Bramwell	Northumbria University	PPIE, Air Quality monitoring
Dr Tarek Ahmed	Northumbria University	Building performance and energy efficiency
Mr Colin White	Newcastle City Council	Housing Renewal Intervention lead
Dr Kay Rogage	Northumbria University	Data Specialist
Prof Anil Namdeo	Northumbria University	Air Quality Management
Prof Luke Vale	London School of Hygiene and Tropical Medicine	Health economics

Community partcipants have been, and continue to be, involved in all elements of the protocol design (for further details see Appendix 2).

viii. KEY WORDS

indoor air quality

energy efficiency

building fabric improvement measures

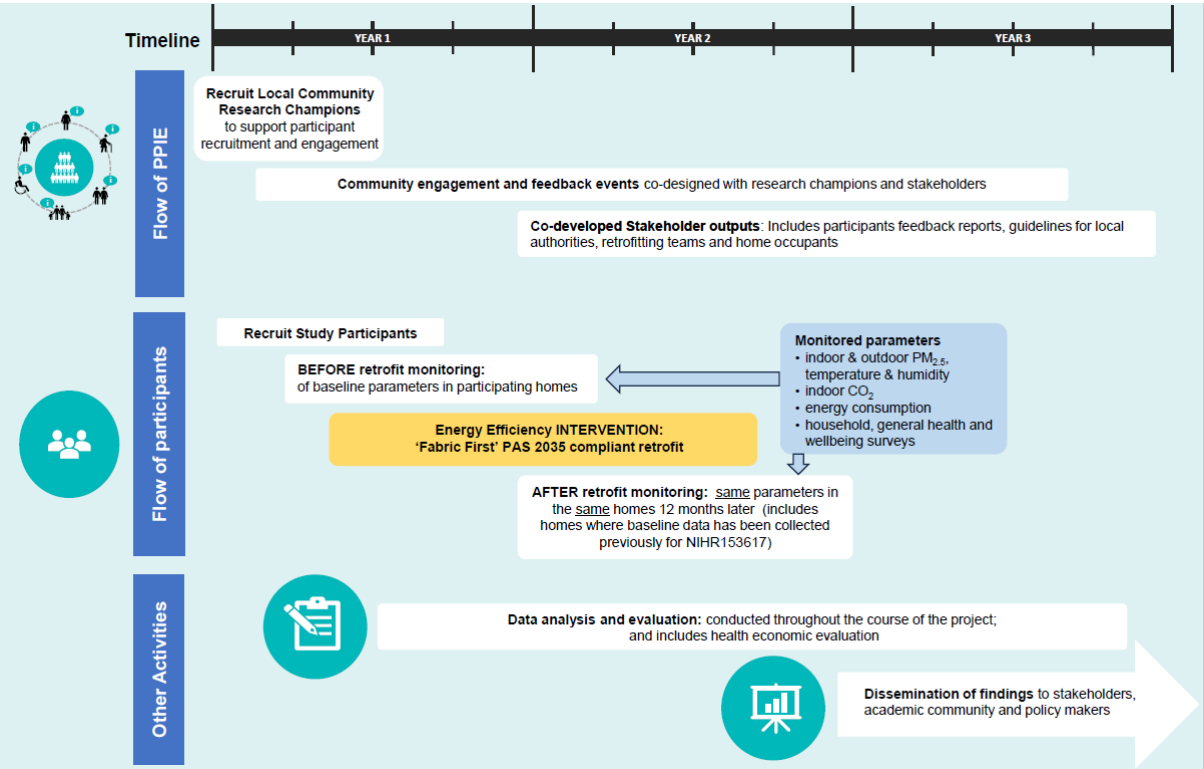
social housing decarbonisation

occupant self-reported general health and wellbeing

ix. PROJECT FLOW CHART

The study's before-and-after group will consist of the same homes/households monitored both before (i.e. the pre-intervention [baseline] group) and after the energy efficiency refurbishments (i.e. the post-intervention group); Figure 1.

Figure 1. In2Air flow diagram.



1 Background and Scientific Rationale

Tackling climate change through interventions designed to reduce household energy use, offers a significant opportunity to improve indoor environmental quality and deliver health and wellbeing co-benefits alongside reduced fuel poverty. The UK Government has set a target of 'net zero' greenhouse gas emissions from human activity by 2050 [1]. The residential sector is a key contributor to greenhouse gas emissions (currently the UK housing sector accounts for 15% of emissions with heating being the primary contributor [1]) and to achieve the targets the majority of homes will require insulation improvement and adoption of new low-carbon heating and power systems. The UK Government has committed £3.8bn to the Social Housing Decarbonisation Fund over 10-years to improve the energy efficiency of social housing, thus helping to support reaching the Net Zero 2050 goal. Due to the scale of the task, a phased scheme has been adopted prioritising a 'fabric-first' approach to retrofit the poorest performing housing stock (e.g. improving external wall, loft and under floor insulation, new windows/doors), to reduce energy demand. These interventions may reduce energy bills and carbon footprints but may also reduce ventilation, resulting in particulate matter (PM), moisture and other air pollutants building up indoors. However, such alterations can adversely impact indoor air quality (IAQ) and compromise occupants' health and wellbeing, though continuous mechanical ventilation can be included in the retrofit design as a mitigating measure.

Few studies have evaluated the effect of a fabric-first approach on IAQ in occupied social housing and there is a lack of quantification of the wider health and wellbeing co-benefits; a research gap we target with In2Air, working in partnership with the Local Authority. Our primary outcome measure is indoor $PM_{2.5}$ concentration because of its well-established associations with health impacts [2,3] and that it can be measured accurately and unobtrusively with low-cost monitors. The study will investigate the impact of these retrofits on IAQ, health and wellbeing in existing social housing. This research, incorporating health economic evaluation (including Cost Consequence Analysis [CCA] and Social Return on Investment [SROI]) is essential for directly informing evidence-based decision making by council retrofit teams through providing reliable and relevant information on co-benefits and costs. This is important because affordable housing organisations operate within constrained budgets, and the additional costs associated with mechanical ventilation beyond those required for minimum regulatory compliance can be financially prohibitive. Our partnership with local government officers is crucial to translate the research evidence into practical application. Local Authorities are particularly well-positioned to disseminate co-benefit-related messaging to their communities, playing a pivotal role in engaging a broader public audience to contribute to a cleaner, greener future [4].

The focus on IAQ is of critical importance because air pollution is a leading cause of global mortality and morbidity and a major driver in exacerbating health inequalities. Poor IAQ leads to adverse health outcomes and exhibits a disproportionate impact on specific demographic groups: people who spend significant periods in the home, such as children and young people (it can damage growing lungs and stunt growth) and older people (aged >65 years); those with compromised immune systems or with relevant pre-existing medical conditions (e.g. chronic obstructive pulmonary disease [COPD] and asthma). The adverse effects are further exacerbated for residents in deprived areas, characterised by elevated levels of both indoor and outdoor air pollution and poorer quality housing [5,6]. Given that we spend a great deal of our time indoors, IAQ plays a central role shaping our health and wellbeing. Improvements to the indoor environment represents a crucial mechanism for addressing health disparities, particularly among low-income and vulnerable populations [7].

NICE guidelines [6] and systematic reviews of household air pollution [8,9,10] highlight the health risks of poor IAQ. PM is a major contributor to air pollution [5]. Potential sources of indoor PM encompass the influx of outside air, cooking, heating, smoking, cleaning, burning candles and various other occupant activities [5,10]. While there are no legal limits in the UK for indoor PM concentrations, the recent reduction of WHO guideline values for annual mean

$PM_{2.5}$ exposure (from 10 to 5 ug/m^3 [5]) is indicative of health effects observed at much lower concentrations than previously suggested. Both short and long-term exposures to PM are associated with increased mortality from all causes, cardiovascular disease, respiratory disease and lung cancer [2,11,12]. Robust evidence supports a causal relationship between short-term PM exposure and adverse effects on conditions such as asthma, COPD exacerbations and combined respiratory-related diseases [13]. Furthermore, studies show that exposure to $PM_{2.5}$ can contribute to or exacerbate hypertension, diabetes, and elevate the risk of Alzheimer's [14-17].

The importance of investigating the effect of fabric-first retrofitting on IAQ is highlighted by the scale of the works that are required to meet the UK's Net Zero 2050 target. Overall, homes will need to significantly reduce energy demand, necessitating highly insulated buildings, increased air tightness and the adoption of new ventilation strategies. It is anticipated, as part of the strategy to meet this target, a minimum of band C will be required for the Energy Performance Certificate (EPC) by 2025 for both private rented and social housing [18]. This will result in a substantial increase in the number of homes requiring energy upgrades; it is estimated that over 15 million English homes fall below the EPC C standard and require additional insulation measures to effectively reduce energy demand [19]. A fabric-first approach is a commonly used low-tech intervention method aimed at reducing energy demand and providing more comfortable environments for occupants [20]. It is worth noting that the retrofit intervention studied in the In2Air project, funded via the Social Housing Decarbonisation Fund, primarily focuses on improving the energy efficiency of the building and is not specifically targeted at improving IAQ, though it presents a timely opportunity to investigate this aspect. Fabric-first energy retrofit schemes are designed to decrease the air permeability of the building envelope, making homes relatively airtight. The potential health impacts of poor IAQ, especially relating to $PM_{2.5}$ concentrations, have been discussed above however it should also be noted that in the absence of adequate ventilation, concentrations of moisture, carbon dioxide (CO_2) and other indoor air pollutants can accumulate within homes, compromising health and wellbeing [21] through Increased risk of allergic and respiratory diseases and also promoting mould growth. For example, a recent study of household energy efficiency interventions across social housing in Southwest England (where IAQ was not monitored) concluded that residing in energy-efficient homes could increase the risk of adult asthma. Specifically, for every unit increase in household energy efficiency there was a 2–3% higher risk of adults consulting a doctor for asthma [22]. To capture these additional threats to wellbeing, the In2Air study will monitor changing concentrations of moisture and CO_2 in the study homes, as well as $PM_{2.5}$, allowing an assessment of whether the buildings are adequately ventilated and provide a comfortable environment when occupied, both before and after the retrofit.

Over the past decade, researchers have investigated a wide range of green retrofit building practices and policies [23]. Most of this research has focused on exploring the advantages associated with improved energy efficiency from environmental sustainability and carbon emission reduction perspectives. A noticeable gap emerges in the literature, with a scarcity of studies that incorporate IAQ (beyond humidity and temperature), along with health and wellbeing to enhance the efficient design of retrofit interventions targeting the wider health co-benefits [24]. Furthermore, assessment of the Social Return on Investment (SROI) resulting from energy efficiency interventions is overlooked in these inquiries, thereby neglecting the assessment of broader co-benefits and harms. This gap in the existing body of research emphasises the need for a more holistic and integrated approach in understanding the multifaceted impacts of energy retrofit initiatives on both the built environment and the occupants. With more stringent air quality guidelines anticipated for PM by 2040 [25] and increasing recognition of the necessity to engage with under-represented groups as part of the net-zero challenge [4], this focus becomes imperative.

While improvements in the general health and wellbeing in adults have been associated with green-retrofit interventions [26,27], results are often equivocal and typically reflect the range of interventions that are co-deployed under this broad term and other confounding variables, including occupant behaviours and the presence or absence of mechanical ventilation [28-32]. Ventilation with outdoor air plays an important role in influencing human exposures to indoor pollutants [29], mitigating the well-documented health issues associated with low building ventilation rates [33]. Studies indicate that homes without continuous mechanical ventilation can exhibit PM concentrations approximately double those in homes with such systems [29]. The In2Air study will contribute to the evidence base of the cost effectiveness and health benefits of including mechanical ventilation in fabric-first retrofits designs.

2 RESEARCH QUESTION, OBJECTIVES AND OUTCOME MEASURES

Research question: *Can fabric-first energy retrofit interventions bring co-benefits for residents in social housing (tackling climate change whilst maximising health and wellbeing by improving indoor air/environmental quality and reducing fuel poverty) and be efficient to implement?*

The aims and objectives (Obj) of this 36-month study are provided below.

Aim 1: Evaluate changes in indoor air quality, energy consumption, health and wellbeing resulting from 'fabric-first' household energy efficiency interventions.

Obj 1.1 Low-cost sensors co-location/calibration study.
Obj1.2 Recruit households and undertake pre-intervention baseline monitoring and surveys, and control surveys.
Obj1.3 Data analysis and evaluation of baseline conditions.
Obj1.4 Post-intervention monitoring and surveys, and control surveys of the same homes/participants.
Obj1.5 Data analysis and evaluation of post-intervention conditions.
Obj1.6 Evaluation of pre- to post-intervention changes in measured parameters and health economic evaluation.

Aim 2: Maximise impact through multi-channel stakeholder engagement.
Obj2.1 Co-design and deliver community inclusion and engagement events (establish community steering group and work with local representatives as community research champions).
Obj2.2 Co-develop guidelines to inform strategic approaches to social housing decarbonisation (including mapping the specialist skills and knowledge required to inform the development of retrofit teams).
Obj2.3 Co-develop guidelines to educate and inform tenant behaviours in retrofit properties (including co-benefit related messaging helping to engage wider publics in creating a cleaner, greener future).

2.1 Outcome measures

Primary Outcome Measure: indoor concentration of $PM_{2.5}$ (ug/m^3).
Change of $PM_{2.5}$ concentration.

Secondary Outcome Measure 1: indoor concentration of CO_2 (ppm), temperature (degree Celsius) and relative humidity (%).
Change in these variables.

Secondary Outcome Measure 2: general health and wellbeing metrics.

Data collected using SF-36v2 and ICECAP-A surveys and converted to scores using related software/validated algorithms.

Secondary Outcome Measure 3: energy consumption in homes (kW/h).

Secondary Outcome Measure 4: costs overall and to different stakeholders.

Secondary Outcome Measure 5: Health Economic Evaluation.
CCA and SROI; the SROI ratio will show the amount of social value obtained for every £1 spent in retrofitting homes.

3 PARTICIPANT ELIGIBILITY CRITERIA

This section sets out precise definitions of which participants are eligible for the study, defining both inclusion and exclusion criteria. The inclusion criteria define the population the study is aiming to include. Exclusion criteria excludes sub-groups of the population due to, for example, safety and other confounding variables.

3.1 Inclusion criteria

- Participants capable of providing informed consent.
- Current resident of social housing in Newcastle or the wider region scheduled for energy retrofitting during the research period; residence for the purpose of this study is defined as individuals typically spending a minimum of 5 nights per week (or equivalent) in the home.
- Plan to reside in the property for the entire duration of the next 16 months.
- If participant is a smoker, agreement to refrain from smoking indoors during the air monitoring period and as far as practicable from the vicinity of the outdoor monitoring unit.

3.2 Exclusion criteria

- Participants who are unable to provide informed consent. We consider this exclusion to include vulnerable adults (most likely those requiring support worker/s).
- Participants below 18 years of age.
- Any participant, in the judgment of the investigator (such as due to safety concerns), deemed unsuitable to participate in the study.

4 STUDY PROCEDURES

4.1 Recruitment

This section describes how human participants are identified and recruited.

4.1.1 Participant identification

NCC owns almost 25,000 homes in the city of Newcastle upon Tyne and it is estimated that to achieve net zero it will require the majority of these properties to be upgraded, costing £434m and reducing CO_2 emissions by 92%. Across the North-East there are a further 16 Social Housing Providers who manage over 189,000 homes and are also working towards net zero target for their homes. Building on the recruitment of occupants in 30 bungalows owned by NCC as part of the pilot project (NIHR 153617), in Autumn 2024 the occupants of 2 tower blocks (90 homes per block) received details via communications from the delivery specialist team at NCC of the planned retrofit works and information on voluntary participation in the In2Air study. Further properties across the local area, identified for retrofitting by NCC and

other social housing providers over 2024-2025, will be targeted to provide a mix of other housing typologies.

Working in collaboration with the delivery team at NCC and the retrofit provider, a range of activities and resources are in development to drive interest and recruitment. Resources include: publicity flyer, project website, community engagement events. For detailed information available for participants see the Participant Information Leaflet (PIL; appendix 2).

4.1.2 Eligibility Screening

Following participant expression of interest, members of the research team set up a phone or F2F meeting to assess suitability against the noted inclusion and exclusion criteria. Participants who do not meet eligibility criteria will be informed immediately at the end of the screening interview.

4.1.3 Payment

To remove financial barriers to study participation financial incentives/compensation will be provided. Financial incentives/compensation for participation will cover costs incurred related to time spent with a researcher and energy use of the sensors. Up to £80 per household: £20 voucher at initial home visit; £20 voucher at end of first 'baseline' monitoring; £20 voucher at start of the post-retrofit monitoring; £20 voucher at end of the post-retrofit monitoring.

Financial incentive/compensation is also available for those participants who take part in focus groups and workshops associated with the health economic elements of the study, as well as the community research champions.

To remove mobility barriers participants can undertake all elements of monitoring from their home; to remove language barriers we will provide translated study materials where relevant; to remove time barriers we have co-developed easy to complete study materials through previous PPIE and will continue to co-develop these materials.

4.2 Consent

The co-PIs retain overall responsibility for the conduct of research. Informed consent is to be obtained prior to the participant taking part in the study. For the study cohort, this will be recorded by a hard-copy signed Participant Consent Form (PCF) following a verbal discussion between the potential participant and an individual knowledgeable about the research. This will allow the opportunity for potential participants to ask questions and for the researcher to outline the nature and objectives of the trial and possible risks associated with participation. For the control cohort, the Participant Consent Form (PCF) will be signed electronically.

As delegation of consent is granted to the Senior Researcher on the project the co-PIs will ensure that they are trained and competent to participate according to the ethically approved protocol.

As detailed in the PIL, any participant has the right to refuse participation without giving reasons; remains free to withdraw at any time from the study without giving reasons and without prejudicing his/her further treatment and is provided with a contact point where he/she may obtain further information about the study; data and samples collected up to the point of withdrawal will only be used after withdrawal if the participant has consented for this (any intention to utilise such data are outlined in the consent literature).

Written materials provided to potential participants (e.g., participant information leaflet and consent form; included in Appendix 2) are approved by Northumbria University Research

Ethics Committee (REC) and follow local regulatory and legal requirements. The PIL and PCF explain what information are being collected, how we are going to use it and the lawful basis under which the data is processed. Participants will also receive a copy of Northumbria University's Research Participant Privacy Notice.

4.3 Data collected

The following data will be collected at both baseline and post-retrofit follow-up:
i) co-collected/matched indoor-outdoor concentrations of $PM_{2.5}$, temperature and humidity data;
ii) indoor CO_2 concentrations;
iii) energy consumption, (data collected for up to 12 months before and 12 months after retrofit);
iv) self-reported general health and wellbeing measured using the ICECAP-A and SF-36v2 surveys;
v) use of Health and Care Services collected via participant completed questionnaires;
vi) home and household questionnaire;
vii) total costs for up to 12-months pre- and 12-months post-retrofit and costs incurred by different stakeholders (householder, Local Authority, society, etc.);
viii) Additional qualitative data collection via a semi-structured interview with participants to explore perceptions and understanding of living in a retrofitted home and to capture any relevant changes of behaviour (e.g. changes to the use of rooms in the home after retrofitting).

Post-intervention monitoring will take place 12 +/- 2 months after completion of the retrofit works to allow time for the building to stabilize and for the occupants to experience a range of seasons/operating conditions (in keeping with recommendations in [34]). Whilst the timing of pre- and post-retrofit monitoring will be seasonally matched, a further control will be the co-collected indoor and outdoor concentrations of $PM_{2.5}$, temperature and relative humidity that will allow for the evaluation of confounding variables in the quantification of post retrofit change. The matched collection of indoor/outdoor data will also allow us to monitor any impact of the retrofit works on the I/O ratio (Indoor $PM_{2.5}$ concentration/Outdoor $PM_{2.5}$ concentration).

Detailed approach undertaken for monitoring domestic air quality is available in supplementary information (SI) 1.

Our approach undertaken for monitoring of DEC is available in SI-2.

Deployed survey questions are available in SI-3.

Quality assurance procedures: For precision checks on the air quality monitors before field deployment (i.e. standardisation / reproducibility across the monitors) all monitors were co-located in a test chamber, housed at the Building Research Establishment (BRE), UK and subjected to a range of environmental conditions to mimic field conditions within the specialised, controlled environmental test chamber. To ensure a common reference for the performance of the monitors (i.e. accuracy check), collocation of the monitors with relevant reference instruments was undertaken (e.g. i. DustTrak monitor for particles, calibrated by the manufacturer compliant with ISO 12103-1; ii. Vaisala CO_2 Probe [GMP252] and Humidity and Temperature Transmitter [HMT120 / HMP110] all calibrated to the requirements of ISO/IEC 17025). A report on the monitors' performance against each other and against the reference monitors will be made available.

Control data set: A control group will focus on the key health/wellbeing measures and allow us to determine changes in these attributes occurring in the control group without the retrofit intervention. The control group will target the health and wellbeing scores (ICECAP score and SF36 score) and use of services (cost per person) using an online questionnaire survey.

The control cohort will also receive the home/occupier survey allowing us to characterise the control cohort.

5 STATISTICS AND DATA ANALYSIS

A detailed Statistical Analysis Plan to be developed by project month 6 (for inclusion in SI-5).

5.1 Sample size calculation

Our enrolment target was determined using assumptions based on our earlier study [35] and a similar study in the USA where homes moved from on-demand mechanical ventilation to continuous mechanical ventilation as part of the energy efficiency retrofit works [7]; they observed a reduction in mean $PM_{2.5}$ of 25% (with an overall reduction in mean $PM_{2.5}$ from 17.7 to 13.3 ug/m^3). Our baseline study (on non-smoking households) observed an indoor mean concentration of 10.0 +/- 6 ug/m^3 $PM_{2.5}$ on which the power calculation is based using a paired t-test and assuming a mean difference between the pre- and post-retrofit groups of 25 % (i.e. a reduction of mean concentration of 2.5 ug/m^3 from 10 to 7.5 ug/m^3 $PM_{2.5}$). The results of this power calculation indicated a minimum of 72 homes are needed in each before and after group to potentially see a statistically significant difference (with 80% power, alpha = 0.05, one-sided test) in $PM_{2.5}$ between the two groups. We plan to recruit 60 homes across the properties that are scheduled for retrofitting in 2024/5. Baseline conditions in 30 bungalows have already been established as part of [36], resulting in an overall target cohort of n = 90. This sample size allows for ~ 20% dropout rate between the two periods.

5.2 Data analysis

5.2.1 Air-quality dataset

After quality assurance checks and application of any resultant data correction factors, descriptive statistics will be computed (e.g. mean 24hr $PM_{2.5}$, SD, medians, max., Q1, Q3). Each parameter will be checked for normality using graphical plots and statistical tests (e.g. Kolmogorov-Smirnov test) with transformations of non-normal data using log or square root transformations. If normality is not achieved by transformation then non-parametric statistics will be analysed. Logistic regression and shadow matrices will be used to determine data that are missing at random. Missing data will be imputed using mean, median and regression-based imputation as appropriate [36]. T-tests will be used to test for statistical differences between means and, for non-normally distributed data, Mann-Whitney tests will be used to test for statistical differences between distributions (which may reflect differences in medians or shapes of the distributions).

A series of simple linear regression models will be used to explore putative associations between the monitored environmental variables (e.g. the association between indoor $PM_{2.5}$ as the response variable and indoor humidity as the independent variable in the model). Those variables that have been found to be statistically significant (in this scenario taken as $p<0.1$) from the univariate regression will then be included as covariates in multivariable regression models with the outcome measures taken to be $PM_{2.5}$ and, separately, CO_2 concentration. Linear regression will also be used to explore associations between pre- and post-monitored data. For example, our primary outcome measure $PM_{2.5}$, where we will compare the means and medians of the n=90 pre- and n=90 post-intervention homes. The matched indoor and outdoor data will be included in the regression models using differences, as ratios and as separate covariates to account for any effects these outdoor environmental variables may have on the change detected. This will allow us to establish whether the interventions improve indoor air/environmental quality.

Exploratory analyses will be undertaken to investigate regression to the mean as part of sensitivity analyses. This will include the use of adjusted means to correct imbalances due to outliers.

The collected outdoor temperature data will allow us to consider differences in temperature from one winter to the next. We will test for differences in outdoor temperatures between the two survey periods and then adjust as necessary by including outdoor temperature in all of the regression models. Using this approach, all of the models will include an adjustment for outdoor temperature. We will include both mean and median outdoor temperatures in separate multivariable regression models. In addition, we will also carry out sensitivity analyses including upper and lower quartiles and minimum and maximum outdoor temperatures in separate multivariable regression models.

5.2.2 Energy performance dataset

Statistical analysis (daily and annual averages), will be applied to the collected energy usage data to delineate energy performance benchmarks within the study cohort both pre- and post-retrofit interventions. We will investigate these benchmarks in conjunction with occupant-indicated energy usage patterns from the energy audit to identify issues, variations, mismatches, and atypical events. These data will indicate the effectiveness of the retrofit energy performance and provide a basis for the council's rationalisation and justification of associated investment as part of their net-zero transition. The analysis of these data will also determine whether the interventions contribute to alleviating fuel poverty.

5.2.3 General health, household and wellbeing dataset

Histograms, bar charts and descriptive statistics will be used to summarise these data. For SF-36v2, two key domains will be presented (a physical component summary and a mental health component summary), along with SF-6D scores, whilst for ICECAP-A, the validated scoring algorithm will be used to convert responses into a single score. Multi-variable analysis will be used to explore the effect of monitored indoor environmental variables on health and wellbeing measures. Backwards elimination will be used to determine the best fitting models. These data will allow us to determine whether the interventions yield co-benefits for residents, addressing climate change whilst optimising health and wellbeing. Comparison with control group data will allow us to identify changes specific to the retrofit group.

Differences between participants' pre- and post- retrofit home/household questionnaire responses will be used to identify trends in perceptions of home thermal comfort and a range of behaviour changes (e.g. attitudes to energy saving, use of supplementary heaters, perception of damp, odours and draughts, opening of windows and doors for fresh air, cooking ventilation habits, laundry habits). In addition, we will explore perceptions and understanding of living in a retrofitted home, wider co-benefits of tackling climate change and capture any relevant changes of behaviour (e.g. changes to the use of rooms in the home after retrofitting). We will: i) describe the data; ii) analyse changes between the pre- and post-retrofit responses; iii) analyse the qualitative feedback using software such as NVivo and AI tools to discern thematic responses within the dataset, providing an understanding of recurrency, patterns, trends, and nuanced insights derived from the qualitative data.

5.2.4 Procedure(s) to account for missing or spurious data

Community engagement events and communication with participants will promote and maximise follow-up and reduce missing data. Any missing data (e.g. from surveys or measurements) will be logged to allow an audit record. Missing air quality and energy consumption data will be handled, where feasible, by using validated methods including single and/or multiple imputation methods. Sensitivity analyses will be employed to assess the robustness of results under different methods of handling missing data.

5.2.5 Control data set

We will develop a propensity score method [an approach that can be used to minimise the sample size for a control group; 37,38,39] to allow us to understand how closely participants in homes undergoing retrofit and controls match. We propose a control group across n = 90 homes, the same number of homes as in the retrofit intervention group.

6 ECONOMIC EVALUATION

Given the complex impact of home retrofitting, methods of evaluation have been chosen that have the flexibility to consider these impacts. The two approaches chosen are CCA and SROI [40, 41, 42]. CCA has been described as a form of disaggregated cost-benefit analysis (and cost benefit analysis itself should include all costs and all benefits no matter on whom they may fall).

6.1 Health Economics Analysis Plan

A detailed Economic Evaluation Plan to be developed by project month 6 (for inclusion in SI-4).

6.2 Cost-consequence Analysis

The CCA will be presented in the form of a balance sheet with costs and consequences presented in a disaggregated way. This will allow the highlighting of the choices and trade-offs inherent in any decision. The CCA will support the SROI described below.

6.3 Social return on Investment

The SROI will compare the social benefits reported in monetary terms with the costs. It will seek to consider the range of health, social, environmental and economic costs and outcomes of the retrofit intervention. The SROI should provide a single metric that will incorporate the costs and consequences presented in the CCA. The SROI follows a 4-step process.

6.3.1 Stakeholder identification and logic model development

We will conduct 10 qualitative interviews, involving key stakeholders such as individuals whose homes have undergone the retrofitting interventions (e.g. the community research champions) and those involved in the design of the intervention (e.g. NCC and their contracted architects). Individuals whose homes have undergone the retrofitting interventions meeting the eligibility criteria (section 3) with recruitment supported by the community research champions. Working with NCC, the community research champions and the CSG and IPAB will help identify the resources required to deliver the retrofitting, help describe how these ‘inputs’ link to outputs and the outcomes of interest. We will also conduct a scoping review and documentary analysis to develop our logic model for the evaluation of the retrofit intervention. The focus of this model will be to describe the causal pathways of the retrofitting of homes on potential inputs, outputs and outcomes. Once we have developed an initial logic model we will conduct 2 workshops, each with 8 participants, to help refine our model. One workshop will be with those whose homes have been retrofitted (e.g. the community research champions), the other with wider stakeholder group (e.g. NCC and other local authorities, representatives of relevant professional bodies [i.e. RIBA, UKHSA] and industry professionals [i.e. BRE, Space Group, from across our networks). In the workshops we will seek to finalise the health, wellbeing, environmental, economics and other societal outcomes. We will also seek to identify relevant sources to measure and value our inputs, outputs and outcomes of interest.

6.3.2 Calculation of inputs

Working with NCC we will identify and value the resources required to deliver a programme of retrofitting homes. We will also consider and value the costs incurred over time in terms of maintenance and servicing of the retrofitting intervention. Sensitivity analysis will be conducted (see below) to explore how these valuations might change should the retrofitting be widened to more homes in NCC locality. The values to be explored within the sensitivity analysis will be informed by discussion with NCC but we will also seek to identify if there is a threshold value for the cost of the programme that could change the conclusions of the SROI.

Evidencing and valuing outcomes*:* Data on the effect of retrofitting on impact on outcomes of interest will come from multiple sources. First the data collection approach and statistical analysis described in sections 5.2.2 and 5.2.3, respectively, will provide estimates on health, well-being, cost of any care used, energy use in the short term. For the SROI for health and wellbeing we will initially focus on responses to the ICECAP-A and use these data to estimate any additional quality adjusted survival for differences for different time periods after retrofitting [43]. These will be valued using a range of society's willingness to pay values. In an alternative analysis we will convert SF-36 scores into SF-6D scores [44], replicate the statistical analysis described in section 5.2.3, and then replicate the analysis used for the ICECAP-A. This analysis focusing on the SF-6D focuses on the narrower concept of health rather than wellbeing and any differences in the conclusions drawn from analyses using the ICECAP-A and SF-6D will highlight the importance of perspective – wellbeing or health.

For longer term health outcomes, we will estimate the impact on health of changes in air quality as measured by $PM_{2.5}$ from the literature using recognised modelling methods [45]. To estimate the short- and long-term health effects of the intervention, we will apply epidemiologically-derived relative risk (RR) factors for a range of long term (stroke, chronic obstructive pulmonary disease, lung cancer and ischaemic heart disease) [11;46] and acute health effects (emergency hospital emissions, and mortality) [47,48] that are associated with $PM_{2.5}$. RRs allow the calculation of changes in prevalence of these health effects for each unit increase or decrease in $PM_{2.5}$ concentration.

Use of health and care services and the financial cost of energy to houses will be measured and valued. Use of health and care services will be collected using a bespoke questionnaire designed using feedback from our earlier study [35], previous tools [49] and will also include an open-ended question to capture 'out of pocket expenses' related to health seeking activities, such as the purchase of products from a pharmacist for self-medicating. The collated data will be coded (e.g. score of 0 where no service has been used), with numbers representing an intensity of need for individuals. Responses will be combined with unit costs from routine sources [e.g. 50] and study specific estimates to estimate cost of care used in the pre- and post-retrofit period. The environmental cost of energy use will be sought from data sources available at the time of analysis (e.g. the cost of a tonne of CO_2, [51]). The logic model may also identify further societal outcomes beyond the environmental effect of changes in energy use (e.g. wellbeing gained from additional investment in the local built environment and positive climate action [a caring externality]). Should such outcomes be identified, we will seek to value these using data from the literature and expert opinion from stakeholders. We will also consider whether their inclusion could change the conclusions of the SROI. If their likely direction of effect could only strengthen conclusions then this can be highlighted in the CCA. Where inclusion could potentially change the conclusion of the SROI we will again note this in the CCA but also explore using threshold analysis whether it is plausible that the value of the outcome could plausibly be of sufficient magnitude to change conclusions.

As the statistical analysis may not capture all outcomes of interest to householders, as identified on our logic model we will explore with a small sub-sample (n=30, given the focus of the SROI is on developing explanatory theory rather than obtaining statistically significant results) whether there are householder changes in other outcomes that may affect them directly. Data will be captured by a further questionnaire (this additional questionnaire will be

added to SI-3 in project year 2) completed during focus groups (these focus groups will allow input from our community research champions), informed by our logic model and developed in collaboration with our CSG. After obtaining consent, participants in the focus groups will complete the questionnaire to estimate the changes in the identified outcomes of interest. We will also seek to establish what would have happened had retrofitting not have taken place.

6.4 Establishing impact & estimation of the SROI ratio

We will develop a spreadsheet-based model to link our inputs, outputs and outcomes. The model will be parametrised using data from sections 6.2 and 6.3 above to allow the calculation of the SROI ratio. The SROI ratio will show the amount of social value obtained for every £1 spent in retrofitting homes. The analysis will account for deadweight (the value of a change that would have occurred even without the retrofitting), displacement (i.e. the extent to which other similar activities conducted by others have been displaced), attribution (i.e. the extent to which other activities could have resulted in the changes estimated) and drop-offs (i.e. duration and waning of costs and benefits) to determine the "true" value of the investment [52].

The same spreadsheet used for the estimation of the SROI ratio will also be configured to produce the CCA. This will ensure that a paired CCA is available for every SROI ratio calculated as part of sensitivity analysis (see below). It will also allow the identification of counterintuitive results for further exploration (which may be identified when, for a given analysis, an estimate in the CCA looks unusual/implausible) and if necessary, correction.

We will also conduct sensitivity analyses to understand key uncertainties and impact of choices made when estimating valuations of outcomes. We will discuss with CSG and PAB whether we might expect inputs and outcomes to differ according to how and where retrofitting is implemented. We will then see how this affects the SROI ratio. Specifically, this latter work will see to explore how the SROI ratio might change in other situations both within NCC and for other localities.

7 DATA MANAGEMENT

7.1 Data protection and participant confidentiality

The data collected in the study relates directly to the objectives of the project and is required to achieve the outcomes of the research. As such, the research team processes the special categories of personal data under Article 9(2)(j) GDPR, which permits processing that is necessary for scientific research purposes, providing we have appropriate security safeguards in place. The Data Management Plan (DMP) is available on request from either of the Project PIs.

All source documents (e.g. original signed informed consent forms; coded original questionnaire responses) will be scanned into electronic format. This, and recorded data from automated instruments, will be retained in an appropriate format for a period of at least 3 years after the end of the study in accordance with NU's Research Records Retention Schedule (principle of storage limitation).

An audit trail of data changes will be maintained.

Informed by the Data Protection Impact Assessment, the following personal data will be directly collected/stored only in electronic form on password protected devices in password protected files: data on ethnicity, disability, household location data, email address where supplied. This personal quantitative data will remain confidential to the project researchers and will not be shared with other agencies. Sensitive data and the linking code will be securely maintained in separate locations using password protected digital files on password protected storage media.

All other survey data will be collected/stored using pseudonymised identifiers: gender and age category; selected environmental health related behaviours (e.g. ventilation strategy); general health and wellbeing (using established and widely used health-related quality of life measures). These self-reported health and wellbeing data, collected for all adults in each household, can be considered special category data and hence will only be stored using pseudonymised identifiers. Where collected as paper hard copy, survey papers will be held in a locked bag for transport to the office. Surveys will then be locked in a filing cabinet until data scanned to electronic format. The hard copy will then be put in confidential waste.

Study records for data analysis will use only study identification numbers and computer data files will be password protected to protect participants confidentiality.

Online surveys will be delivered via JISC Online Surveys (GDPR compliant and certified to ISO 27001 standard).

Data security measures to protect against unauthorized access, backup of the data and archiving of source data (electronic copies) will be detailed in the DMP.

Direct access will be granted to authorised representatives from the Co-PIs to permit study-related monitoring, audits and inspections in-line with participant consent.

In summary, all investigators must comply with the requirements of the Data Protection Act 1998 with regards to the collection, storage, processing and disclosure of personal information and will uphold the Act's core principles. Ethical guidelines, in accordance with Northumbria University's information security policy (principle of integrity and confidentiality) will be followed for securely anonymising, separating, and holding information on household and personal identifiers to ensure confidentiality obligations.

7. 2 Data Access

A detailed Data Access Management Plan (DAMP) will be developed and will be available on request from either of the Project PIs by project month 6.

8. ETHICAL CONSIDERATIONS

Ethical approval for the study has been granted from Northumbria University REC (submission reference ID8064) and subject to continued compliance with the University policies on ethics, informed consent, and other policies applicable to this study.

As updates are available, updated protocols are to be submitted via an Ethics Amendment Form to maintain compliance.

Any incidents which have an adverse effect on participants, researchers or study outcomes are to be reported via an ethical incident form to the REC.

8.1 Public and/or Patient Involvement and Engagement

The study researchers work with members of the public not patients. Members of the public have been and will continue to be involved in the research process as described below. Meetings and engagement events with community members will be conducted using recommendations from the INVOLVE website http://www.invo.org.uk/.

8.1.1 Design of the research

The indoor AQ investigation methods, questionnaire, informed consent form and monitoring equipment choice have been directly informed by several rounds of interaction with a consumer panel and a community group (drawn from a similar geographical location and socioeconomic group to our target population). Activities were supported through a Public Involvement Fund (award rds3897) from the then Research Design Service North-East and Cumbria. We continue to co-develop and refine the study design and materials throughout the project.

8.1.2 Management of the research and undertaking the research

A Community Steering Group (CSG), including residents from the study location, will inform the research management. CSG will, for e.g., provide advice on community engagement (newsletter drops, Facebook group, local engagement events), meetings and confirm preferred shared communication platform for the group. A CSG member will join the IPAB. We will support members of the community to contribute to the research through events in the local neighbourhood to encourage community members to participate, share experiences, and feedback on acceptable methods to engage and retain participants in future studies.

8.1.3 Analysis of results

The CSG and wider community will be encouraged to inform the research team on aspects of the study of particular interest to them to ensure this is addressed in the results analysis.

8.1.4 Dissemination of findings

The CSG and wider community will be encouraged to inform the research team on preferred pathways for participant and community feedback e.g. written communications and event invitations via NCC, local community information boards and newsletter drops to homes in the participating housing estates, household report on monitored data.

The proposed PPIE activities include:

- Information on purpose and participation in the study distributed via NCC, letters from NCC to tenants regarding retrofit works, and to relevant local community groups and venues;

- Establish CSG and review study PPIE protocol;
- Public engagement and recruitment events: including meet the research team, study participation information, research team finds out about community's air quality concerns and barriers to participation;
- Study progress updates shared via CSG, NCC and any other routes recommended;
- Community feedback collected through the same channels;
- Study support telephone number (researcher has pre-prepared Q&A sheets);
- Local public engagement events to thank the communities and CSG, share findings and experiences, provide Q&A opportunity, collect feedback.

8.2 Participant safety, protocol compliance and recording/reporting of breaches to protocol

Unanticipated outcomes of the study could include: raised anxiety levels among participants about increased energy costs (due to the monitoring instrumentation and mechanical ventilation as part of the intervention), exposure to indoor air pollution and reduced fresh air indoors. To reduce incidences of anxiety we will: provide vouchers which more than cover the cost of additional electricity used; de-brief participants during researcher visits to discuss concerns; provide a study contact telephone number/email/website with researchers having pre-prepared Q&A responses. Where participants may feel uncomfortable answering survey questions, the researcher will move on to the next question. Following completion of the research, we will make recommendations to remove or reduce any negative impacts (so called 'unintended consequences') of fabric-first retrofit interventions.

The research will additionally be informed and guided by any additional suggestions from the DMEC.

Departures from the approved protocol (i.e. protocol non-compliances), where not considered serious breaches (i.e. those that can be accommodated within the scientific scope of the study) will be adequately documented and reported to NU REC on the appropriate Ethics Amendment Form.

Deviations from the protocol which are found to frequently recur will require immediate action and could potentially be classified as a serious breach. A "serious breach" is a breach which is likely to effect to a significant degree –

(a) the safety or physical or mental integrity of the participants of the study; or
(b) the scientific value of the study

In this situation the NU REC and the funder will be notified immediately of any instances where the above definition applies during the study. Where appropriate, the study protocol will be amended within 7 days of becoming aware of the serious breach.

8.3 Indemnity

The study collaboration agreement details the indemnity arrangements for the study. All partners are signatories to this collaboration agreement.

8.4 Post study participant follow-up

No post study clinical care will be required for participants as this is not a clinical trial.

9 RISK MANAGEMENT AND CONTINGENCY

A set of possible risks has been identified and contingency planning has been undertaken to limit the impact on the project deliverables. Risk analysis has been carried out to: define the risk; evaluate the probability that such a risk may occur during the project; identify the seriousness of the risk and its impact on the project; specify the countermeasures in order to mitigate the effect of the risk to the project and/or to prevent the risk occurring. Table 9.1 summarises the risks identified and proposed risk-mitigation measures. Risks and risk management will be a standing item on the monthly Project Management Board meetings, along with the maintenance of a risk register.

Table 9.1 summarises the risks identified and proposed risk-mitigation measures

Description of risk	**level of likelihood**	**Proposed risk-mitigation measures**
Limited engagement/ take-up by participants	Medium	A co-designed inclusive engagement strategy, with compensation vouchers for participation (to reduce participant cost concerns) and input from a local, professional, participatory design company; if recruitment rate is low we will review the inclusion/exclusion criteria and re-consider the messaging. NCC have further property across the city and will look to deliver retrofit work in other neighbourhoods in the city where necessary, plus we will collaborate with other social housing providers as necessary. Given there is a wide range of occupancy turnover across the tower blocks, our sample size has been set to allow for ~ 20% dropout rate between the two periods. Increase incentive/compensation rate as necessary.
Issues related to Covid-19	Medium	Regular review of researcher-community engagement and interaction plans. For example, participant informed consent and delivery/set up of air quality monitoring equipment can be altered to enable delivery without entering the residence if significant concerns occur in relation to Covid-19.
AQ kit related: Delay in kit procurement Loss of equipment Equipment failure	Medium	We can commence data collection using instruments already purchased as part of the baseline study and additional time-flexibility has been built into contingency plans to extend the monitoring phase should this be required (i.e. natural experiment with flexible length monitoring periods); Sensors' security considered in the placing and fixing of outdoor monitors; Contingency plans to retain 2 sets of monitors un-deployed to enable rapid deployment in case of damage, robbery etc.;
Poor quality of AQ data	Medium	Quality assurance protocols to be undertaken before kit deployment; best practice guidelines for AQ sensor location to be followed;
Changes to the planned intervention	High	Experience from our baseline study [36] has influenced the monitoring design with continency/flexibility in mind. Household data collection timelines can respond to street by

schedule/delay in intervention delivery timeline (such as a result of supply chain, builder issues, or reduction in the number of homes with scheduled intervention)		street, home by home retrofit schedules, with pre- and post-retrofit seasonality of monitoring over spring and summer periods (rather than autumn/winter) if required. If deemed necessary, we can also reduce the household monitoring period to 2 weeks and/or reduce the planned 12 +/-2 months post-intervention 'settling-in' period phase should this be required. NCC facilitated collaboration with other social housing providers across the North-East as/where necessary.
Extended researcher illness Staff departure to another HEI	Low	Given the overlapping/complementary research expertise of the project researchers in some areas, tasks will be allocated to another member of the research team in the short-term with a new member co-opted/recruited to cover the skills/expertise where appropriate.

10 DISSEMINIATION

The study collaboration agreement details ownership of the data arising from the study and who has the rights to publish any of the data. The funding body is to be acknowledged within any publications arising from the study.

10.1 Study protocols

Scalable Standard Operating Procedures/Protocols for collecting data to facilitate an evaluation of the impact of retrofitting on IAQ, household energy use, general health and wellbeing will be made publicly available on the project website (due to go live in project month 3 month). Protocol updates will be posted as necessary.

10.2 Access to the study dataset

All of the named researchers involved in the project will have access to the datasets [pseudoanonimised where relevant] to facilitate data analysis.

Access to the draft study report will be granted to all members of the project committees to enable peer review.

The baseline data arising from this study will be embargoed for 24 months after collection to allow time for post-intervention monitoring, although there are no embargo periods on any data included in publications arising from the current study within this timeframe.

A detailed Data Access Management Plan (DAMP) will be developed and will be available on request from either of the Project PIs by project month 6.

10.3 Other dissemination pathways

Multi-channel/multi-format initiatives will be utilised to maximise academic and wider stakeholder reach and impact tailored to:
-Policymakers/civic actors, targeting policy-focussed forums and networking events;
-General public, through a range of communication strategies (co-developed and informed through PPIE) to reach our target audiences to improve public awareness of the potential co-benefits of net zero interventions;

-Industry and Professional bodies, engaged throughout via activities including use of social media channels (e.g. LinkedIn), workshops and talks at industry events as well as at events hosted by our partners/their networks.
- Academia, through engagement via conferences, speaker programmes, webinars targeting established networks to maximise knowledge exchange/impacts.

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12. APPENDICIES

Appendix 1 - Representation on the Committees/Boards

Project Management Board

Contributor	Affiliation	Relevant expertise
Prof. Jane A Entwistle (Chair)	Northumbria University	Indoor Air Quality monitoring, PPIE
Dr Richard McNally (co-Chair)	Newcastle University	Statistics (health)
Dr Lindsay Bramwell (Sec.)	Northumbria University	PPIE, Indoor/Outdoor Air Quality monitoring
Dr Tarek Ahmed	Northumbria University	Building performance
Mr Colin White	Newcastle City Council	Housing Renewal Intervention lead
Dr Kay Rogage	Northumbria University	Data handling and data management
Prof Anil Namdeo	Northumbria University	Air Quality Management
Dr Michael Deary	Northumbria University	Air Quality Monitoring
Prof Luke Vale	London School of Hygiene and Tropical Medicine	Health economics

Community Steering Group (CSG)

Contributor	Affiliation	Role
Dr Lindsay Bramwell	Northumbria University	Chair
tbc		
tbc		
tbc		

Independent Study Advisory Group (ISAG)

Pending – awaiting NIHR review/invitations

Dr Lindsay Bramwell (Sec.)
Northumbria University
Lindsay.bramwell@northumbria.ac.uk

Data Monitoring and Ethics Committee (DMEC)

Pending – awaiting NIHR review/invitations

Contributor	Affiliation

tbc (Sec.)
Newcastle University

Appendix 2 – Participant consent/information leaflet (for both study and control cohort).

In2Air: Measuring indoor air quality, energy use and residents' wellbeing before (and after) energy efficiency renovation works

Participant Information Leaflet

We are inviting you to take part in a study to help explore how home energy efficiency modifications affect indoor air quality, energy use, health and wellbeing. Before deciding whether to participate, here is some information about the project and what you would be asked to do if you take part.

Why are we doing this study?

The UK Government has set challenging targets to reduce our production of greenhouse gases (the 'net-zero' challenge) as these gases cause the planet to warm and drive climate change. Homes play a large part in greenhouse gas emissions and housing providers are making changes to homes to reduce household energy use. Local Authorities and private homeowners around the UK are adding extra insulation and reducing draughts in their homes to make them more energy efficient. We want to find out if these improvements change the amount of fresh air in the home or the health and wellbeing of residents.

We want to measure the energy use, temperature, humidity, small inhalable particles and fresh air in homes before the energy efficiency building works are carried out, and again after. Technology is now available that can do this with small, quiet monitors.

What will you be asked to do?

If you decide to take part in the study, your participation will involve the following:

1. Placing a small, quiet, air quality monitor in your living room and another outside your home. The monitors will record the very small (inhalable) particles in air, ventilation, temperature and humidity in the room. The sensors will be left in place for at least 3 weeks, ideally longer, or until your retrofit works begin whichever is sooner.
2. Allow the researcher to see your gas and electricity bills for the previous 12 months.
3. Allow the researcher to read your gas and electricity meters at the start and end of your monitoring period.
4. Help us complete a survey about your health and wellbeing and about your home and things that affect it like number of people, activities, ventilation, if you have damp problems and items in your home that may use lots of energy.

We will also ask you to do this again, one year after the energy efficiency works have been completed.

We want to ensure that people from a range of diverse backgrounds have equal opportunity to participate in the research. We will collect data on your age category, gender, ethnicity and any disability so we can see if we are reaching a diverse population of participants. Where the data suggest we are not, we can put in place other ways to engage people across a wider diversity.

Who can take part?

Anyone over the age of 18 years old living in social housing who will be having energy efficiency retrofit works on their home can participate. For households where someone smokes indoors, if the smoker agrees to smoke outside during the study, then the household can take part.

How will we process the data obtained from you?

Your questionnaire answers and air data will be stored in anonymised form on the password protected secure private network of Northumbria University. It will only be accessed by researchers working directly on this project.

If you do not want to continue participating in this research, what should you do?

You can change your mind and exit the study at any time without giving a reason. If you withdraw from the study, we will process the data according to your wishes, either retain, or delete it from our records. However, please note it is not possible to delete anonymised data once published (see below for further details).

What will happen to the results of the research and how will my confidentiality be protected?

Your personal information will be stored on a password protected secure private network at Northumbria University and will only be accessed by researchers working directly on this project. We will write up the findings of this study to share with all interested parties, however your information will not be identifiable (you will remain anonymous). If you would like, we will also provide you with a summary of the findings and your air quality data.

What are the possible benefits and disadvantages to taking part?

There are no expected disadvantages from taking part in this study. You will be reimbursed up to £80 for having the air quality monitor in your home and for your time answering the questionnaires. Reimbursement will be in shopping vouchers with two £20 vouchers available for the first round of monitoring, and a further two £20 vouchers when we monitor again in about 12 months' time. We provide you with findings of the study and you will gain understanding of activities that impact the air in your home and your energy use.

Who is organising this research and what if there is a problem?

The research is being led by Northumbria University (Professor Jane Entwistle), Newcastle University (Dr Richard McNally) and Newcastle City Council. If you have any questions, you can contact one of the project team on [redacted] (Lindsay Bramwell or Michael Deary) or email ee.in2air@northumbria.ac.uk and we do our best to answer your questions.

You might also like to …...Get more involved and help us to design parts of the study

We are looking for residents to join the Community Steering Group or to act as community Research Champions, to help us plan community activities and to make sure we target any of the community's worries and interests around air quality and fuel efficiency. If you would like to find out more about these roles (again vouchers will be available to acknowledge your time helping on the project), please contact Lindsay Bramwell on [redacted] or ee.in2air@northumbria.ac.uk

In2Air: Measuring indoor air quality, energy use and residents' wellbeing before (and after) energy efficiency renovation works

Participant Information Leaflet

We are inviting you to take part in a study to help explore how home energy efficiency modifications affect indoor air quality, energy use, health and wellbeing. Before deciding whether to participate in our control group (that is someone living in social housing that will not undergo energy efficient renovation works over the next year or so), here is some information about the project and what you would be asked to do if you take part.

Why are we doing this study?

The UK Government has set challenging targets to reduce our production of greenhouse gases (the 'net-zero' challenge) as these gases cause the planet to warm and drive climate change. Homes play a large part in greenhouse gas emissions and housing providers are making changes to homes to reduce household energy use. Local Authorities and private homeowners around the UK are adding extra insulation and reducing draughts in their homes to make them more energy efficient. We want to find out if these improvements change the amount of fresh air in the home or the health and wellbeing of residents.

In homes that are scheduled to have energy efficiency building works, we want to measure the energy use, temperature, humidity, small inhalable particles and fresh air in homes before the energy efficiency building works are carried out, and again after. In homes that are not scheduled to have these changes we want to survey the residents both now and again in about 12 months' time to find out about changes in homes, health and wellbeing that are not due to energy efficiency renovations. These are our control homes group.

What will you be asked to do?

If you decide to take part in the study, your participation will involve completing a survey about your health and wellbeing and about your home and things that affect it like number of people, activities, ventilation, if you have damp problems. We will also ask you to do this again in about 12 months.

We want to ensure that people from a range of diverse backgrounds have equal opportunity to participate in the research. We will collect data on your age category, gender, ethnicity and any disability so we can see if we are reaching a diverse population of participants. Where the data suggest we are not, we can put in place other ways to engage people across a wider diversity.

Who can take part?

Anyone over the age of 18 years old living in social housing whose home is not scheduled for energy efficiency building works.

How will we process the data obtained from you?

Your questionnaire answers will be stored in anonymised form on the password protected secure private network of Northumbria University. It will only be accessed by researchers working directly on this project.

If you do not want to continue participating in this research, what should you do?

You can change your mind and exit the study at any time without giving a reason. If you withdraw from the study, we will process the data according to your wishes, either retain, or delete it from our records. However, please note it is not possible to delete anonymised data once published (see below for further details).

What will happen to the results of the research and how will my confidentiality be protected?

Your personal information will be stored on a password protected secure private network at Northumbria University and will only be accessed by researchers working directly on this project. We will write up the findings of this study to share with all interested parties, however your information will not be identifiable (you will remain anonymous). If you would like, we will also provide you with a summary of the findings and your air quality data.

What are the possible benefits and disadvantages to taking part?

There are no expected disadvantages from taking part in this study. You will be reimbursed £10 for your time answering the questionnaire, with a further £10 voucher when we survey again in about 12 months' time. We provide you with findings of the study and you will gain understanding of activities that impact the air in your home.

Who is organising this research and what if there is a problem?

The research is being led by Northumbria University (Professor Jane Entwistle), Newcastle University (Dr Richard McNally) and Newcastle City Council. If you have any questions, you can contact one of the project team on [redacted] (Lindsay Bramwell or Michael Deary) or email ee.in2air@northumbria.ac.uk and we do our best to answer your questions.

You might also like to …...

Get more involved and help us to design parts of the study

We are looking for residents to join the Community Steering Group or to act as community Research Champions to help us plan community activities and to make sure we target any of the community's worries and interests around air quality and fuel efficiency. If you would like to find out more about these roles (again vouchers will be available to acknowledge your time helping on the project), please contact Lindsay Bramwell on [redacted] or ee.in2air@northumbria.ac.uk

In2Air: Measuring indoor air quality, energy use and residents' wellbeing before (and after) energy efficiency home renovation works

Participant Consent Form

I have read and understood the information for participants in the In2Air research project of Northumbria University, a project in collaboration with Newcastle City Council, Newcastle University, the Building Research Establishment and the London School of Hygiene and Tropical Medicine.

I understand that this research will explore how home energy efficiency modifications affect indoor air quality, energy use and the general health and wellbeing of the study participants.

The study has been explained to me by

Name:

I understand that taking part is voluntary and that I can change my mind at any time without giving any reason, without penalty. If consent is withdrawn, any personal data collected up to that point will be destroyed unless consent is given to keep it. ☐

I understand that the information I provide will be treated with the strictest confidence and stored securely. ☐

I am aware I will be asked to provide the following:

- Survey responses (including questions on my general health and wellbeing) ☐
- Details of gas and electricity bills ☐
- Access to gas and electricity meters ☐

I consent to the collection of indoor air quality data in my home ☐

I agree that all these data will be stored in an anonymised form at Northumbria University and may be used for further related research ☐

The Data Protection Officer for Northumbria University is Duncan James.

If you have any questions which you feel have not been covered by the Participant Information Leaflet, or if you have concerns or a complaint in relation to the University processing your personal data, please do not hesitate to email us at: dp.officer@northumbria.ac.uk. If your request is urgent, please call 0191 243 7357.

I have also received a copy of the In2Air Research Participant Privacy Notice ☐

I would like to be informed of the research findings for my home ☐

Please provide the email or postal address where you would like the results sent to

……

I agree to take part in the study. ☐

Signed: Name: Date:

I confirm that the above person has received the participant information leaflet about the In2Air study. I have explained the nature of the study and allowed an opportunity to ask questions about the study.

Signed: Name: Date:

In2Air: Measuring indoor air quality, energy use and residents' wellbeing before (and after) energy efficiency home renovation works

Participant Consent Form (control group – homes not undergoing energy efficiency renovation works)

I have read and understood the information for participants in the In2Air research project of Northumbria University, a project in collaboration with Newcastle City Council, Newcastle University, the Building Research Establishment and the London School of Hygiene and Tropical Medicine.

I understand that this research will explore how home energy efficiency modifications affect indoor air quality, energy use and the general health and wellbeing of the study participants.

The study has been explained to me by

Name:

I understand that taking part is voluntary and that I can change my mind at any time without giving any reason, without penalty. If consent is withdrawn, any personal data collected up to that point will be destroyed unless consent is given to keep it. ☐

I understand that the information I provide will be treated with the strictest confidence and stored securely. ☐

I am aware I will be asked to provide the following:

- Survey responses (including questions on my general health and wellbeing) ☐

I agree that all these data will be stored in an anonymised form at Northumbria University and may be used for further related research ☐

The Data Protection Officer for Northumbria University is Duncan James.

If you have any questions which you feel have not been covered by the Participant Information Leaflet, or if you have concerns or a complaint in relation to the University processing your personal data, please do not hesitate to email us at: dp.officer@northumbria.ac.uk. If your request is urgent, please call 0191 243 7357.

I have also received a copy of the In2Air Research Participant Privacy Notice ☐

I would like to be informed of the overall research findings ☐

Please provide the email or postal address where you would like the research summary sent to

……

I agree to take part in the study. ☐

Signed: Name: Date:

I confirm that the above person has received the participant information leaflet about the In2Air study. I have explained the nature of the study and allowed an opportunity to ask questions about the study.

Signed: Name: Date:

Appendix 3. Documentation amendment history

Ethical approval for the study has been granted (23/09/2024) from Northumbria University REC (submission reference ID8064) based on this draft protocol. As the protocol is updated, re-submission to Northumbria University REC will be made.

A record of changes made relative to the previous protocol are listed in the table below.

Protocol Amendment History

Amendment No.	[new] Protocol version no.	Date of update issued to REC committee	Author(s) of changes	Details of changes made
1.	V1.1	03/12/2025	JE	Minor updates to note DMP is now available (DMP v1.1 uploaded as part of the ethics re-submission) and the maintenance of a risk register. REC approval date: 08/12/2024

Appendix 4. Study protocols/plans in detail

The following Supplementary Information (SI) files are associated with this protocol:
SI-1: Detailed approach undertaken for monitoring domestic air quality
SI-2: Auditing and monitoring domestic energy consumption
SI-3: Survey questions
SI-4: Health Economic Evaluation Plan [available project month 6]
SI-5: Statistical Analysis Plan [available project month 6]

A record of changes made relative to the finalised version of each SI (v1.0) are listed in the table below.

Supplementary Information Amendment History

Amendment No.	[new] SI version no.	Date of update issued to REC committee	Author(s) of changes	Details of changes made
1	SI-3v1.2	03/12/2025	JE	Minor updates to the questionnaire surveys and confirmation of the wording of the personal data collected online only
2	SI-1v1.1	03/12/2025	JE	Minor updates to Table 1 and the associated descriptive text
3				
4				
5				
6				

In2Air Supplementary Information 1.
Detailed approach undertaken for monitoring domestic air quality

Air quality measurements

The In2Air Study will measure $PM_{2.5}$, CO_2 temperature and humidity indoors, paired with $PM_{2.5}$, temperature and humidity outdoors. PM are a measure of inhalable smoke and fine dust particles such as those from cooking, smoking or outdoor traffic. Exposures to PM are associated with increased risk of allergic and respiratory diseases. CO_2 is a good indicator of the level of air exchange between indoor and outdoor environments. Raised levels of CO_2 are regarded as sign of inadequate ventilation and often used as a surrogate measure of the amount of outdoor air introduced into the home. Humidity is linked to occurrence of black mould in homes. The more frequently air quality (AQ) measurements are recorded by the AQ monitors, the more precisely the impacts of activities in or outside the home on indoor AQ can be identified.

Sampling period

We will measure co-collected/matched indoor and outdoor air conditions for a minimum of 3 weeks duration before homes are retrofitted with the energy efficiency measures. Current literature on the length of monitoring required to establish an indoor AQ baseline varies widely from a few days (e.g. 4 days) with weekend/weekday and seasonal sampling, up to 12 months [1, 2, 3, 4].

Equipment

Air quality measurements

One combined indoor monitor will be placed in the living room of each home, and one outside the property (so we can correct for relevant external factors). To contain study costs In2Air will deploy low-cost monitors. Another consideration has been to minimise the burden on participants. IQAirVisual Pro (AVPro) (indoor) and IQAirVisual Outdoor (AVO) have been selected for the In2Air study as they each combine $PM_{2.5}$, CO_2, temperature and relative humidity into a compact, quiet, unit minimising space required and disruption in participants homes. Power and internet access (wi-fi connection) for the AVO are provided by a flat PoE ethernet cable (power and data) through a window, wall or door feed through.

Comms and data access

The AVPro and AVO monitors are linked together by Wi-Fi. We will provide a Wi-Fi hotspot (e.g. me-fi or pebble) to each home so researchers can connect to and manage the monitors remotely as well as download the data without needed to visit the residence.

The AVPro screen shows easy to read traffic light air quality index indicators, however the AVPro screen will be disabled so as not to provide information on the quality of air to study participants, which could alter behaviour. Measurements will continue to be taken and stored with the screen off. The screen can be disabled by turning on power saving mode and switching the screen off with the power button. A touch of the power button will switch the screen back on, the screen will not switch on and off automatically in the morning and evening. Researchers contact details to be left with participants in case of any issues with the monitors.

The IQAir units will be networked to the IQAir data cloud where current and historic data can be viewed on the IQAir AirVisual mobile app (https://www.iqair.com/commercial/air-quality-monitors/airvisual-platform/air-quality-app) or on the IQAir web dashboard https://www.iqair.com/. Measurements will be available for the research team to download from the web dashboard.

Detailed historical data logs are held in the monitor's internal memory for up to 5 years, depending on measurement frequency. A .csv or .txt file containing all data can be downloaded wirelessly from the unit by logging into the same Wi-Fi as the AV units (this requires visiting the home) and using ‘Samba’ software on a laptop

https://www.iqair.com/us/blog/resources/download-the-airvisual-node-pro-s-data-using-samba or by mobile phone https://support.iqair.com/en/articles/3343422-export-historical-data-from-your-airvisual-pro-using-a-mobile-phone

Placement of equipment

Indoor

Ideally the indoor monitor should be placed in a room most commonly used by occupants. For the In2Air study we have selected the living room. The monitor should be away from doors, openable windows, air supply vents and grilles (minimum 1 m >2 m if possible), and specific sources of pollutants (e.g. fireplace, or place where candles or incense are burned). If there are incoming ventilation supply points the monitor should be placed between these. The monitor should not be placed somewhere that would be a nuisance to the study participants, or use a socket that they regularly need, or have a trailing power cable that could be a trip hazard. Head height (where participants are breathing when seated) is desirable if possible. An adapter plug can be used in order that the Wi-Fi hotspot and AQ monitors use only one socket. See BS40101:2022 [4].

Outdoor

Placement near to any ventilation inlets (or frequently opened doors or windows) will give the quality of air that will be ventilating into the building. Shelter from direct sunshine and prevailing rain is desirable. When using paired indoor-outdoor units connected by cable, secure placement with no trailing cables should be ensured. Recommendations and consideration for installation of the IQAir Visual Outdoor in the IQAir Visual Outdoor User and Installation Manual should be adhered to where possible. See BS40101:2022 [4].

Where BS40101: 2022 guidance for placement cannot be followed a note to reflect this will be reported in the meta data.

Technical Information (extracted from AVO & AVPro User manuals)

Size

The indoor AVPro's dimensions are 21 x 12 x 8 cm, weight: 0.8 kg.
AVO dimensions are 16 x 7 x 20 cm
Wi-Fi hot spot approx. 10 x 6 x 2 cm

Sensor specifications

AVO & AVPro

Nephelometer: Laser light scattering technology with remote calibration. This technology is quieter than is typical gravimetric technology equipment. This particle count approach provides a calculated mass concentration based on assumed density and shape of the particles.

- $PM_{2.5}$ (Fine dust) 0 to 1,000 µg/m³ ±10 µg/m³ / or ±10%

Measurement frequency

AVPro: In standard mode the AVPro records time, $PM_{2.5}$, CO_2, temperature, humidity, AQI, and outdoor AQI data every 10 seconds
AVO: The AVO collects data every minute in standard mode.
A uniform sampling frequency of 1 minute will be selected for all outdoor and indoor monitors

Internet connectivity

AVPro: Wi-Fi (802.11 b/g/n - 2.4 GHz)
AVO: Ethernet (100 Mbit fast Ethernet), Wi-Fi (802.11 b/g/n - 2.4 GHz), optional: 3G/4G/LTE via USB modem

Power rating

AVO: 48VDC, 12 W

AVPro: AVPro has an internal rechargeable Li-on battery providing up to 4 hours of disconnected use. It will remain plugged in for the purposes of the In2Air study
Wifi hotspot: Average 6 W

Equipment energy use
Department of BEIS 2021 average electricity prices were 18.9 pence per kWh, estimated to rise to 36 pence per kWh by end of 2022. In September 2024 average UK price per kWh is 22.36 pence (Table 1).

Table 1: Estimated cost of electricity for equipment use based on power rating and estimated price of electricity

device	wattage	hours use per day	kWh (per day) (wattage x hrs used)	Cost per day @22.36p/kWh (pence) (kWh x cost per unit)	Cost estimate for a typical monitoring period of 21 days (cost per day x 21 days)
avo	12.00	24.00	0.288	6.43968	£1.35
avpro	15.00	24.00	0.36	8.0496	£1.69
wifi hotspot	6.00	24.00	0.144	3.21984	£0.68
total	33.00		0.79	17.71	£3.72

Equipment maintenance and recalibration requirements
The AVPro & AVO $PM_{2.5}$ sensor can benefit from maintenance, as laser (light-scattering) sensor readings may experience some degree of drift after a prolonged period of exposure to pollutants. The extent of this will vary depending how much pollution the sensor is exposed to. This 'drift' is likely to happen more quickly in high-pollution environments, for example in cities with generally high outdoor pollution levels (e.g. US AQI frequently above 150). If using the sensor in an outdoor, high pollution environment (AQI frequently > 150), then the sensor may require recalibration/replacement after approximately 12-18 months. These are guidelines - the best way to tell if a sensor is experiencing any drift, is to compare its readings with another relatively new sensor [5].

Default sensor mode takes measurements approximately 12x less frequently than Continuous sensor mode - so Continuous mode should expose the sensor to 12x more pollution over time, which may impact the rate of drift.

Note: IQAir have a recalibration service. Currently, this requires your Node/Pro to be posted to one of the service centres.

AQ Reading metadata to be reported
Property data: • Site/Project; • Address; • Postcode;
Location of data point: • Floor/level, • Room/zone
Device: • Manufacturer of device; • Model; • Serial number; • Accuracy of data captured provided by the device (from technical data sheet or calibration record); • Calibration date (most recent)
Information should be stored in a spreadsheet with structure & naming according to BS 40101:2022 [4].

References

[1] National Center for Healthy Housing. *Studying the Optimal Ventilation for Environmental Indoor Air Quality*. Columbia, MD: Enterprise Community Partners. [Internet] 2022. [Accessed 31 May 2022]. Available from: https://nchh.org/ resource-library/report_studying-the-optimalventilation-for-environmental-indoor-air-quality.pdf.

[2] Colton MD, MacNaughton P, Vallarino J, Kane J, Bennett-Fripp M, Spengler JD, Adamkiewicz G. Indoor air quality in green vs conventional multifamily low-income housing. *Environmental Science & Technology*. 2014 Jul 15;48(14):7833-41.

[3] Lajoie P, Aubin D, Gingras V, Daigneault P, Ducharme F, Gauvin D, Fugler D, Leclerc JM, Won D, Courteau M, Gingras S. The IVAIRE project–a randomized controlled study of the impact of ventilation on indoor air quality and the respiratory symptoms of asthmatic children in single family homes. *Indoor Air*. 2015 Dec;25(6):582-97. doi.org/10.1111/ina.12181

[4] BS 40101. 2022. BSI. *Building performance evaluation of occupied and operational buildings (using data gathered from tests, measurements, observation and user experience)* — Specification BS 40101:2022

[5] IQAir Knowledge Base https://www.iqair.com/us/blog/resources/airvisual-pro-maintenance-and-sensor-recalibration (accessed 09.09.22)

In2Air Supplementary Information 2.
Auditing and monitoring domestic energy consumption

Acquisition of accurate energy data underpins all carbon reporting and will be used to support Newcastle City Council establish a protocol for energy monitoring to create evidence-based net zero strategies. Before embarking on implementing building energy efficiency measures, it is important to establish a baseline of the current building performance and where it stands with respect to current standards, so that measurement and verification of proposed interventions are attainable. The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) has developed guidelines for energy audits and categorised them into: Level 1, 2 and 3.

Level 1 Energy Audit
Data collection will involve a Level 1 Energy Audit on all homes in the study. For each home, pre- and post-retrofit, this involves i) a basic walk-through assessment and completion of an Energy Audit Template to provide an overview of the energy use, identify initial opportunities for energy savings and raise awareness about the importance of energy savings; ii) ~12 months electricity and/or gas bills reviewed to understand energy usage patterns
and identify seasonal variation and how they impact heating and cooling requirements; iii) where energy supply is per individual property, we will record meter readings at the start and end of each AQ monitoring period for both the pre- and post- retrofit phases to provide an average daily energy use which can be used for benchmarking.

This basic evaluation is designed to identify energy efficiency problems and understand the current building performance. Data collected will be analysed to create a profile for the selected architypes and establish baseline energy consumption pre-intervention.

Building general data

Building Architype	
Participant ID	
Date of Energy Audit	
UPRN (unique property reference number)	
Gross floor area	
Number of stories	N/A
Building Age	
Energy consumption per m2	[to be calculated as part of the data analysis]
Number of occupants	[obtained from survey data]
Typical Hours of occupation per week	[to be calculated as part of the data analysis]
Start of baseline monitoring date:	
Gas MPAN (Meter Point Administration Number)	Include digital photography of the meter and the reading
Gas Meter reading at start of monitoring	
Electric MPAN (Meter Point Administration Number)	Include digital photography of the meter and the reading
Electricity meter reading at start of monitoring	
End of baseline monitoring date:	

Gas Meter reading at end of monitoring	Include digital photography of the meter and the reading
Electricity meter reading at end of monitoring	Include digital photography of the meter and the reading
Start of post-retrofit monitoring date:	
Gas MPAN (Meter Point Administration Number)	Include digital photography of the meter and the reading
Gas Meter reading at start of monitoring	
Electric MPAN (Meter Point Administration Number)	Include digital photography of the meter and the reading
Electricity meter reading at start of monitoring	
End of post-retrofit monitoring date:	
Gas Meter reading at end of monitoring	Include digital photography of the meter and the reading
Electricity meter reading at end of monitoring	Include digital photography of the meter and the reading

Building Characteristics

Building structure	
External wall cladding	
Roof Cladding	
Wall insulation	
Roof/Loft Insulation [type(s)]	
Roof/Loft Insulation [type(s)]	Very minimal; Minimal; Acceptable (recommended amount); Good (above recommended amount); Very good
Floor Insulation	
Externals Windows (No.)	
Externals Windows (type)	
External Doors (No.)	
External Doors (type)	
EPC	
Details of ventilation	
Details of any passive (trickle) ventilation (and their status – in use/covered etc)	e.g. window trickle vents, air bricks, roof vents
Details of any continuous ventilation (and their status – in use/covered etc)	

Extractor fan(s) in kitchen (if present: detail location(s) (above hob etc), Extraction to outside or recirculation, Maintenance status.	
Extractor fan in bathroom (if present: detail location(s) (in ceiling etc), Extraction to outside or recirculation, Maintenance status	
Tumble drier (if present: detail location (in kitchen etc), Extraction (none, to outside, condensing type)	

Large Equipment and Appliances Inventory

Area No	Description	Item	Type	Total Power	Typical daily operating hours	Any additional comments
Example:	Lounge Room	LED TV	Samsung			
Example:	Kitchen	Stove				
Example:	Kitchen	Fan				

Heating, Air Conditioning and any additional Ventilation

Area No	Description	Item	Type	Total Power	Temperature set	Typical daily operating hours
Example:	Kitchen	Boiler				
Example:	Kitchen	Radiator				
Example:	Bathroom	Electric shower				

Supplementary information

Area No	Description	Notes and observation
		e.g is water heated by gas but with an electric shower
		Note: we are not capturing detailed info on individual light fittings and type but if significant lighting in property this should be captured here (e.g. may be useful to consider over the December monitoring period if the property is exceptionally well illuminated!)

Supplementary Information 3
Survey questions

Survey 1 & 2

When: at commencement of baseline monitoring activity (note: survey can be split into parts to allow the participant a break from answering questions and to allow other activity, such as installing AQ monitoring equipment).

How: for the study cohort, the questionnaire will be delivered by the researcher working directly with the participant; for the control cohort, the survey will be delivered remotely online. Where responses are collected via hard copy, responses will be entered directly into the online forms via the researcher's password protected IT device as soon after collection as practicable.

Where: study cohort - face to face in the participants home or communal building area; control cohort – remotely online.

Survey 3 & 4 – for study cohort only

When: survey 3 at end of both periods of monitoring activity on collection of units; survey 4 at end of the second (post-retrofit) period of monitoring on collection of units.

How: the questionnaire will be delivered by the researcher working directly with the participant. Responses will be entered directly into the online forms via the researcher's password protected IT device or using hard copy for subsequent transfer to into the online forms.

Where: Face to face in the participants home or communal building area.

Note: *As detailed in the DMP, no personal details or special category information that can lead to participant identification will we recorded in hard copy but entered directly into a password protected electronic form. Below is the survey used to collect these data. Participants respond to the survey direct via a link accessed from the project mobile. The survey platform is JISC Online Surveys (GDPR compliant and certified to ISO 27001 standard).*

Sex, gender identity and ethnicity

One way to ensure a diverse range of participants are included in our research is to identify potential underrepresentation of certain groups and make adjustments as necessary. Asking the following questions helps us to do this.

Q1. What is your In2Air Participant Identifier? This is your unique ID number so that we keep your personal details and special category information separate to your name and address.

Q2. What is your sex? If you are one or more of non-binary, transgender, have variations of sex characteristics, sometimes also known as intersex, the answer you give can be different from what is on your birth certificate. If you're not sure how to answer, use the sex registered on your official documents, such as passport or driving licence, or whichever answer best describes your sex. The next question gives the option to tell us if your gender is different from your sex registered at birth, and, if different, to recorded your gender.

Male
Female
Prefer not to say

Q3. Is the gender you identify with the same as your sex registered at birth?

Yes
No
Prefer not to say

Q4. **If you answered No, please enter the term you use to describe your gender.** This is also voluntary, so you can leave it blank if you prefer.

Q5. What is your ethnicity? ethnic origin is not about nationality, place of birth or citizenship. It is about the group to which you perceive you belong. This is a two-part question. *Ethnicity Part 1* - please select the appropriate option from the list below

Asian or Asian British
Black, African, Caribbean or Black British
Mixed or Multiple ethnic groups
White
Other ethnic group

Q6. *Ethnicity Part 2* - If you selected **Asian or Asian British** please tell us more by selecting from the options below.
Indian
Pakistani
Bangladeshi
Chinese
other Asian background
Prefer not to say
Q7. if you selected **other Asian background** please write in below:

Q8. *Ethnicity Part 2* - If you selected **Black, African, Caribbean or Black British** please tell us more by selecting from the options below.
African
Caribbean
other Black, African or Caribbean background
Prefer not to say
Q9. If you selected **other Black, African or Caribbean background** please write in below:

Q10. Ethnicity Part 2 - If you selected ***Mixed or Multiple ethnic groups*** please tell us more by selecting from the options below.
White and Black Caribbean
White and Black African
White and Asian
other Mixed or Multiple ethnic background
Prefer not to say
Q11.
If you selected **other *Mixed or Multiple ethnic*** background please write in below:

Q12. *Ethnicity Part 2* - If you selected ***White*** please tell us more by selecting from the options below.
British (e.g. English, Welsh, Scottish, Northern Irish)
Irish
Gypsy or Irish Traveller
other White background
Prefer not to say
Q13. If you selected **other *White*** background please write in below:

Q14. *Ethnicity Part 2* - If you selected ***Other ethnic group*** please tell us more by selecting from the options below.
Arab
other ethnic group
Prefer not to say
Q15. If you selected ***other ethnic group*** please write in below:

Disability
One way of promoting access and inclusion of disabled people in our research is by asking questions on this form. It helps us to assess if we have included a range of voices/experiences in the research project.

Q16. **Do you have any physical or mental health conditions or illnesses lasting or expected to last 12 months or more?**
Yes
No
Prefer not to say

Q17. **Do any of your conditions or illnesses reduce your ability to carry out day-to-day activities?**
Yes, a lot
Yes, a little
Not at all

Survey 1

[Adapted from NIHR153617 In2Air pilot study survey [35] which was adapted from an unpublished questionnaire developed by the Building Research Establishment]

(to be completed by the lead participant in the project)

Household and Participant Reference Code: **……**

Introduction

This questionnaire will take up to 20 minutes to complete. It is made up of 3 sections which cover: who lives here, the home environment and residents' activities. The information will assist us in interpreting the results of the air, fuel, health and wellbeing data collected as part of the In2Air study. Please respond 'decline' to any questions that you prefer not to answer. The information you provide will be completely confidential to the researchers. Your answers will be combined with the answers of other study participants and reported in such a way that it will not identify you.

Section 1: Occupants of the household

1. How many people live in the property for at least 5 days in a typical week?

[Note: questionnaire set up online for more than one response where multiple occupants in the property]

2. Please indicate the number in each age group and gender:

	M	F
<16		
16 - 25		
25 – 34		
35-44		
45-54		
55-64		
65 or over		

3. In a typical week, how many hours are the adults living here (people over 18 years old) usually **out** of the home each day?

Occupant 1 (you)

Day	Mon	Tue	Wed	Thurs	Fri	Sat	Sun
Hours out of the home (occupant 1)							

Occupant 2

Day	Mon	Tue	Wed	Thurs	Fri	Sat	Sun
Hours out of the home (occupant 2)							

Section 2: The home environment and residents' activities

Introduction

This section is split into four parts (Part A, B, C and D). We will ask you questions about heating and energy patterns, ventilation and dampness of your home and any activities that might influence the indoor air freshness.

A. Heating and energy use patterns

A1. What is the **main** way you **heat** this property during the winter?

Central Heating:

1. Gas	
2. Oil	
3. Solid Fuel	
4. Electric (storage)	

Fixed Room Heaters:

1. Electric (storage)	
2. Gas	
3. Electric (other than storage)	
4. Solid fuel (open fire/enclosed stove)	

Portable Heaters:

1. Electric	
2. Bottled gas/paraffin	
3. Oil filled	
4. Other portable heaters	

Other:

1. Communal or district heating	
2. Other (specify)	
3. Don't know	

A2. Do you use any supplementary heating devices (e.g. electric fan heater/oil filled radiators, electric blanket etc) in the house?

1. Yes	
2. No	

If yes **A2a**.What supplementary heating devices do you use

A3. Has your energy use behaviour changed over the last year or so because of the recent energy crisis and increase of changes in energy prices?

1.Yes	
2. No	
3. Don't know	

A4. Which of the following statements best describes your recent efforts to change the amount of fuel you use to **heat your home**?

1. I haven't tried to reduce my usage	
2. I have tried to reduce my usage, but have found it hard to achieve	
3. I have reduced my usage, but could reduce it further	
4. I have reduced my usage as much as I possibly can	
5. Don't know	

A5. Which of the following statements best describes your recent efforts to change the amount of **electricity** you use (other than for heating)?

1. I haven't tried to reduce my usage	
2. I have tried to reduce my usage, but have found it hard to achieve	
3. I have reduced my usage, but could reduce it further	
4. I have reduced my usage as much as I possibly can	
5. Don't know	

B. Temperature

B1. Would you generally describe the temperature in your home in summer as….

1. Uncomfortably cold	
2. Comfortably cool	
3. Comfortable	
4. Comfortably warm	
5. Uncomfortably hot	

B2. Would you generally describe the temperature in your home in winter (when using the heating) as….

1. Uncomfortably cold	
2. Comfortably cool	
3. Comfortable	
4. Comfortably warm	
5. Uncomfortably hot	

B3. Are there any rooms in the home that are significantly warmer or cooler than the other rooms in the home? (Please indicate the room and if it is warmer or cooler)

Room	Warmer	Cooler

B4. In **Summer**, how do you cool rooms in your home when too hot?

1. Open windows	
2. Use portable air conditioning unit	
3. Use fans	
4. Other (please specify)	
5. Have not needed to cool rooms	

B5. On average, how often, if at all, do you leave any of the windows in your home open in **Winter** just to let in cooler air because your home is too hot?

1. Every day	
2. Most days	
3. Occasionally	
4. Never	
5. Don't know	

B6. On average, how often, if at all, do you leave any of the windows in your home open in **Winter** to let in fresh air or for any other reason.

1. Every day	
2. Most days	
3. Occasionally	
4. Never	
5. Don't know	

B7. During the **Winter** months, do you generally find that your heating keeps you warm enough at home, or not?

1. Yes, always	
2. Most of the time	
3. Only some of the time	
4. No, never	
5. Don't know	

B8. Overall, how happy are you with the temperature in your home?

1. Very happy	
2. Happy	
3. Satisfied	
4. Unhappy	
5. Very unhappy	

C. Ventilation and air quality

C1. Generally, how would you describe the air in your home:

	[Very] 1	2	[Neutral] 3	4	[Very] 5	
a) Dry						Humid
b) Stale						Fresh
c) Odourless						Smelly
d) Still						Draughty

C2. Typically, do you do the majority of your laundry at home?

1. Yes	
2. No	

C3. Typically, how do you dry your clothes in **summer**? Select up to **2** options

1. On an airer in the house	
2. On a radiator / towel rail	
3. Outside	
4. Tumble drier vent to outside	
5. Tumble drier internal vent	
6. Tumble drier condenser	
7. Other – please specify	
Detail of other:	

C4. Typically, how do you dry your clothes in **winter**? Select up to **2** options

1. On an airer in the house	

2. On a radiator / towel rail	
3. Outside	
4. Tumble drier vent to outside	
5. Tumble drier internal vent	
6. Tumble drier condenser	
7. Other – please specify	
Detail of other:	

C5. Do you use a humidifier or a de-humidifier?

	a) Humidifier	b) De-humidifier
1. Often		
2. Sometimes		
3. Rarely		
4. Never		
5. Don't know		
If yes, detail on where used:		

C6. Have you noticed any **condensation** on the windows/walls/ceiling?

	a) Windows	b) Walls/ceiling
1. Often		
2. Sometimes		
3. Rarely		
4. Never		
5. Don't know		
If yes, detail on room/s affected:		

C7. Have you noticed any **damp patches** on the internal walls (on any wall inside your home)?

1. Often	
2. Sometimes	
3. Rarely	
4. Never	
5. Don’t know	

If yes, **C7** Which rooms are affected?

C8. Have you noticed any **mould** on the walls/ceilings?

1. Very abundant	
2. Common	
3. Occasional	
4. Rare	
5. No	
6. Don’t know	

If yes, **C8** Which rooms are affected?

C9. Does anyone usually smoke outside this property?

1. Yes	
2. No	
3. Don’t Know	

If yes, **C9** how many people commonly smoke outside this residence?

C10. Does anyone usually vape indoors?

1. Yes	
2. No	
3. Don't Know	

If yes, **C10** how many people commonly vape inside this residence?

C11. What is your primary/main source of fuel for cooking (please select one category only)

1. Gas	
2. Electricity	
3. Both gas and electric (e.g. electric oven/ gas hob)	
4. Solid fuel (e.g. kerosene, diesel, coal, wood)	
5. Other - Please provide more details	
Details of other	

C12. Do you have an extractor fan in the kitchen?

1. Yes / extractive	
2. Yes / recirculating	
3. Yes / don't know which type	
4. Yes - other	
5. No	

If yes, **C12** Where is it located (e.g. over the hob, in a window)?

If yes, **C12** how often do you use the extractor fan when cooking?

1. Often (includes always)	
2. Sometimes	
3. Rarely	
4. Never	

C13. Do you open a window or an external door [to the outside] when cooking?

1. Often (includes always)	
2. Sometimes	
3. Rarely	
4. Never	

C14. Do you close the internal kitchen door when cooking?

1. Often (includes always)	
2. Sometimes	
3. Rarely	
4. Never	
5. N/A (e.g. No internal door)	

C15. Do you have an extractor fan in your bathroom?

1. Yes	
2. No	

If yes, **C15** How often do you use the extractor fan in your bathroom?

1. Comes on automatically	
2. Often (includes always)	
3. Sometimes	

4. Rarely	
5. Never	

C16. Do you regularly (typically once a week or more) use air fresheners, or burn candles, incense, or similar products in your home? Please select all that apply.

1. No	
2. Candles	
3. Burning of incense or similar product	
4. Diffuser (plug-in diffuser, read diffuser or similar products)	
5. Sprays (e.g. air freshener spray, fabric freshener spray)	
6. Other (e.g. powder carpet fresheners) please provide more details	
Detail of other scented products used:	

End of Questionnaire

Survey 2

Introduction

Survey 2 will take up to 25 minutes to complete. It is made up of 3 sections which cover: your views about your health, how you feel and how well you can do your usual activities and finally some questions relating to you and your household's use of different health and social care services, and time off work due to ill health. The information will assist us in interpreting the results of the air, fuel, health and wellbeing data collected as part of the In2Air study. Please respond 'decline' to any questions that you prefer not to answer. The information you provide will be completely confidential to the researchers. Your answers will be combined with the answers of other study participants and reported in such a way that it will not identify you.

Sections 1 to 3 should be completed for each member of the household 18 years and over

- SF36-v2 will take up to 10 minutes to complete
- ICECAP-A will take up to 5 mins to complete
- Use of Services will take up to 10 minutes to complete

Section 1: Quality of life

Introduction

In this section we will ask you some questions about your views about our health, how you feel and how well you are able to do your usual activities. **There are no right or wrong answers**. Some questions will seem more relevant to you than others, or you may be unsure about how to answer, but please try to answer all the questions as best you can.

SF36-v2. Quality of life questionnaire

[Copyright Protection on SF36-v2. The Survey Materials are copyrighted works owned by QualityMetric Incorporated, LLC.]

Section 2: ICECAP-A measure v2 - ABOUT YOUR OVERALL QUALITY OF LIFE

[The ICECAP measures are free to use under User Agreement from www.bristol.ac.uk/icecap].

Section 3: Use of Health and Care Services

[Adapted from NIHR153617 In2Air pilot study survey: Entwistle JA, McNally R, Bramwell L, Ahmed T, Namdeo A, White C, NIHR153617. *In2Air: the impact of 'net-zero' household energy intervention on indoor air quality, occupant self-reported general health and wellbeing, and household energy use*. 22/69 PHR Rapid Funding Scheme. 2022]

Introduction

This survey will take up to 10 minutes to complete. In this section we will ask you some questions relating to you and your household's use of different health and social care services, and time off work (where relevant) due to ill health. This section is split into 3 parts (Part A, B and C). Some questions will seem more relevant to you than others, but please try to answer all the questions as best you can. As with the earlier section, there are no right or wrong answers. Some questions will seem more relevant to you than others, or you may be unsure about how to answer, but please try to answer all the questions as best you can.

Part A: Use of Health Care Services

This section is about **you or your household use of health care services in the last 3 months**. We know that it can be difficult to remember the services you have used precisely, but please be as accurate as you can.

A1. In the last **3 months**, have you or your household had any **consultations** with a health care professional **at a GP Practice, Hospital or other health-related Clinic**?

Yes	☐
No	☐

A2. If you ticked **YES** for question **A1**, please indicate in the boxes below what health professional provided a **face to face consultation at a GP Practice, Hospital or other health-related Clinic,** and how many consultations in total you or your household have had in the past **3 months**? The number of times could be approximate if you cannot remember exactly.

Health Care Professional	Yes	No	Number of Consultations
General Practitioner (GP)	☐	☐	☐☐
Pharmacist	☐	☐	☐☐
Nurse (at a GP practice)	☐	☐	☐☐
Nurse (at a hospital)	☐	☐	☐☐

Other (Please Specify)			
Other (Please Specify)			

A3. In the last **3 months**, have you or your household had any **face to face consultations** with a health care professional **in your home**?

Yes	
No	

A4. If you ticked **YES** for question **A3**, please indicate in the boxes below what health professional provided a **face to face consultation at your home** and how many consultations in total you or your household have had in the past **3 months**? The number of times could be approximate if you cannot remember exactly.

Health Care Professional	**Yes**	**No**	**Number of Consultations**
General Practitioner (GP)			
Nurse			
Pharmacist			
Other (Please Specify)			
Other (Please Specify)			
Other (Please Specify)			

A5. In the last **3 months**, have you or your household had any **consultations** with a health care professional **by phone/video call/other online interaction**?

Yes	
No	

A6. If you ticked **YES** for question **A5**, please indicate in the boxes below what health professional provided a **consultation by phone or video call /other online interaction** and how many consultations in total you or your household have had in the past **3 months**? The number of times could be approximate if you cannot remember exactly.

Health Care Professional	**Yes**	**No**	**Number of Consultations**
General Practitioner (GP)			
Nurse			

Pharmacist			
Other (Please Specify)			
Other (Please Specify)			
Other (Please Specify)			

A7. In the last **3 months**, have you or your household contacted NHS111 (or any other out of hours NHS telephone line) for any health problems you faced?

Yes	
No	

A8. If you ticked YES for question A7, please record the number of times you or your household **have** contacted NHS 111 (or any other out of hours NHS telephone line) in the last **3 months** below:

Number of Consultations	

A9. In the last **3 months**, have you or your household attended accident and emergency (A&E) because of illness?

Yes	
No	

A10. If you ticked YES for question A9, please record the number of times you or your household **have** attended accident and emergency (A&E) in the last **3 months** below:

Number of Attendances	

A11. In the last **3 months**, have you or your household had to call an ambulance because of illness?

Yes	
No	

A12. If you ticked YES for question A11, please record the number of times you or your household **have** called an ambulance in the last **3 months** below:

Number of Calls		

A13. In the last **3 months**, have you or your household had any out-of-pocket costs related to health seeking activities, such as the purchase of products from a pharmacist for self-medicating.

Yes	
No	

A14. If you ticked YES for question A13, please estimate the amount of expenditure you have paid out in the last 3 months.

Amount (£)	

A15. Do you or your household currently experience any respiratory related health issues (e.g. such as asthma, COPD?). If yes, please say what.

Part B: Your Use of Social Care Services

This section is about **your or your households use of social care services in the last 3 months**. We know that it can be difficult to remember the services you have used precisely, but please be as accurate as you can.

B1. In the last **3 months**, have you or your household **accessed social care services at your home**?

Yes	
No	

B2. If you ticked **YES** for question **B1**, in the boxes below can you please indicate how many times in the past **3 months** you or your household have accessed the following social service **at your home**? The number of times could be approximate if you cannot remember exactly.

Type of Social Service	Yes	No	Number of Times
Paid Carer (Provided by Council)			
Paid Carer (Provided by NHS)			
Meals on Wheels (or Similar)			
Support from a Charity worker			
Other (Please Specify)			

B3. In the last **3 months**, have you or your household **accessed social care services by phone or video call**?

Yes	
No	

B4. If you ticked **YES** for question **B3**, in the boxes below can you please indicate how many times in the past **3 months** you or your household have accessed the following social service **by phone of video call**? The number of times could be approximate if you cannot remember exactly.

Type of Social Service	Yes	No	Number of Times
Paid Carer (Provided by Council)			
Paid Carer (Provided by NHS)			
Support from a Charity worker			
Other (Please Specify)			

Part C: Your Employment

C1. If you or your household are in paid employment, have you had to take time off work in the last **3 months** due to illness?

Yes	
No	
N/A	

C2. If you ticked YES to question C1, please write below approximately how much time you or your household have taken off in total during the last 3 months due to illness or caring for someone who is unwell.

Number of Days	
N/A	

Thank you for your time in completing this survey.

End of Questionnaire

Post monitoring

Survey 3

(to be completed by each member of the household where possible, but as a minimum by the lead participant in the project)

Introduction

This questionnaire will take up to 30 minutes to complete. The information will assist us in interpreting the results of the air, fuel, health and wellbeing data collected as part of the In2Air study and also inform any changes/improvements that we might need to make to the procedures.

Section 1: Negative/positive factors associated with taking part in the baseline study & compliance with protocol

1.What did you **like** about taking part in this study?

the researcher will explore this question in relation to

- taking part in research (free text)
- the AQ monitors, (free text)
- energy monitoring, (free text)
- meeting and working with researchers, (free text)
- other (free text)

2.What did you **not like** about taking part in this study?

the researcher will explore this question in relation to

- completing survey questions (free text)
- the AQ monitors, (free text)
- energy monitoring (free text)
- meeting and working with researchers, (free text)
- other (free text)

3.Did anyone smoke or vape in the house during the time you had the AQ monitor?
[reassure the resident this won't impact on the voucher they receive for taking part]

1. Yes (details free text)
2. No
3. Don't know

Section 2: Change in behaviour(s)

4.Do you think having the AQ monitor(s) changed your behaviour at home?

1. Yes (How -free text) *the researcher will explore this question in relation to how*

2. No
3. Don’t know

5. Did your usual pattern of opening/closing of windows change?

1. Yes (How -free text)
2. No
3. Don’t know

6. Did your use of any home extractor fans change?

1. Yes (How -free text)
2. No
3. Don’t know

7. Do you think taking part in the energy audit changed your behaviour at home?

1. Yes (How -free text) *the researcher will explore this question in relation to*
2. No
3. Don’t know

8.Did your usual pattern of energy use (for example use of heating, use of electrical equipment) change?

1. Yes (How -free text) *the researcher will explore this question in relation to*
2. No
3. Don’t know

[post-baseline monitoring questions only]
9.What would encourage you to take part in the repeat study in about 12 months time? (free text)

Thank you for your time in completing this survey.

End of Questionnaire

Post retrofit monitoring

Survey 4

(to be completed by each member of the household where possible, but as a minimum by the lead participant in the project)

[Survey adapted from co-benefits questionnaire survey developed by Jennings J, Paterson, P. *How do UK citizens perceive the co-benefits of climate action*? 2023. Grantham Institute and PCAN Report. 10.25561/106595]

Introduction

This questionnaire will take up to 15 minutes to complete. It focusses on the extra benefits of action against global warming & climate change to you, your local area, and for the UK that happen when we take action to limit climate change.

Remember there are no right or wrong answers

The extra benefits from energy efficient homes:

Cleaner air and better health by reducing the amount of air pollution from vehicles and buildings.

Warmer homes that cost less to heat Home energy costs are reduced by improving the energy efficiency of homes which makes them easier and cheaper to heat.

Keeping cool in summer Reducing climate change can reduce the risk of more extreme heat events in summer.

Secure energy - Using solar panels and wind farms instead of relying on oil and gas from other countries can make the UK energy supply more dependable, as well as keeping the air cleaner by cutting down on pollution.

Creating Jobs - When we use new energy efficient technologies and start green climate friendly businesses, we make new jobs for people.

Reduced inequality - When we take action to limit climate change, it can make things better for everyone, especially those with less money. For example, making homes more energy-efficient can really help people with lower incomes because they often live in homes that are hard to keep warm.

Q1 Please rate how important these benefits are to you on a scale of 1 to 5.

5-point scale, 1 (Not important), 2 (Slightly Important), 3 (Quite important), 4 (Important), 5 (Very Important)

	To You	To Your local community	To the UK
Cleaner air and better health			
Warmer homes that cost less to heat			

Keeping cool in summer			
Secure energy			
Creating Jobs			
Reduced inequality- making things fair for everyone			

Q2 Climate change perception questions

2a Which of the following statements best describes why you think climate change is happening?

- Its a natural process (1)
- Its mainly a natural process (2)
- About equally by natural processes and human activity (3)
- Mainly human activity (4)
- Entirely human activity (5)
- I don't think climate change is happening (6)
- I don’t know (7)

2b How good or bad do you think the impact of climate change will be on people around the world?

Give your answer as a number on a scale of 1to 10, where 1 is very good impacts where 10 is very bad impacts.

1 2 3 4 5 6 7 8 9 10

2c How worried are you about climate change?

Give your answer as a number on a scale of on a scale of 1 to 5, where 1 is not worried at all and 5 is very worried

Worried for yourself

1 (not worried),

2 (slightly worried),

3 (moderately worried),

4 (worried quite a lot), or

5 (very worried)

Worried for your children, grandchildren other young people

1 (not worried),

2 (slightly worried),

3 (moderately worried),

4 (worried quite a lot), or

5 (very worried)

2b How responsible do you feel for trying to reduce climate change?

Give your answer as a number on a scale of on a scale of 1 to 10, where 1 is not at all responsible and 10 is extremely responsible.

1 2 3 4 5 6 7 8 9 10

For further comments

Thank you for taking part in our climate change survey

In2Air Supplementary Information 4.
Economic Analysis Plan

To be available project month 6

In2Air Supplementary Information 5.
Statistical Analysis Plan

To be available project month 6

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