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Health Impact of Structural Energy Performance Investments in Wales: An Evaluation of the Arbed Programme

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1. Aims/Objectives:

In this project we aim to evaluate the health impacts of large-scale Strategic Energy Performance Investments in Wales. The core objectives of the Arbed programme are to deliver affordable warmth, alleviate fuel poverty, and reduce CO2 emissions through area-based energy-efficiency improvements. In this project we will examine whether Arbed investments provide cardio-respiratory and mental health benefits to low-income households, can help to reduce health inequalities, reduce the financial burden to the NHS as a result of lowered health service use, alongside exploring the social and economic processes at the household level that contribute to better mental/physical health

The project has the following objectives:

- To determine the impacts of the Arbed investments on hospital admissions of residents of low-income neighbourhoods for cardio-respiratory conditions.
- To determine the impacts of the Arbed investments on the prevalence of respiratory symptoms and mental health status of residents of low-income neighbourhoods.
- To assess the impacts of the Arbed investments on energy use, indoor temperature/ humidity, and space usage of households in low-income neighbourhoods.
- To identify the social and economic processes that are part of the pathway linking the Arbed investments to physical and mental health.
- To calculate the cost savings of the Arbed investments to the health system.
- To determine the incremental cost-utility of the Arbed investments as a result of improved quality of life of residents of low-income neighbourhoods.

2. Background:

The Marmot Review Team (1, 2) has identified cold homes and fuel poverty as major factors in health inequalities that could easily be addressed through energy efficiency interventions. It is well known that living in cold conditions pose severe health risks. The literature has shown that low indoor temperatures are associated with increased risk of strokes, heart attacks and respiratory illnesses in temperate climates, as well as with common mental disorders (3). Countries with the lowest thermal efficient standards have the highest levels of excess winter mortality (EWM) and people living in the least energy-efficient housing are at higher risk of death than those living in more energy-efficient homes (1, 2, 4, 5). There are plausible biological and social mechanisms that link poor quality housing to different health outcomes and EWM, with thermal stress putting strain on the cardio-respiratory system (6), respiratory health being affected by mould through allergy, infection and toxicity (7), and mental health being negatively impacted by financial stress and reduced choice and control (2).

A clear relationship has been found between low thermal efficiency of housing, low indoor temperatures and EWM (1, 2, 5). It is estimated that about 40% of all EWM is attributable to circulatory diseases, and 30% to respiratory conditions (2, 8). Temperatures below 16°C may affect resistance to respiratory infections, while temperatures below 12°C increase strain on the cardiovascular system (6, 9). In particular in older people lower indoor temperatures are associated with elevated blood pressure (10, 11), with those living in poor quality houses in relatively cold areas being the most at risk of diastolic and systolic hypertension (12). The effects of changing temperature on haemostasis, blood viscosity, and vasoconstriction provide plausible biological mechanisms that can explain the increase in heart disease and mortality (13).

Cold temperatures may directly affect resistance to respiratory infections, and people living in cold and damp houses are at higher risk of respiratory infections through exposure to mould, dust mites and fungal spores (7). Damp and mould are more likely to occur in poorly insulated homes, which may lead to respiratory symptoms and illness through allergic reactions and lowered resistance to infections (8). There is consistent evidence that allergic reaction, such as asthma, and respiratory symptoms are more common in damp living conditions and exposure to mould, particularly in children (14, 15). Children living in damp and mouldy homes are between 1.5 and 3 times more likely to have symptoms of asthma and other respiratory conditions than children in dry homes (16, 17). While mould removal has been shown to improve self-reported asthma symptoms and a reduce rhinitis in a randomised trial (14), other studies suggest that in certain cases insulation and central heating systems may lead to worse indoor air quality, higher relative humidity, and as a result more mould and dust mites (2). Overall though 'affordable warmth' measures have been found to contribute to higher indoor temperatures and reduced relative humidity (18-20) and fewer respiratory symptoms (21, 22).

A number of studies have been conducted examining the relationship between housing quality and mental health. Literature reviews by Evans and colleagues (23, 24) suggest that those living in high-rise multi-dwelling housing have more adversarial psychological outcomes, while general housing quality is positively associated with mental wellbeing. Cold housing is more likely to affect mental health and social functioning than is damp housing (25). Those living in cold or damp houses are more likely to have common mental disorders (26) with housing quality and financial problems becoming relatively more important for mental health as the population ages (20). Various processes have been suggested that may mediate the relationship between housing quality and mental health. Poor housing may be stressful for a number of reasons, including stigmatisation and social isolation which may affect self-esteem, financial worries, a lack of control over living environment, and prolonged thermal discomfort (23, 27).

The literature review above shows that there is consistent evidence that housing quality is positively associated with physical and mental health. However, most evidence of the links between poor housing and poor health comes from cross-sectional research. This is problematic, as those living in poor housing are most likely to be socio-economically deprived and have long-standing illness (28). The causality of poor housing contributing to poor health can therefore only be determined by thorough intervention studies. Longitudinal and/or field experimental evidence of the health impacts of housing interventions is more limited. It is often argued that the lack of evidence in housing may be attributable to pragmatic difficulties evaluating housing interventions. In a systematic review of the literature, Thomson et al (21) identified only a small number of high quality intervention studies. The review shows that general health outcome measures were generally better after installation of affordable warmth/energy-efficiency measures as compared to the control groups. Similarly, there is good evidence that warmth/energy-efficiency measures alleviate respiratory conditions. The evidence of possible impacts of housing interventions on cardio-vascular and mental health is however less firm. One high quality study showed significant improvement in happiness and vitality scores (20). These findings have not been confirmed in other intervention studies. The effect sizes reported in a high-quality cluster randomised study in New Zealand (20) were larger than those reported in the UK, which may reflect differences in housing quality and conditions at baseline.

A lack of detailed energy, temperature and humidity measurements has made it difficult to assess the effectiveness of the interventions in terms of improved indoor environmental conditions, thermal

comfort, and fuel poverty. Oreszczyn et al (18, 19) stand out as one of the few that have monitored internal conditions to evaluate the Warm Front energy efficiency scheme; showing that scheme contributed to higher indoor temperatures, reduced relative humidity, and lowered energy use. Howden-Chapman (20) similarly reported a statistically significant increase in indoor temperature and decrease in relative humidity after intervention. This information is essential for exploring processes at the household level that are part of the pathway to health. Very little research has been conducted on the possible social and economic processes that underlie the mental and physical benefits of energy performance improvements.

Although fuel poverty is central to understanding the relationships between housing and health, very few studies have attempted to further explore the social and economic processes that might link housing quality with physical and mental health (27). In particular the health and life chances of low-income households are affected by living in energy inefficient housing at various levels. Fuel poor families often face the choice whether to spend their disposable income on basic necessities such as food and clothing or to heat their home to a comfortable temperature (the “heat or eat” dilemma). This means that fuel poverty may negatively affect health and mental wellbeing through low indoor temperatures, reduced dietary opportunities, strains associated with reduced choice and opportunities, and reduced thermal comfort and financial worries (2). Living in a cold home can further exacerbate social isolation. Fuel bills may prevent people from going out and may make them reluctant to invite others into the house (29)

There is some evidence that housing affordable warmth or energy-efficiency interventions improve the financial position of low-income households through reduced fuel consumption (20); and a number of qualitative studies suggest an increased use of the home for a variety of activities, better family/social interactions, more control over (and expansion of) living space, and better emotional security (30); all of which are likely to contribute to better mental wellbeing. There has been no systematic research to examine the socio-economic processes underlying the health effects of energy performance investments in low-income households.

3. Need for the current study:

The research is timely for a number of reasons. First, it aligns the agendas of climate change mitigation and health inequality reduction by evaluating an energy-performance scheme aimed at improving the thermal efficiency of existing housing stock (2). Wales is the only country to have sustainable development as a core principle in its founding statute; and has a duty to promote sustainable development through all its policies. The evaluation of the intervention may help to strengthen the integration of the aims of the UK One Future Framework of living within environmental limits while striving for a healthy and just society (31).

Second, the Marmot Report on cold homes and fuel poverty noted that in particular those with no access to social housing are the most vulnerable and lack the resources to deal with the consequences of living in cold homes. Compounding this, it has proven difficult to improve the quality of privately owned and rented housing. The Arbed programme will offer all households living in low-income neighbourhoods –irrespective of tenure– energy-efficiency improvements free of charge. There is a clear need to evaluate schemes that aim to improve the energy performance of the most deprived and vulnerable households to address inequalities in health resulting from cold homes and fuel poverty.

Third, steep increases in energy bills, rising unemployment, and stalling incomes have forced many households into fuel poverty in recent years. Analyses of the Living in Wales property survey suggests that between 2004 and 2008 the number of households in fuel poverty has more than doubled from 134,000 in 2004 to 332,000 in 2008, equivalent to 26% of all households in Wales. A more recent estimate suggests that Wales is the region with the highest level of fuel poverty at 32% –double the number of households as in London (32). The severity of the fuel poverty situation shows that urgent action is needed to improve the financial position and living conditions of low-income households in Wales.

4. Methods:

4.1 Setting

The setting for the research is low-income neighbourhoods in Wales that have or will receive structural energy-efficiency improvements under the Arbed scheme. In this study we will use the Secure Anonymised Information Linkage (SAIL) system to retrospectively evaluate Arbed phase 1, and a community-based study to prospectively study the health impacts of Arbed phase 2. These two parts of the research have the following study populations:

The study population of WP1 are residents of properties in low-income neighbourhoods that received energy efficiency improvements in the first phase of the Arbed programme (2010-2011). It will be attempted to include all residents of the 7,460 houses that have undergone the improvements in this period.

The study population of WP2 are residents of properties of the schemes that will take place in 2013 and 2014, from which approximately 500 participants will be recruited. Arbed 2 schemes are selected on the basis of the percentage of low-income households and hard-to-treat homes in the area, and alignment with strategic Communities First regeneration areas. It is anticipated that at least 50% of the households own or rent their house privately. The household monitoring (WP3) will be conducted in a subset of those surveyed for WP2.

4.2 Design

The research aims to investigate the health impacts of structural energy performance investments in low-income neighbourhoods through six interlinked work packages. These work packages are described in detail below:

WP1: SAIL System: The SAIL will be used to retrospectively to evaluate *Arbed phase 1.* SAIL is an ethically approved tool developed and hosted by Swansea University. SAIL is used to anonymously link property-based data to routinely collected health service data. The system ensures that individuals remain anonymous, while retaining the ability to make links between different datasets. By using record linkage of routine longitudinal data, we plan to compare the health of residents of the 7,460 houses in low-income neighbourhoods before and after receiving energy efficiency improvements, and compare these health changes to those of residents in 13,000 household living in social housing. We believe this is an appropriate comparator, as about 80% of the Arbed 1 intervention involved social housing. We will also compare the Arbed 1 schemes to all low-income neighbourhoods in Wales. That is, we will select the top 10% deprived areas in Wales according to the Welsh Index of Multiple Deprivation (WIMD). This will ensure that changes in GP consultations and hospital admissions

of Arbed 1 households can be compared to secular trends of those living in low-income neighbourhoods in Wales. The Arbed 1 addresses will be removed from both comparators. The Health Information Research Unit (HIRU) operates an environment GIS database (eGIS) containing a point location for each residence, along with address data. These data have been used to establish a method of anonymously linking each residence to health data for individuals within the SAIL databank using Residential Anonymous Linking Fields (RALFs) (33). While the housing intervention data are within the eGIS, they are completely separate from health data in SAIL. Therefore we are able to know the location and other information about the house and neighbourhood without compromising confidentiality and privacy. We will obtain the addresses and specific energy-efficiency measures from WG, local authorities, and housing associations involved in the first phase of the Arbed programme. These data are subsequently sent to NHS Wales Informatics Service (NWIS) where addresses are replaced with a consistent RALF. Now the data may be brought back into the SAIL databank and linked to Anonymous Linking Fields (ALFs) for individuals, enabling links to health data to be made. We will create links to variables at multiple levels to explore potential changes in disease burden for individuals nested within houses related to the housing improvements. WP1 is used specifically to examine the impacts of the Arbed investments on hospital admissions for cardio-respiratory conditions. Seasonality is likely to be an important factor here, with most admissions taking place over the winter period (34). We will therefore conduct additional analyses to explore if the Arbed investments have been successful in reducing excess winter admissions for cardio-respiratory conditions. Data generated in this work package will be used in WP4 to calculate the costs savings of the investments to the health system.

WP2: Community-Based Study: A community-based health impact study will be set up to evaluate the second phase of the Arbed programme. Approximately 500 householders will be surveyed before and after the Arbed intervention that will take place in 2013 and 2014. The Arbed 2 schemes are selected on the basis of the percentage of low-income households and hard-to-treat homes in the area, and alignment with strategic Communities First regeneration areas. Comparators will be selected using the same criteria, through the WIMD and close collaboration with the local authorities involved in choosing the Arbed scheme areas. The control neighbourhood will be conceptualised as Output Areas, as their size is comparable to the average Arbed 2 scheme. A similar number of control households (n=500) will be surveyed in the same before and after periods as the intervention group. Once the successful schemes have been announced in 2013, we will coordinate the interview survey with the visits of the Scheme Managers during the 2013-2014 heating season. The survey need to be finalised before the improvement works start in spring-summer 2014. The households will be contacted again in the 2014-15 heating season after improvements have taken place.

Data will be collected via the *drop-off-and-collect* method of survey administration. Cardiff University staff will visit the different Arbed schemes in South Wales alongside the Scheme Managers during the *home surveying stage*. Cardiff University staff will in this way be introduced to the different communities. The drop-off-and-collect method involves the personal delivery of the questionnaires to occupants, who will then be invited to take part in the research. Researchers return several days later to pick-up the questionnaires in person at designated times. A freepost envelope and spare questionnaire are left if occupants are away at the time of pick-up. This allows potential respondents who are not at home to return the completed questionnaire to the University. The drop-off-and-collect method has delivered good response

rates in previous research (22). The same drop-off-and-collect method will be used to collect data in the control neighbourhoods. To allow occupants with literacy problems to be involved in the research, they will also be given the option to be interviewed face-to-face. Schemes and occupants who could not be approached at the *home surveying stage* will be contacted at the *contract stage* of the Arbed improvements. The questionnaires can be returned to the University using freepost envelopes

WP2 will use self-reported respiratory symptoms and mental health status as the primary health outcomes. It is expected that the mental benefits of the energy performance investments will become apparent soon after the improvements have been made. It is expected that within the first heating season following the intervention, reduced exposure to cold temperatures will reduce the number of respiratory symptoms, improve thermal experience and as a result mental wellbeing (cf. 6, 9 25). A further aim of the community-based study is to explore plausible social and economic pathways that link the intervention to better mental and respiratory health. The survey will therefore be designed to include measures of these mediating processes. It is expected that the Arbed investments will improve the financial position and dietary choices of low-income households, and reduce social isolation, all which are thought to contribute to better mental health*.*

The questionnaire will include the SF12 scale, a widely-used and validated generic quality of life (QoL) instrument that includes physical and mental components. Upper and lower respiratory symptoms will be measured using the selection compiled by Fisk et al (35). A version of this scale has been used previously by the principal applicant. The study will further include measures relating to household financial position and stress, fuel poverty, thermal comfort, dietary choices, and social isolation. The most appropriate scales will be selected after reviewing the relevant literature. It is likely that this will include the Duke University Financial Stress Questionnaire. Measures of dietary choices will be measured using questions adapted from the US Adult Food Security Survey (USDA), and social isolation will be measured using questions from the adult psychiatric morbidity in England, 2007 – Household Survey. Where applicable we will use questions from the Welsh Health Survey (WHS) or from the UK Office of National Statistics so that we can compare our study sample to larger populations.

WP3: Household Monitoring: WP3 is directly linked to WP2 by conducting detailed energy consumption and indoor temperature/humidity measurements in a subset of those surveyed in the community-based study. The study will include a subset of households undergoing Arbed improvements (n=50) and a control group where no such improvements will take place (n=50), which will be recruited from WP2. The first measurements will be made in the heating season before the intervention has taken place (Feb-Apr 2014). The measurements are repeated in the same households in the heating season after the Arbed intervention (Jan-Mar 2015). Detailed indoor temperature and relative humidity measurements will be made with Tinytag data loggers in the living room, main bedroom, and hallway. Recording will be logged every 15 minutes over a 4 week period in the heating season to make a reliable assessment of average temperature and humidity after which they will be collected. Energy use over the same period will be estimated by meter readings made at the installation and collection of the monitors. The data will be adjusted for external meteorological conditions. Thermal experience is very much dependent on the behaviours, activity level and clothing of the occupants. The occupants will be asked to fill out a detailed comfort survey method, developed by Tweed, which allows occupants' thermal comfort to be tied directly to physical measurements of environmental

conditions. This WP is used to assess the impacts of the Arbed investments on energy use, indoor temperature/humidity, and space usage of households in low-income neighbourhoods, all of which may be part of different pathways to health. By linking the physical measurement to the community-based study, we will explore whether better indoor hydro-thermal conditions may explain improvements in respiratory conditions, and better thermal comfort and 'expansion of living space' (i.e. a greater heated area) improves experienced control and mental wellbeing.

WP4: Health Economic Assessment Tool: The HEAT for Housing tool is used to provide an economic evaluation of the Arbed energy performance investments. HEAT was initially developed to estimate the economic savings as a result of improved health due to regular cycling and walking. In the currently active NIHR-PHR project, the tool is being adapted so it can be used for housing improvements. In this project the newly developed 'HEAT for housing' tool will be applied to data collected in both WP1 (SAIL) and WP2 (community-based study) to determine if the investments can be considered an efficient way of improving public health over and above the other intended benefits of the Arbed programme: (1) the first approach is a cost-consequences analysis (CAA) from the perspective of the public sector as a whole, using SAIL data (WP1). The costs of delivering the Arbed programme will be compared to the cost savings as a result of reduced health service use. Comparisons in health service will be made between intervention and control areas; with future costs and benefits being discounted to bring them into present values. The costs of delivering the programme will be assessed through financial documents and discussions with key staff involved in the programme (WG and scheme managers). The cost savings to the health system as a result of lower health service use are calculated with PSSRU, BNF and NHS reference costs. Probabilistic sensitivity analysis will consequently determine the robustness of the CCA; (2) the second approach is to determine the effectiveness of the programme in improving the quality of life of residents of low-income neighbourhoods. This will be done via a cost-utility analysis based on QALYs derived from SF6D utilities calculated from responses to the SF12 in the community-based study (WP2). By comparing the responses of the intervention and control groups to the SF12 scale will be able to estimate the improvements in health-related quality of life that results from the Arbed intervention. The cost-utility will subsequently be determined by comparing these improvements to the costs of delivering the energy-efficiency improvements, providing the costs per additional QALY.

WP5: Study Steering Committee: We will convene a study steering committee (SCC) for the project for advice and critical feedback on the design and direction of the research. The panel comprises both public policy and academics in housing and health research. The board will meet bi-annually throughout the research. Having members from Public Health Wales and WG on board ensures that the research keeps sight of its policy relevance and the results will be directly disseminated to policy makers.

WP6: Resident Engagement: The research is informed by resident engagement. Focus groups will be conducted in areas where improvements have been made under Arbed 1 and/or the first year of Arbed 2 (n=2x7) and where they are expected to take place (n=2x7). This resident engagement aims to get a better understanding of experiences of low-income households living in energy-inefficient houses; and show how the Arbed improvements may have changed these experiences. Topics include perceived changes in health and wellbeing, thermal comfort, use of living space, financial position, and social interactions (30). Qualitative methods allow the residents to express these experiences in their own words. The results will

be used to improve the survey design, and where possible adjust the direction of research. A number of participants will be recruited to attend the bi-annual SCC meetings. At the end of the project we will make the results available to residents via a number of community presentations at central locations and an easy-to-understand key findings brochure.

Figure 1 shows how the work packages 1 to 4 are interlinked.

4.3 Data Analysis

The primary method of analysis for WP1 is multilevel modelling. The data are hierarchical with individual residents nested within households nested in the 28 schemes of Arbed 1. Because the data includes repeated measurements ('before' and 'after' the intervention) an extra 'within participant' level will be introduced reflecting the different measurement occasions. The simplest models will only involve houses that were upgraded in Arbed to look at absolute changes over time. This will compare the hospital admissions (and other secondary outcome measures) before and after the intervention. It is important to model the data according to the different sources of variation in order to estimate the correct effect sizes at the different levels. The analyses will include fixed factors at each level, e.g.: scheme (location, level of deprivation), household (type of intervention, household type), individual (gender, age), and measurement occasion (before, after). The changes in the health outcomes will subsequently be compared to controls in the form of households in similar low-income neighbourhoods to assess relative changes (we will work with a local authority to identify around 13,000 household living in social housing to act as control). Controls will be included as a fixed effect at the household level (intervention: yes, no). The exact multilevel models will depend on the used outcome measure. The type of data mostly requires logistic models for binary outcomes and Poisson models for hospital admission counts. The changes will also be compared to the Welsh population living in the top 10% deprived neighbourhoods to control for secular trends in hospital admissions.

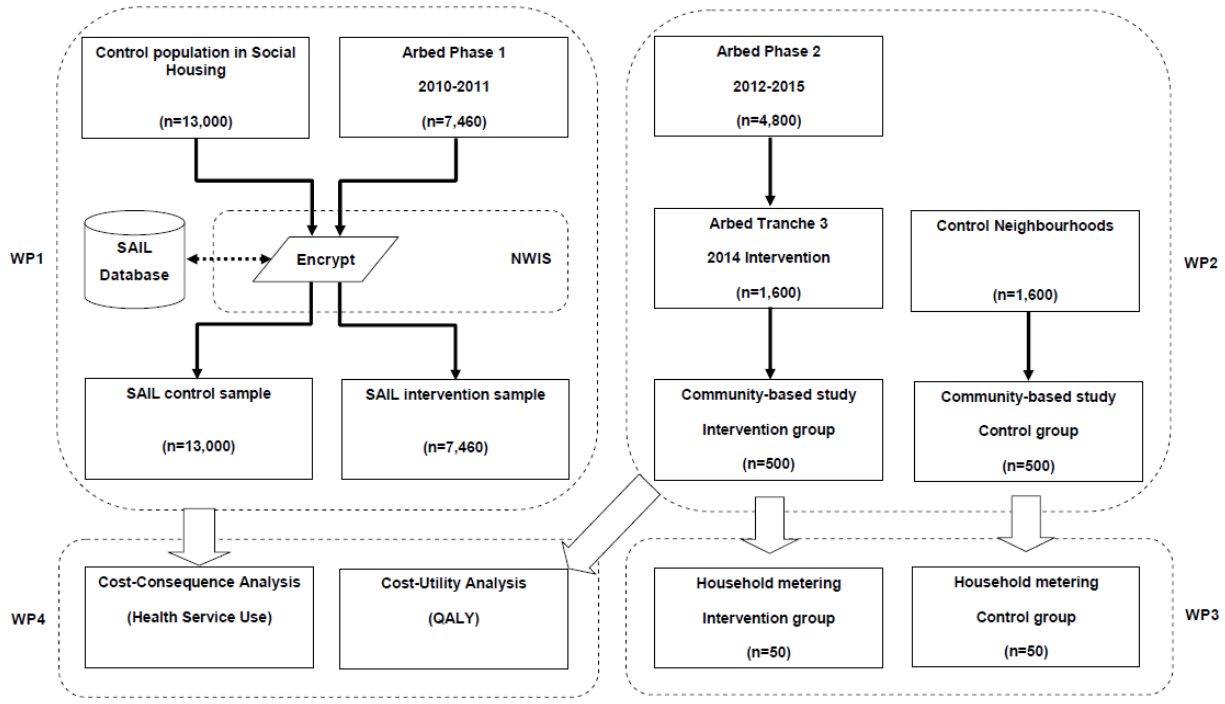

Figure 1: Flow diagram

The primary method of analysis for WP2 is mixed-design Analysis of Variance (ANOVA). The community-based study has been set up to examine changes in health over time (before, after) and compare them to a control group. The analysis therefore combines two types of independent variables, i.e., a within-subject factor: measurement occasion (before and after) and a between-person factor (intervention: yes, no). A mixed design ANOVA with repeated measures is necessary because the outcome variables before and after the intervention are dependent observations. That is, the post measurement is likely to be (part) dependent on the 'pre' measurements due to individual differences (e.g. susceptibility to respiratory infections). The intervention effect may therefore be 'contaminated' by unrelated individual variation. The repeated measures analysis completely removes the individual variation from the error term, increasing the accuracy of the F-statistic (ignoring the dependence of observations would inflate the error term and thus reduce the statistical power). The mixed design ANOVA allows for time x intervention effects to examine if health has improved in the intervention group as compared to the control group. Paired t-tests, repeated measures ANOVA, and McNemar tests will be used to examine absolute changes in reported health status before and after the intervention (depending on the type of outcome variable).

Secondary methods of data analysis for WP2 include structural equation modelling (SEM). In addition to the main research questions (the cardio-respiratory and mental health benefits of the Arbed programme), the study aims to explore the social and economic processes that may be part of the pathways to health. The survey will therefore include indicators of financial position, fuel poverty, thermal comfort, dietary choices, and social isolation. The analysis will explore if these variables may mediate the relationship between the Arbed intervention and physical and mental health in different ways.

5. Contribution to existing research:

The combination of the different work packages in the research allows a comprehensive assessment of the health benefits of structural energy-efficiency investments in low-income households, helps to explore plausible social and economic pathways to these benefits, and validates results based on self-reports with routinely collected data. The community-based study and SAIL components of the research have different strengths, and will deliver complementary information on the health impacts of the Arbed intervention. The strength of SAIL is that it can link the intervention with actual health service use data without compromising patient confidentiality. In contrast to studies that involve direct data collection, SAIL is not marred by low response rates or attrition that can adversely affect validity, generalisability and power to detect important effects. The community-based study will provide more detailed information on a wider range of health outcomes and the social and economic processes at the household level (e.g., financial position, fuel poverty, thermal comfort, social isolation) that may be part of pathways to mental and physical wellbeing.

6. Project management:

6.1 Ethical arrangements

The evaluation of Arbed 1 (WP1) is based on a system of anonymously linked data. The design of this system involves an NHS Information Organisation (NWIS) to carry out identity matching and subsequent encryption of NHS numbers and address identities without access to any clinical or intervention content. As the SAIL databank is anonymised it does not fall into the remit of the National Information Governance Board. An independent Information Governance Review Panel (IGRP) assesses whether all proposals for analysis meet the strict information governance

arrangements set out in the multiple data access agreements, ensures anonymity and does not require referral to NRES. IGRP includes members from the BMA, NRES, Public Health Wales NHS Trust, Informing Healthcare and lay members. We have sought additional advice from NRES in relation to the SAIL databank and have now been informed that since the evaluation of Arbed 1 uses SAIL data only, it does not require NRES review because it does not involve NHS patients or staff but falls under the category of anonymised research database.

The evaluation of Arbed 2 (WP2) will require participant consent since we will be collecting personal health data and monitoring homes for temperature and humidity. Because the project does not involve NHS patients or staff, it does not require NRES review. Instead, the entire research procedure will be scrutinised by the School Research Ethics Committee (SREC) at Cardiff University, which follows the ESRC ethics framework and the Code of Ethics and Conduct of the British Psychological Society. Obtaining ethical approval for this part of the research is a milestone that needs to be completed before the start of the data collection in winter 2013-14.

Participants will be fully informed beforehand about the purpose, methods, possible uses of the research, and what their participation in the research entails. As the research involves sensitive personal health data, special attention will be given to the management of data to ensure the highest level of confidentiality. Precautions are being taken to ensure that all participants provide informed consent and are aware that they may withdraw from the research at any time. We will follow established procedures such as using participant numbers and password protected linkage files, and will not use the responses of any one individual or household in publications in such a way that they could be identified. The research does not incorporate any activities that could be deemed harmful to the physical or psychological health of the participants

6.2 Research Governance

We will establish a multi-agency *Study Steering Committee* (SSC) to oversee and guide project activities. The SSC will include the lead and co-applicants from Cardiff and Swansea University, and representatives of WG and NHS Wales. We will also recruit two members of the *Occupant Panel* to engage tenants in the research. The leads of the different work packages will form an *Executive Group* that will meet at a regular basis for day-to-day management of the project. This group is responsible for determining the overall strategy and direction of research. A *Management Group* consisting of all investigators and researchers will meet three times throughout the project to discuss content and progress of the research. The SSC will agree terms of reference, frequency of meetings and modus operandi to support optimum management and development throughout the project.

6.3 Plan of Investigation

A Gantt chart with a number of milestones will be used to ensure that the research proceeds in a timely matter. The project will start in May 2013 and will finish in April 2016.The research will target households that take place in 2013 and 2014 (the 2nd and 3rd year of Arbed 2). The objectives listed under "*1. Aims and Objectives*" will all be delivered by the end of the project in April 2016.

WP1: SAIL

- April 2013: Recruitment of project staff.
- October 2013: Ethical Approval (IRGP) sail study (WP1).
- July 2014 Data cleaning and variable selection.
- December 2014: Finalise comparators creation and data collection.
- March 2015: Finalise data linkage in SAIL.
- September 2015: Complete statistical data analyses of SAIL study.
- December 2015: Complete technical report of SAIL study.

WP2: Community-based study

- April 2013: Recruitment of project staff.
- October 2013: Ethical Approval (SREC) community-based study (WP2).
- October 2013 Complete survey construction.
- March 2014: Complete baseline survey.
- September 2014: Complete statistical data analyses of baseline survey.
- December 2014: Complete technical report of baseline survey.
- March 2015: Complete follow-up survey.
- September 2015: Complete statistical data analyses of follow-up survey.
- December 2015: Complete technical report of follow-up survey.

WP3: Household monitoring

- April 2013: Recruitment of project staff.
- October 2013: Ethical Approval (SREC) household monitoring study (WP3).
- April 2014: Complete baseline monitoring.
- September 2014: Complete statistical data analyses of baseline monitoring.
- December 2014: Complete technical report of baseline monitoring.
- April 2015: Complete follow-up monitoring.
- September 2015: Complete statistical data analyses of follow-up monitoring.
- December 2015: Complete technical report of follow-up monitoring.

WP4: Health economic assessment

- April 2015: Recruitment of project staff.
- July 2015: Complete data preparation for HEA analysis.
- December 2015: Complete statistical analysis for cost-consequence and cost-utility analyses.
- December 2015: complete technical report of heath economic assessment.

WP6: Residents engagement

- June 2014: Complete focus groups.
- September 2014: Complete technical report of focus groups.
- January 2016: Dissemination meetings.
- April 2016: project papers written and submitted.

Reports to NIHR:

- Interim reports: every 6 months (in November and May).
- Final Report: May 2016

7. Service users/public involvement:

This application includes a dedicated work package on resident engagement. Focus groups will be conducted in the first stages of the research. This will used to improve the survey design of the community-based study where appropriate. A number of participants of these groups will be recruited to form a panel that will meet three times throughout the research. Public engagements will further occur through occupant representation on the SSC. Results of the project will be made available to residents via easy-to-understand key findings brochure.

8. References

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