Housing retrofit protocol – PHIRST LiLaC

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Evaluation of a housing retrofit programme delivered across Liverpool City Region.

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Signature page

The undersigned confirm that the following protocol has been agreed and accepted by the PHIRST LiLaC Chief Investigators.

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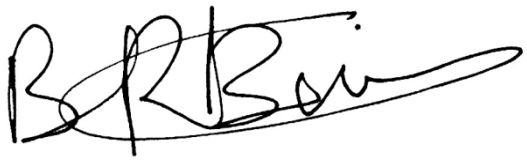

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Plain English summary

Background: Housing retrofit programmes include a range of measures aimed at improving the energy efficiency, safety, and comfort of existing buildings. These measures can result in improvements to peoples' financial situation because their heating costs are reduced, along with health and wellbeing benefits because their home is warmer, less damp and more comfortable to live in which can also help people to feel less stressed. Housing retrofit programmes are typically targeted at those who are less able to afford to make improvements to their home and as such they may play an important role in reducing health inequalities. However, we do not know whether current programmes get support to the people who need it most, what kinds of support have the biggest benefits, and how these differ for different groups. We are therefore evaluating Liverpool City Region's programme to retrofit more than 6,000 homes between 2021 and the present day (approximately early 2025 when the research commences) to address these knowledge gaps.

Aims: The study aims to understand: 1) whether access to housing retrofit programmes in Liverpool is fair for everyone and, if not, what impact this could have on differences in people's health, 2) how people experience the programme including the ways in which it has or has not influenced their financial situation, health and wellbeing, 3) what helps the programme to work well and what hinders it, and 4) what impact the programme could have on potentially reducing use of NHS services if housing retrofit programmes help improve people's health and wellbeing.

Methods: In this study we are working with Liverpool City Region Combined Authority. We will use data they collect on people who make use of their housing retrofit programme to understand whether access is fair for everyone and what impact this could have on differences in people's health along with the wider implications of any changes in health for NHS services. We will also undertake focus groups with people living in Liverpool who have received housing retrofit support, along with staff and stakeholders across the city who help people to access this support, to understand the ways in which it has or has not influenced peoples' financial situation, health and wellbeing. The focus groups will also help us to understand what is currently working well in the programme and what hinders it.

Public involvement: Plans for public involvement during the study will be monitored by the PHIRST LiLaC Public Advisor Panel and the designated public contributor will be involved in overseeing and contributing to public involvement activity throughout the study. We plan to work closely with organisations in Liverpool who support people to access the housing retrofit programme and they will be invited to provide feedback on the findings from the study.

Sharing the findings: Results from the study will be shared with Liverpool City Region Combined Authority and other organisations across Liverpool who support people to access the housing retrofit programme. They will also be shared with other local authorities and stakeholders across the country who are interested in, delivering, or funding similar programmes along with policy makers. The findings will also be published in academic journals. Further, we will be guided by local organisations regarding any additional outputs that it may be beneficial to produce.

1) Background and introduction

1.1 Housing retrofit programmes

The UK has some of the least energy efficient housing in Europe (Faculty of Public Health, 2022). This is coupled with higher than European (EU28) average household energy prices, that also saw some of the biggest rises in Europe in 2021 after Russia invaded Ukraine (HEPI, 2024), and more than one in five people (22%) living in poverty (2021/22), including 8.1 million working age adults, 4.2 million children, and 2.1 million pensioners (Joseph Rowntree Foundation, 2024). In 2023, 13% of households in England were officially in fuel poverty – determined by a balance of income, fuel cost, and energy consumption, which is affected by the energy efficiency of dwellings (Hinson, 2024). One in five households in England containing children were in fuel poverty in 2020 (Lee, 2022).

The housing retrofit programme in Liverpool City Region supports the social and health objectives of the LCRCA and Cheshire and Merseyside Integrated Care System. The LCRCA's Corporate Plan (2021) sets out commitments to support 'positive health and wellbeing' and 'people experiencing poverty, exclusion and inequality'.

The majority of the Liverpool City Region's local authorities have a higher rate of fuel poverty than the national average. In improving domestic energy performance, the housing retrofit programme is potentially mitigating increasing fuel costs and alleviating fuel poverty. The LCRCA believe that these financial benefits, coupled with improved thermal comfort, create better mental and physical health outcomes for residents potentially leading to a reduction in health inequalities. Additionally, eligibility criteria prioritise low income households to attempt to target funding at those who are more likely to be negatively impacted by health inequalities.

Further, reducing domestic carbon emissions is key to the UK Government's Net Zero Strategy. Housing accounts for around 30% of the Liverpool City Region's carbon emissions, so retrofitting is a priority for the region to achieve net zero carbon by 2040 or sooner, as outlined by the LCRCA in the Five Year Climate Action Plan (2023). All local authorities are scaling up delivery of retrofit programmes to meet their carbon reduction targets. Therefore, understanding the impacts of the LCRCA's extensive retrofit programme will likely be of interest to other local authorities taking a similar approach.

Housing retrofit programmes are one means to address some of the above issues. They typically include a range of measures aimed at improving the energy efficiency, safety, and comfort of existing buildings. These measures often focus on reducing energy consumption, lowering greenhouse gas emissions, and enhancing the overall liveability of homes. Housing retrofit programmes are typically targeted at those who are less able to afford to make improvements to their home and as such they play an important role in reducing health inequalities.

The types of measures that are implemented as part of a housing retrofit are diverse and may include some of the following components:

- ***Energy efficiency upgrades:*** e.g. adding or upgrading insulation, replacing inefficient windows and doors, sealing gaps and cracks to prevent air leakage.
- ***Heating and ventilation:*** e.g. upgrading heating systems including replacing boilers and improving ventilation systems to enhance indoor air quality, address issues with mould, and ensure adequate airflow.
- ***Renewable energy integration:*** e.g. installing solar photo-voltaic panels.
- ***Lighting and electrical systems:*** e.g. replacing incandescent or fluorescent lighting with energy-efficient LED lights, improving the overall efficiency of the home's electrical system.
- ***Smart home technologies:*** e.g. installing smart meters, which provide real-time energy usage data.
- ***Structural repairs and upgrades:*** e.g. roof repairs to improve the thermal performance and durability of the roof.

1.2 Health and wellbeing benefits

Since housing retrofit programmes are diverse in nature, they may result in a wide range of health and wellbeing benefits. These may include:

- ***Improved indoor air quality:*** by addressing issues such as mould, mildew, and dampness through better insulation and ventilation, retrofits can reduce the presence of allergens and pollutants. This can lead to fewer respiratory issues such as asthma and allergies.
- ***Enhanced thermal comfort:*** improved insulation and heating systems help maintain a stable indoor temperature, preventing extremes of hot and cold that can affect health and comfort. Better heating can reduce the risk of cold-related health issues such as hypothermia, particularly among vulnerable populations.
- ***Noise reduction:*** enhanced insulation can reduce external noise, leading to a quieter living environment. This can decrease stress levels and improve sleep quality.
- ***Safety improvements:*** ensuring the building's structural soundness can prevent accidents and injuries related to building decay or collapse.
- ***Mental health and wellbeing:*** a comfortable, safe, and energy-efficient home environment can reduce stress and anxiety.
- ***Financial benefits:*** reduced energy costs can reduce financial stress and additionally free up resources for other essential needs, thus improving overall quality of life.
- ***Community and social wellbeing:*** when retrofit programmes are implemented on a large scale, they can lead to broader community health improvements, such as reduced strain on healthcare systems and increased community resilience. Providing access to retrofit programmes for low-income and vulnerable populations can help to reduce health disparities and promote social equity.
- ***Environmental health:*** lower energy consumption means fewer greenhouse gas emissions and reduced air pollution, contributing to better overall environmental health.

Access to housing retrofit provision often comes through government programmes like the Energy Company Obligation (ECO), the Green Homes Grant (when it was available), and local council initiatives. Homeowners, tenants, and landlords can access these schemes by applying through their local authority or energy provider. Eligibility often depends on factors such as income, property type, and energy performance ratings.

2) Overview of the housing retrofit programme to be evaluated

2.1 Intervention location

The intervention location is the Liverpool City Region. The area includes the City of Liverpool local authority area, the Metropolitan Boroughs of Knowsley, St Helens, Sefton, and Wirral, and the Borough of Halton. Liverpool City Region Combined Authority (LCRCA) is a strategic authority with powers and responsibilities over the region's transport, economic development and regeneration, culture and tourism, energy, justice, and health.

2.2 Intervention delivery to date and future plans

The publicly funded housing retrofit schemes that will be evaluated in this study include the Social Housing Decarbonisation Fund (SHDF Waves 1 and 2.1), Green Homes Grant Local Authority Delivery (LAD2 and LAD3), and Home Upgrade Grant (HUG1 and HUG2).

To date the LCRCA has completed delivery of LAD2, LAD3 and HUG1, resulting in the retrofit of 4,195 private homes since 2021. Additionally,1,225 social homes have been retrofitted through an LCRCA-led SHDF Wave 1 consortium of Registered Providers (RPs). A further 5,000 homes will be completed under SHDF Wave 2.1 and HUG2 by 2025.

In terms of funding the delivery and administration of capital works of the schemes, central government (Business, Energy & Industrial Strategy (BEIS) and Department for Energy Security

& Net Zero (DESNZ)) provided all capital funding for the LAD2 (£13.96m), LAD3 (£24.98m), HUG1 (£1.97m), and HUG2 (£10.08m). Additionally, central government provided £8.93m capital funding for the SHDF Wave 1 programme, which was match-funded by the RPs, who provided £10.88m. Further, central government provided £23.85m capital funding for the SHDF Wave 2.1 programme and this was match-funded by the RPs, who provided a total of £43.27m.

In terms of raising awareness of the housing retrofit schemes with private homeowners, for LAD2, LAD3, HUG1 and HUG2 this involved leafleting residents, attendance at community events, engagement with local authority statutory services and community groups, and social media marketing. In terms of raising awareness with those living in social housing, RPs have communicated with their tenants early in the process to inform them of proposed installations.

Whilst eligibility criteria differ between the schemes (see Table 1), all schemes prioritise low income households. A key reason for setting criteria related to household income is that residents are not required to make any contribution towards the cost of works themselves: for private homeowners these are fully covered by Government; for those living in social housing they are part-funded by Government and match-funded by RPs as described above; and for those privately renting the landlord is required to cover at least one-third of the total costs and Government cover the remaining costs.

Table 1: Summary of eligibility criteria for different housing retrofit schemes.

Scheme	Eligibility criteria
Home Upgrade Grant	• Are low income. • Are off the gas grid. • Have an Energy Performance Certificate (EPC) between D and G.
Social Housing Decarbonisation Fund	Below Energy Performance Certificate (EPC) band C. All social housing provided by Registered Providers (RPs) including Private and Local Authority providers are eligible for SHDF Wave 1 funding, regardless of archetype (including high rise blocks). Homes both on and off the gas grid are eligible for funding. As per the Housing Regeneration Act 2008, sections 68-70, 'social housing' means: • Low cost rental accommodations (defined by section 69). • Low cost home ownership accommodation (defined by section 70).
Local Authority Delivery Scheme	The scheme aims to improve domestic properties rated in EPC band D or below with the install of insulation and/or low-carbon heating such as solar photo-voltaic panels or heat pumps.

The national funding streams detailed in Table 1 set minimum standards for delivery, however the LCRCA have some flexibility around local implementation. For example, the objective of each scheme is to improve homes to an Energy Performance Certificate (EPC) of B or C. After a property has been identified as eligible to receive the intervention then an assessment is undertaken to determine which retrofit measures are suitable for that specific property in order to raise its EPC to the required grade. The LCRCA have some flexibility built into both the eligibility criteria and assessment process so that they can influence which measures are installed in which homes and therefore maximise benefits as far as possible.

2.3 Need for evaluation

The LCRCA provides a strong case study for evaluation of a housing retrofit programme as it has delivered the second largest publicly funded Social Housing Decarbonisation Fund Wave 1 scheme nationally and is amongst the leading authorities in Local Authority Delivery. This allows for a comparison of the health impacts of retrofitting homes of different tenures.

We propose to undertake an evaluation of the LCRCA housing retrofit programme focusing on examining: i) equity of access to and uptake of the programme, ii) the impact it has on residents' financial situation, health and wellbeing, and iii) the potential impact on healthcare utilisation and health inequalities. There is a need for evaluation as housing retrofit programmes have been operational for some time and are part of a growing package of local government energy and welfare provision that as yet has received limited evaluation. Some evaluation has been undertaken locally within Liverpool, as the LCRCA have worked with an independent organisation to better understand grant spending and they also undertook a preliminary assessment of the impact of housing retrofit on carbon emissions. However, neither the LCRCA or the PHIRST LiLaC team are aware of evaluation that has examined the health impacts, both positive and negative, of a housing retrofit on residents who have received the intervention or investigated the impact on wider health inequalities.

3) Review of evidence

We have undertaken a rapid structured review of evidence on health and wellbeing impacts of retrofit energy efficient housing interventions, based on systematic review methods (CRD, 2009; Popay, 2006). The review was not intended to be exhaustive, but broadly representative of the range of major literature to quickly identify key determinants, health outcomes and related measures of interest, and potential areas for further research. Identification of evidence involved iterative advanced Google searches, hand searches of specialist, organisation, expert, and journal websites, academic database searches (OVID MEDLINE, Web of Science Social Science Citation Index), and forward and backward citation searches, conducted by a member of this team who is an expert in systematic reviews of complex social determinants of health and related interventions. Emphasis on supplementary search methods helped to accelerate the speed while enhancing the scope of the review through approaches refined in reviews of theory and evidence on social determinants of health inequalities in Pennington, 2023, 2018; Whitehead, 2014, 2016, for example.

The sections below provide a summary of the findings from the rapid structured review.

3.1 Health-related impacts of fuel poverty, cold and damp homes

Cold homes exacerbate health inequalities, worsening respiratory and cardiovascular conditions, poor mental health, dementia, hypothermia, and problems with child development. Some health problems can be exacerbated to an extent that leads to death. There were an estimated 63,000 excess winter deaths in England in 2020-21, which is higher than the northern European average, with an estimated 21.5% attributed to cold homes and approximately 10% directly to fuel poverty. Asthma is the most common chronic disease in children and young people, and one of the most common reasons for emergency hospital admission, with an admission rate for children in the most deprived areas two and a half times greater than the least deprived (in 2015/16 323 per 100,000 vs 127, respectively) (Kossarova, 2017). According to the World Health Organisation, indoor mould exposure is responsible for 12%, and indoor dampness causes 15% of new childhood asthma in Europe (WHO, 2013). In 2019 it was estimated that over £2.5 billion pounds are spent each year by the NHS treating illnesses linked to cold, damp and dangerous homes (Lee, 2022).

3.2 Inequalities in distribution of impacts

Households that are more likely to be in fuel poverty are those on low incomes, or including people from ethnic minorities, people with disabilities, and families with children. Children, older people,

and people living with disability and chronic illness are more likely to experience adverse health outcomes caused by fuel poverty (Lee, 2022; Marmot, 2020).

3.3 Retrofit energy efficiency interventions

Retrofit interventions that improve the energy efficiency of existing homes are one way of reducing fuel poverty and improving health outcomes particularly for vulnerable groups, in addition to interventions to raise incomes, reduce energy prices, or change the way people use energy. They also have potentially wider health and societal benefits through reductions to pollution and carbon emissions. A simple model showing mechanisms through which improvements to energy efficiency are believed to improve health is shown in Figure 1.

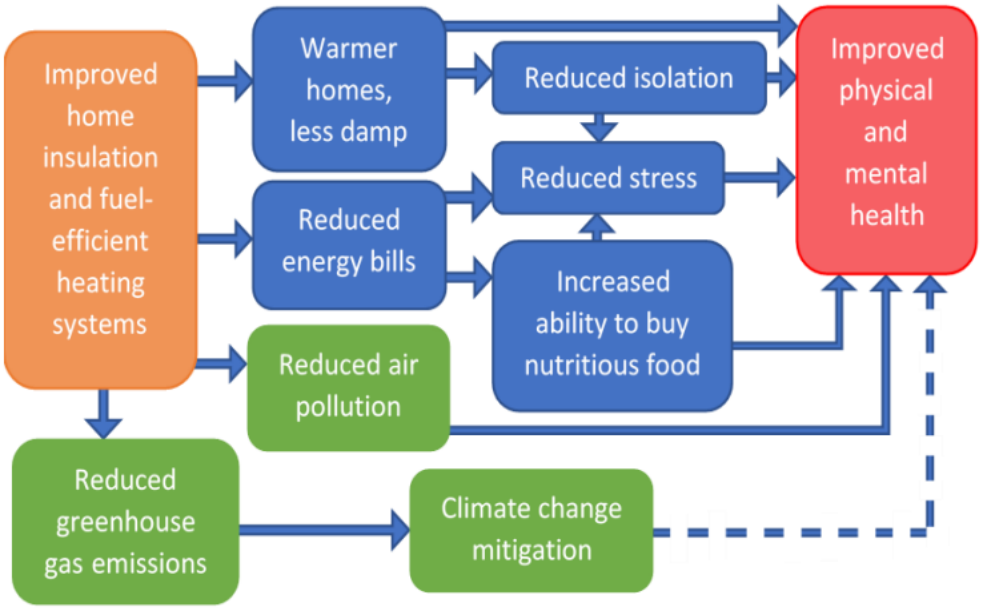

Figure 1: Mechanisms through which interventions to improve home energy efficiency can improve health (FPH, 2022).

3.4 Retrofit intervention types

Included studies in the rapid structured review evaluated interventions that included comprehensive measures, for example, air sealing insulation, external cladding insulation, cavity wall insulation, loft insulation, under floor insulation, door and glazing replacement, and heating system repair and replacements, window furnishings (e.g. blinds, curtains), energy efficient lighting, and/or individual or combinations of measures.

3.5 Building standards (types)

Type/nature of housing stock has been shown to have significant impacts on the effectiveness of retrofit interventions as they may influence/restrict selection of technologies used in the intervention, and/or may systematically limit effectiveness of individual technologies/approaches (Avanzini et al., 2022).

3.6 Systematic review level evidence on impacts

Across eight rapid, realist, and systematic reviews of empirical studies on health-related impacts of retrofitting interventions there is quantitative and qualitative evidence that retrofit energy efficiency interventions improve determinants of health and health outcomes, and reduced health service utilisation and associated costs (Camprubí et al., 2016; Diaz L and Siegel, 2018; Fenwick et al., 2013; Fisk et al., 2020; Green, 2024; Thomson et al., 2013; Wang et al., 2022; Willand et al., 2020). Retrofitting interventions including improvements to insulation, doors/glazing, or energy efficient heating were found to be associated with improvements that **increased**:

- Ease of heating
- Temperature control and thermal comfort
- Housing conditions and pride in home
- Useable indoor space
- Motivation to maintain, clean and tidy the home
- Relationships and social interactions in the home (family, wider networks)
- Relations with housing provider
- Disposable income
- Diet/nutrition
- General physical health
- Respiratory health
- Mental health
- Quality of life

And **reduced**:

- Damp
- Fuel costs and bills
- Financial difficulties
- Social isolation
- Air pollution
- Health service utilisation

Scale of effects

The evidence suggests however that the improvements tended to be small in scale (e.g. Thomson and Thomas, 2015).

Methodological quality

Studies included in reviews used a range of designs, including some higher quality study designs (e.g. RCTs), but critical appraisals of individual study methodological and reporting quality rated most as low to moderate quality, with potential biases from high dropout rates, poor use or reporting of allocation and blinding (participants, assessors), and inconsistency in outcomes measures across before and after time points (e.g. (Green, 2024).

3.7 Potential unintended adverse impacts

There is some evidence of potential unintended adverse impacts. A realist review of the health inequality impacts of Façade insulation retrofitting, and two Health Impact Assessments, identified potential adverse impacts from i) disruption and sense of lack of control during installation phases (Camprubí et al., 2016); ii) poorly timed installation of windows and doors to homes of vulnerable elderly residents during a cold winter (Birley, 2009; Pennington, 2010). Two reviews identified evidence that retrofitting energy-saving measures in airtight buildings and thermal insulation without mechanical ventilation may lead to increases in indoor radon and formaldehyde concentrations (Fisk et al., 2020; Wang et al., 2022). All of these authors concluded that the benefits of energy efficiency improvements outweighed adverse impacts on balance, and unintended impacts could be avoided through sensitive design and delivery of the interventions.

3.8 Measurement of health service outcomes in individual studies/evaluations

Thirteen individual studies examined the impacts of structural retrofit energy efficiency interventions on health service outcomes (Avanzini et al., 2022; Barnard S, 2021; Chapman et al.,

2009; Edwards et al., n.d.; Fyfe et al., 2021, 2020; Osman et al., 2010; Page, 2022; Rodgers et al., 2018; Tonn et al., 2023; Walker, 1999).

Health service outcomes
Hospital admissions, inpatient and outpatient appointments, GP appointments, prescriptions for:

- Respiratory conditions (combined), asthma, COPD (some studies just >65 years of age), upper respiratory tract infection, lower respiratory tract infection.
- Cardiovascular diseases (combined), ischemic heart disease (some studies focused on >65 years of age).
- Appointments and prescription for arthritic conditions.
- A&E attendance.
- All-cause mortality (for people who had pre-intervention CVD or respiratory hospitalisation), mortality from respiratory, or CVD.
- Self-reported, or prescriptions for mental health conditions (typically anxiety and depression), sleep difficulties, headaches.

Estimations of **financial impacts on health services** included cost/benefit analyses, and return of investment estimations.

Disaggregation and stratification of data by population groups included by health conditions, age, sex, ethnicity, area, climate zones, building standard (types, e.g. by age of properties), and intervention types.

3.9 Review conclusions – potential for the evaluation to add to scientific evidence

There is a large body of evidence that retrofit home energy efficiency interventions can have a range of beneficial impacts on health determinants, health outcomes, and health service use, although impacts on health outcomes tend to be small in scale. Health economic assessments suggest the interventions are cost effective when comparing intervention costs to longer-term public sector costs from reductions in spending on healthcare and related services. There is also some evidence of some potential adverse impacts that may be addressed through careful and sensitive (to population need) design and implementation of retrofit interventions. Planning of future interventions should consider the potential for avoiding adverse impacts, and the full range of potential interventions, for example, adding relatively cheap lighting improvements such as energy efficient bulbs, and window furnishings, to maximise health gains and return on investment. Behavioural interventions, addressing people's use of energy should also be considered, though further evidence is needed.

We found limited evidence indicating whether housing retrofit leads to differential beneficial and/or adverse impacts between population groups defined by age, sex, health conditions, ethnicity, geographical area, climate, and housing tenure. Nor whether effects differ by building standards/construction types (with more accurate estimation of building types providing more precise understanding of effects), intervention types (combined, grouped, individual). A wide range of physical and mental health outcomes can and should be considered using routinely collected data on hospital admissions, A&E admissions, inpatient and outpatient appointments, GP appointments, and prescriptions, particularly focusing on respiratory conditions, cardiovascular conditions, arthritic conditions, and common mental health issues such as anxiety and depression. Cost/benefit and return on investment estimations can help make the case for improvements to population health through these interventions on wider determinants of health. This evaluation is designed to address these gaps.

3.10 How the evaluation findings will be used

The findings from the evaluation will be used by the Liverpool City Region Combined Authority to inform the delivery of the housing retrofit programme going forward. In particular, they are interested in better understanding the impact of the programme on residents' financial situation, along with health and wellbeing outcomes. They are also keen to understand the impact of the

housing retrofit programme on health inequalities. Nationally, there would be interest in the findings as learnings will be of relevance to the delivery of similar retrofit programmes by local authorities elsewhere, along with being of interest to organisations with a role or interest in reducing health inequalities or carbon emissions.

4) Co-design of the evaluation

The initial stage of evaluation planning involved undertaking an evaluability assessment to assess both the feasibility of an evaluation and explore stakeholder interests in an evaluation. Below we outline how our approach to knowledge exchange has been, and will continue to be, guided by key principles of good practice (NIHR SPHR, 2018).

Principle 1: Clarify your purpose and knowledge sharing goals
The purpose of the evaluation is to examine equity of access to and uptake of the housing retrofit programme, the impact it has on residents' financial situation, health and wellbeing, and the programme's potential impact on healthcare utilisation and health inequalities. Locally, there is interest in understanding how the programme can maximise any benefits inferred upon residents. Nationally, there is interest in how learnings from the evaluation can inform the delivery of housing retrofit programmes elsewhere.

Principle 2: Identify knowledge users
Our key knowledge users are the LCRCA who are delivering the programme locally. Additional knowledge users include registered providers of social housing, along with representatives from Liverpool-based organisations who support people to access the housing retrofit programme (e.g. Citizens Advice) and local housing charities (e.g. Torus Foundation). National knowledge users include other local authorities and stakeholders interested in or already delivering or commissioning similar programmes along with policy makers. They also include stakeholders interested in housing provision such as architects, building engineers and developers.

Principle 3: Design the research to incorporate the expertise of knowledge users
The design of the evaluation has been informed by discussions with members of the Housing Retrofit team at the LCRCA. This process of engagement has been important for informing practical decisions about the feasibility and focus of the evaluation, including discussions regarding obtaining access to data that are routinely collected by the LCRCA.

Principle 4: Agree expectations
During the initial evaluability assessment stage, we discussed and agreed the focus of the evaluation with our local authority partners.

Principle 5: Monitor, reflect and be responsive in sharing knowledge
Through co-production, we will regularly reflect on emerging findings with local partners and share these more widely where appropriate. This will also inform our plans for dissemination outlined below. Our PHIRST LiLaC oversight group includes representation from national community funders, the Local Government Association, and Directors of Public Health who are PHIRST LiLaC co-investigators and who will advise on opportunities to share findings.

Principle 6: Leave a legacy
Outputs will be aimed at our own local authority partners in Liverpool and those in other parts of the country. This is an important group, as these organisations are responsible for housing retrofit delivery and hence are the gatekeepers of current and future programmes. The findings will also be published in a peer-reviewed academic journal. Further, we will be guided by the knowledge users outlined above regarding any additional outputs that it may be beneficial to produce.

5) Public involvement

When the public gets involved in research, they work alongside researchers and practitioners to help shape what research is undertaken, how it's carried out and how the results are shared and applied in practice. This is important for ensuring lived experiences of an issue inform the research alongside researcher and practitioner expertise. NIHR expect all of their funded research to demonstrate public involvement. The benefits of public involvement include higher quality research with studies more likely to ask appropriate questions in a clear way, with the research also grounded in the experiences of those with lived experiences. Public involvement also contributes to better decisions, because the issues addressed in the research are more comprehensive. A rights-based approach to public involvement is also concerned with the democratic right of citizens to be involved in decisions made 'by agencies, organisations, and institutions which impact upon them' (Russell et al., 2020).

To facilitate the involvement of public contributors in PHIRST LiLaC a Public Advisor panel meets regularly. The panel is co-chaired by a public contributor who is also a PHIRST LiLaC co-applicant and also by a PPIE academic co-lead. The panel is responsible for reviewing involvement processes and providing advice on engagement and involvement plans across the PHIRST LiLaC team and its research. In addition, individual public contributors are assigned to individual evaluations to provide a lay perspective during the evaluation planning stage and throughout delivery. Public contributors are also members of the PHIRST LiLaC Management Group alongside other stakeholders with an academic, policy or practitioner interest in public health.

During the planning stage of this evaluation, Timothy Wilson (public contributor) attended and participated in planning meetings and discussions. During delivery of the evaluation, he will continue to be involved as part of the evaluation team. We also plan to work with our local authority partners and our public involvemennt panel to connect with relevant organisations (such as providers of social housing) who will be able to support us with getting input from at least one local public contributor outside of the PHIRST LiLaC team. We should also be able o use the ARC North West Coast public involvement network to support involvement. Activities the public contributors may wish to be involved with include advising on participant information sheets and recruitment processes, helping to devise and pilot the topic guide for focus groups, and involvement in analysis of data. At the reporting stage they will also have the opportunity to advise on the content and tone of outputs.

6) Health equity assessment

To ensure the research addresses health inequalities, the FOR Equity tool was completed with input from a PHIRST LiLaC public advisor. The aim of the FOR Equity tool is to assist with identifying the equity dimensions of a research topic and how input from public contributors may best support this. A copy of the completed FOR Equity tool is provided in Appendix I, which has been used to inform the design of this protocol.

7) Evaluation objectives

The objectives guiding the evaluation are outlined below:

1) To examine equity of access to and uptake of the programme across different demographic groups, and how this may impact health inequalities.
2) To identify key enablers and barriers to effective implementation of the programme.
3) To explore how residents experience the programme, and the ways in which it has or has not influenced their financial situation, health and wellbeing.
4) To explore the programme's impact on healthcare utilisation.

8) Study design and methods

8.1 Overall study framework

In this evaluation we treat housing retrofit provision in Liverpool as a 'natural experiment' as defined in MRC guidance as "policies which are not under the control of researchers, but which are amenable to research which uses the variation in exposure that they generate to analyse their impact" (Craig et al., 2012). Natural experimental studies can be used as a way of understanding the impact of population-level policies on health outcomes or health inequalities. Although they have certain advantages over planned experiments, for example by enabling effects to be studied in whole populations and may sometimes be the only option when it is not possible to manipulate exposure to the intervention, natural experimental studies are more susceptible to bias and confounding. We will therefore be mindful of this when interpreting and reporting our results, and causal inferences will be drawn with care.

The evaluation consists of three work packages: 1) Equity of access to and uptake of housing retrofit provision and implications for health inequalities, 2) Factors affecting implementation of the programme and impact on residents' financial situation, health and wellbeing, and 3) Impact on healthcare utilisation. Our research will be guided by the logic model shown in Figure 1.

8.2 Work package 1: Equity of access to and uptake of housing retrofit provision and implications for health inequalities (Objective 1)

As part of their delivery of the housing retrofit programme, the LCRCA routinely collect information on people who have applied for retrofit support, including both those who were successful and those who were not. These data are stored in a database managed by the LCRCA and we will take an anonymised extract of the data.

The dataset includes the following variables:

- ***UPRN:*** Unique Property Reference Number.
- ***Property address:*** full address of the property, which will be mapped to Lower Super Output Areas (LSOA) of residence before extraction.
- ***Occupancy:*** the number of people who live at the property.
- ***Retrofit eligibility criteria:*** e.g. whether the property occupiers are considered to have a low income and/or be in fuel poverty.
- ***Retrofit application outcome:*** e.g. whether or not the property occupiers' application for a retrofit was successful and if not why.
- ***Property type:*** e.g. flat, bungalow, house and whether the property is mid-terrace, end-terrace, semi-detached, detached.
- ***Tenure:*** e.g. owner occupied, private rent, social rent.
- ***Existing heating type:*** e.g. gas boiler, oil boiler, electric heaters.
- ***Retrofit measures implemented:*** e.g. insulation, double glazing, solar photo-voltaic panels, air source heat pump, boiler, hot water tank, draught proofing etc.
- ***Date retrofit completed:*** date the works were completed.
- ***Total retrofit cost:*** total cost of the works.
- ***Pre-retrofit Energy Performance Certificate:*** the property's energy performance prior to the retrofit, where A is 'very efficient' and G is 'inefficient'.
- ***Post-retrofit Energy Performance Certificate:*** the property's energy performance after the retrofit, where A is 'very efficient' and G is 'inefficient'.

The database currently contains data for 5,420 homes that the LCRCA have retrofitted since 2021 and a further 5,000 homes are planned by 2025. We plan to obtain an extract of data since 2021 until the present day and we estimate this will provide us with a sample size in the region of up to 6,000 retrofit applications across this time period, including both those that were successful and those that were not.

We will use the data detailed above to examine equity of access to the housing retrofit programme i.e. whether people who need housing retrofit support have contact with the programme. We will also examine equity of uptake of the housing retrofit programme i.e. whether those who have contact with the programme go on to receive support. This will be achieved by mapping the characteristics of housing retrofit applicants/properties to data on the population of Liverpool broken down by LSOA and housing type, housing tenure, household size, housing benefit receipt, unemployment, measures of poor health, disability, and deprivation (English Indices of Deprivation).

For granular data on annual population characteristics, we will utilise data from CIPHA (e.g. whole population individual and household linked primary, secondary and social care data for Liverpool; see the CIPHA website for further information), Office for National Statistics (e.g. census measures of disability), and Department for Work and Pensions (e.g. unemployment and housing benefit receipt). Analysis will investigate the extent to which access (i.e. % of the population referred to the housing retrofit programme) and uptake (i.e. % referrals that are successful, along with the values of the retrofit received) reflect the distribution of the drivers of poverty given above and how this varies across the Liverpool City Region. Where there are outliers (e.g. where retrofit uptake is either higher or lower than expected) will we seek to understand how structural differences within the local landscape affect equity of engagement with the housing retrofit programme e.g. via enablers/barriers to the implementation of the programme. This will be explored during the focus groups with staff, stakeholders, and residents in work package 2.

We will assess the implications of differences in uptake on health inequalities by examining how population health is associated with provision of housing retrofit support. Using local healthcare data from CIPHA we will produce a composite annual measure for 4 sets of conditions:

- Respiratory conditions
- Cardiovascular diseases
- Arthritic conditions
- Common mental health issues such as anxiety and depression.

The composite annual measure will be produced for each Lower Super Output Area (LSOA) based on NHS data for: i) number of GP consultations, ii) prescribing, iii) number of A&E attendances, and (iv) emergency hospital admissions. We will model how these health measures may change by addressing gaps in uptake identified in the analysis above.

8.3 Work package 2: Factors affecting implementation of the programme and impact on residents' financial situation, health and wellbeing (Objectives 2 & 3)

Drawing on Health Impact Assessment stakeholder engagement approaches, will we undertake up to three focus groups each with an average of ten participants that incorporate LCRCA staff, stakeholders (e.g. housing and other local service providers who support residents to access housing retrofit support) and residents. The aim of the focus groups will be to understand the process by which residents apply for and receive retrofit support and any local structural enablers/barriers to this, along with identifying beneficial impacts and any unintentional adverse impacts on health determinants and outcomes. The potential nature of impacts will be discussed and described along with direction of change (e.g. positive, negative), scale and severity of impacts, timing (e.g. latency, duration), and the distribution of impacts across different population groups (e.g. age/life-stage, gender, ethnicity, socioeconomic status, and area and housing type). Discussion will focus on categories of determinants (e.g. financial circumstances, indoor environmental quality) and outcomes (e.g. mental health, respiratory conditions) from the logic model (Figure 1).

Focus groups will be audio-recorded and used to generate transcripts that will be collated and analysed using software such as ATLAS.ti or NVivo. The qualitative descriptions of potential impacts from work package 2 will help inform the final selection of measures and population distribution units in work package 3, as well as supporting the overall interpretation of findings from the evaluation.

8.4 Work package 3: Impact on healthcare utilisation (Objective 4)

To examine the impact that housing retrofit provision may have on use of healthcare services, we are exploring the possibility of linking the LCRCA's data on people who have applied for retrofit support with NHS records at the household level using the Unique Property Reference Number (UPRN) as a shared identifier across both datasets. Initial work to set up the infrastructure for this data linkage has already been undertaken by teams at the NHS Cheshire and Merseyside Integrated Care Board and the University of Liverpool as part of wider research initiatives, and it is hoped that this infrastructure may be complete in time for use in this evaluation.

If data linkage at the household level is possible, this analysis would allow us to examine how housing retrofit support impacts on health care utilisation related to 4 sets of conditions likely to be sensitive to changes in housing:

- Respiratory conditions
- Cardiovascular diseases
- Arthritic conditions
- Common mental health issues such as anxiety and depression

Four types of health care utilisation will be used to derive measures relevant to these conditions including: i) number of GP consultations, ii) prescribing, iii) number of A&E attendances, and (iv) emergency hospital admissions.

The LCRCA's data on retrofit applications includes both those that were successful and those that were not, which would allow us to compare health outcomes between those who received support versus those who did not. We will apply a matched controlled longitudinal design, that we have successfully implemented in a number of other evaluations (Downing et al., 2019; van Berkel et al., 2019), combining 2 quasi-experimental methods including inverse probability of treatment weighting and difference-in-differences. We will use propensity scores (Rosenbaum and Rubin, 1983), to construct a weighted control group of households who have not received the intervention but are similar in terms of observed trends to the intervention populations in the time period before the introduction of the intervention. We will then compare the change in outcomes in the intervention population, to the change in outcomes in the control population, before and after implementation. Subgroup analysis will investigate differences in effect between the types of housing retrofit, deprivation groups, ethnicity, gender, age groups, and condition. If individual level data linkage is not possible within the time frame of this research, we will explore a similar analysis using area-based datasets. The findings would provide insight into whether positive health outcomes result from housing retrofit provision and if so, we would explore how these may translate into reduced costs for health and social care services.

9) Ethics and data management

Ethical approval will be sought from the University of Liverpool's Institute of Population Health Research Ethics Committee prior to the evaluation commencing. The research will involve working with secondary data collected by our local authority partners, as well as primary data collected via focus groups with staff, stakeholders, and residents. We do not feel the research raises serious ethical concerns.

Secondary data collected by the LCRCA on residents who have received housing retrofit support contains identifying information, including a Unique Property Reference Number (UPRN). While identifying information such as home address will be removed from the data prior to the research team receiving a copy, we will retain UPRN so that we may link this to other data such as NHS records. To allow the sharing of secondary data, a Data Sharing Agreement (DSA) will be arranged between the University of Liverpool and the LCRCA. The evaluation team will also undertake a Data Protection Impact Assessment (DPIA) to identify potential risks that could result from the planned data processing and to minimise these risks as far and as early as possible.

Focus groups will be undertaken with staff, stakeholders, and residents. This may have implications for staff and stakeholders being identifiable in the research findings because of their unique roles or residents being identifiable due to their unique circumstances. However, no outputs from the research will name individuals and where possible the findings will be framed in a way that minimises the likelihood of compromising participants' anonymity, for example, reporting findings thematically across organisations and not including details of residents' specific circumstances where possible.

Prior to focus groups taking place, participants will be asked to provide written consent. Where focus groups are conducted face to face, participants will complete a paper version of a form; where focus groups are remote (e.g. by MS Teams or Zoom), an electronic consent form will be provided via a link in Microsoft Forms (an online survey tool which can be easily accessed via mobile phones, tablets and computers). The research may have safeguarding implications due to the sensitive nature of the topics covered in the focus groups (e.g. financial hardship). As part of our ethics approval stage, the evaluation team will complete a safeguarding assessment with our local authority partners and the PHIRST LiLaC Public Advisor panel, which will identify key safeguarding issues and put in place an action plan to mitigate against these.

All data associated with the evaluation, including secondary data shared with the evaluation team by partner organisations as well as primary data collected during the focus groups in the form of audio-recordings and transcripts, will be securely stored online in a shared SharePoint folder. This will be accessible only to members of the team at Liverpool and Lancaster Universities, as well as providing controlled access for external project team members where required.

10) Dissemination and outputs

We will produce a final report for the Liverpool City Region Combined Authority at the end of the evaluation and we also plan to produce a paper for publication in peer-reviewed scientific journal.

In addition to the above outputs, a primary target of our dissemination strategy will be local authorities in other parts of the country. This is an important group, as these organisations are responsible for housing retrofit delivery and hence are the gatekeepers of current and future schemes. We will work with the Local Government Association, the national organisation that represents local government, to disseminate via their routes (e.g. LGA publications, seminars, workshops etc). We also hope to disseminate via the Association of Directors of Public Health (ADPH), which is the representative body for Directors of Public Health in the UK.

We will share all outputs with our local authority partners and invite them to provide feedback prior to any outputs being finalised.

11) Timeline and milestones

Key milestones	**Dates**
Submit protocol to NIHR	October 2024 (month 1)
Apply to university ethics committee	October 2024 (month 1)
Arrange access to data collected by the LCRCA (ethics not required)	October 2024 to January 2025 (months 1-4)
Receive university ethical approval and commence work	January 2025 (month 4)

WP1: Equity of access to and uptake of housing retrofit provision and implications for health inequalities	January to July 2025 (months 4-10)
WP2: Factors affecting implementation of the programme and impact on residents' financial situation, health and wellbeing	January to May 2025 (months 4-8)
WP3: Impact on healthcare utilisation	May to September 2025 (months 8-12)
Complete remaining data analysis and write-up results	October to November 2025 (months 13-14)
Complete final report for the LCRCA	December 2025 (month 15)

12) Governance

A Project Evaluation Group (PEG) will oversee delivery of the research. The PEG will include researchers with relevant expertise from across PHIRST LiLaC, representatives from LCC, and public advisors.

Dr Emma Coombes (University of Liverpool) will be responsible for the day-to-day management of the study. She will co-lead the overall study with senior academic support from Prof Ben Barr (University of Liverpool and PHIRST LiLaC co-lead investigator). Dr Huihui Song (University of Liverpool) will undertake the delivery of the quantitative work, including the analyses related to equity of access and impact on healthcare utilisation and health inequalities. Within our wider research team at University of Liverpool, Dr Andy Pennington has expertise in evidence synthesis, Health Impact Assessment, and PPIE, and he will support the qualitative work in particular including the focus groups with staff, stakeholders, and residents. Timothy Wilson (PHIRST LiLaC public contributor) will advise on public involvement in the research. Prof Sarah Rodgers (University of Liverpool and PHIRST LiLaC co-investigator) has expertise in housing retrofit research and will provide senior academic advice to the study.

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Appendix I

FOR Equity tool

Note taking form

1. Mapping inequalities relative to your research

What is the problem you plan to address and which dimensions of social and health inequalities are relevant?

What are the root causes of those inequalities beyond possible behavioural/lifestyle factors? Have you considered how they intersect?

PPI: How have you involved members of the public and other stakeholders in helping you identify the problem you want to tackle and the relevant dimensions of inequalities?

Housing retrofit programmes have the potential to address multiple dimensions of social and health inequalities by improving living conditions, reducing energy costs, and enhancing comfort. These improvements can in turn lead to positive impacts on residents' financial situation and their health and wellbeing. However, without careful consideration, housing retrofit programmes can exacerbate existing inequalities by leaving out the most vulnerable populations. Tailoring these programmes to address the specific needs of disadvantaged groups is crucial for promoting equity in housing and health outcomes.

Our research will compare the characteristics of people applying to a housing retrofit programme in Liverpool and look to see how programme characteristics relate to the characteristics of successful applicants. In doing so, it will help us understand how best housing retrofit programmes can be run to ensure that local need is met, whilst at the same time particular population groups are not disadvantaged in their ability to access support. In particular, intersectionality (the overlap of different personal characteristics that combine to create advantage or disadvantage) will be considered.

PPI: We have public advisors who are part of the PHIRST LiLaC team who are guiding our research questions and study design. They will support the delivery of the evaluation by contributing to project meetings with our local authority partners, Liverpool City Region Combined Authority.

Note taking form

2. Integrating equity issues into research questions

How can your research questions be framed in a way that enables you to identify potential inequalities and explore their causes?

In order to frame our research questions to evaluate the housing retrofit programme in a way that identifies and explores potential inequalities a comprehensive approach is required. We propose to examine how the programme is implemented and received across different social groups and how it might reproduce or mitigate existing inequalities.

By framing our research questions with a focus on who benefits compared to who is left out and why, we can investigate inequalities in access, financial and health outcomes, and longer-term impacts. This approach not only helps to identify potential inequities in housing retrofit programmes but also explores their root causes and the policy or design flaws that may be perpetuating them.

PPI: Have you involved members of the public and other stakeholders in shaping your research questions?

PPI: The ethos of PHIRST LiLaC is around co-development of evaluation and as such representatives from Liverpool City Region Combined Authority as well as members of our public advisory panel are being involved in the development of the research questions.

Note taking form

3. Designing and conducting research sensitive to inequalities

Will your study design, data collection, and analytical methods enable you to capture the structural causes of inequalities and identify any differential impacts and experiences?

PPI: How have you involved members of the public and other stakeholders in shaping the study design and in analysing and interpreting the data?

To effectively capture the structural causes of inequalities and identify differential impacts and experiences in our evaluation our study design, data collection methods, and analytical approaches will be carefully structured.

For example, we will take a mixed-methods approach that will combine quantitative data (to capture broad patterns and impacts) with qualitative data (to explore lived experiences and structural causes of inequalities). This will allow us to triangulate findings to deepen our understanding of how and why inequalities manifest.

In our quantitative analysis we will compare outcomes across various social and demographic groups (e.g. by age, ethnicity, socioeconomic status, housing tenure, and geographic location) to capture differential impacts.

In our qualitative work we will seek to understand the lived experiences of residents, particularly marginalised groups, to help uncover structural barriers, such as bureaucratic challenges, landlord reluctance, or discrimination, that quantitative data may not readily capture.

PPI: The ethos of PHIRST LiLaC is around co-development of evaluation and as such representatives from Liverpool City Region Combined Authority as well as members of our public advisory panel are being involved in the development of the study design and will be invited to support the interpretation of results.

Note taking form

4. Prioritising findings relevant to action on inequalities in reporting and dissemination

What are the most effective ways you can share your findings relevant to understanding and/or reducing health inequalities? Which audiences should you target and why?

Have you considered whether your research findings and their dissemination could inadvertently contribute negatively to inequalities and how this could be avoided?

PPI: How have you involved members of the public and other stakeholders in planning and disseminating your findings?

The primary target of our dissemination strategy will be our own local authority partners in Liverpool and those in other parts of the country. This is an important group, as these organisations are the gatekeepers of current and future housing retrofit programmes. We will work with the Local Government Association, the national organisation that represents local government, to disseminate via their routes (e.g. LGA publications, seminars, workshops etc). We will also work with organisations such as registered providers of social housing, along with representatives from Liverpool-based organisations who support people to access the housing retrofit programme (e.g. Citizens Advice) and local housing charities (e.g. Torus Foundation).

We also wish to share our findings with academics. We note there is currently little evidence on the impact that housing retrofit programmes may have on inequalities, so we will contribute to this understanding by publishing a paper in the academic literature.

Given that we are not actively modifying programme delivery in this research we believe the risks of inadvertently contributing to inequalities are low. There is some risk of stigmatisation of certain population groups if dissemination activities were felt to be "finger pointing" and we will be very aware of this risk when disseminating our findings. For example, we will use very careful wording and ensure that no individuals or small population groups (e.g. a group of people with a particular characteristic living in a particular neighbourhood) can be identified. We believe that by explicitly identifying inequalities in programme uptake in our dissemination that we have a very strong chance of reducing future inequalities by informing the evolution of housing retrofit programme design and the risk of inadvertent inequality amplification is very low.

PPI: As soon as our research has started, we will involve our public advisors and other stakeholders in planning our dissemination activities.

Note taking form

5. Principles and practice in equity sensitive research

Have you considered whether you may be making implicit assumptions or have implicit biases that influence your research? How might you mitigate against these?

PPI: Are the involvement processes in your work transparent to the members of the public and other stakeholders involved and is there a feedback/complaints process set up?

We have considered this. An important part of PHIRST LiLaC's research is a focus on involving participants and stakeholders along with public advisors in reviewing and validating our findings to help ensure that our interpretations reflect realities, rather than being shaped by our own assumptions. We will undertake an iterative research process, where we return to the data and refine our analysis based on feedback. This continuous engagement reduces the risk of biased interpretations going unchallenged.

PPI: We believe our involvement processes are transparent. Our protocol will set out the processes for involvement during the evaluation, and team members and stakeholders will have the opportunity to review and comment on this before it is finalised. Our public advisors and stakeholders will have the opportunity to feedback throughout the evaluation at regular project meetings and will be made aware that they may contact members of the PHIRST LiLaC team with feedback or to raise a concern or complaint at any time.