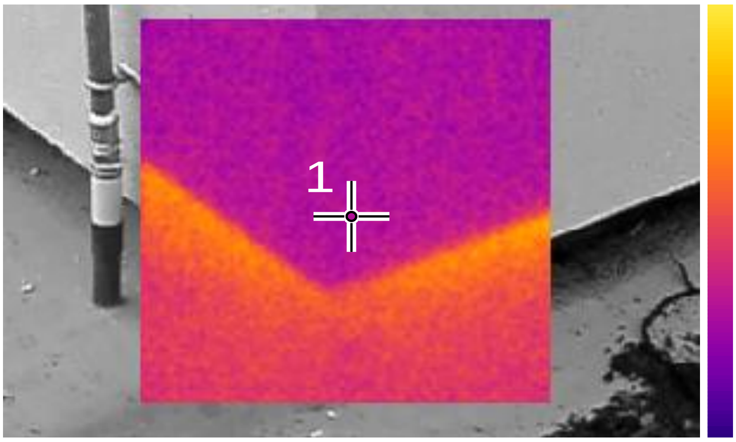
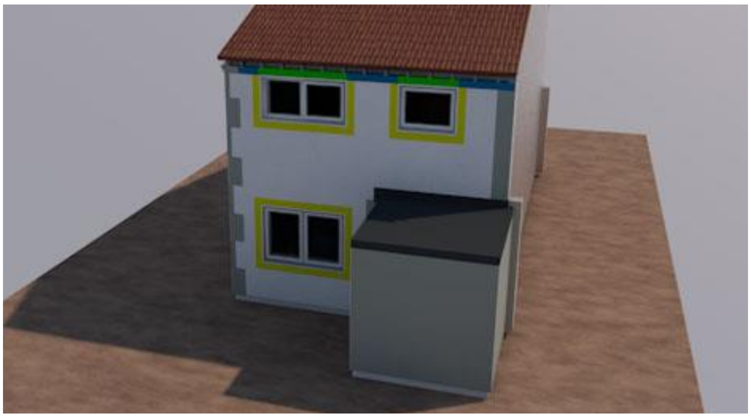
No-fines concrete housing insulation and air-tightness project, Halton, Cheshire
Riverside Housing Group

Technical Evaluation Report





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Background

About National Energy Action

National Energy Action (NEA) is the national fuel poverty charity working across England, Wales and Northern Ireland, and with sister charity Energy Action Scotland (EAS), to ensure that everyone can afford to live in a warm, dry home. In partnership with central and local government, fuel utilities, housing providers, consumer groups and voluntary organisations, it undertakes a range of activities to address the causes and treat the symptoms of fuel poverty. Its work encompasses all aspects of fuel poverty, but in particular emphasises the importance of greater investment in domestic energy efficiency.

About the Technical Innovation Fund

NEA believes that there is huge potential for new technologies to provide solutions for some of the 4 million UK households currently living in fuel poverty, particularly those residing in properties which have traditionally been considered too difficult or expensive to include in mandated fuel poverty and energy efficiency schemes. However, more robust monitoring and evaluation is needed to understand the application of these technologies and assess their suitability for inclusion in future schemes.

The Technical Innovation Fund (TIF) which was designed and administered by NEA, formed part of the larger £26.2m Health and Innovation Programme along with the Warm Zone Fund and Warm and Healthy Homes Fund.

TIF facilitated a number of trials to identify the suitability of a range of technologies in different household and property types and had two strands: a large measures programme to fund the installation and evaluation of technologies costing up to a maximum £7,400 per household, and a smaller measures programme with up to the value of £1,000 per household. It launched in May 2015, with expressions of interest sought from local authorities, housing associations, community organisations and charities wishing to deliver projects in England and Wales.

Over 200 initial expressions of interest were received and NEA invited 75 organisations to submit full proposals. Applications were assessed by a Technical Oversight Group, chaired by Chris Underwood, Professor of Energy Modelling in the Mechanical and Construction Engineering Department at Northumbria University who is also a trustee of NEA. In total, 44 projects were awarded funding to trial 19 different types of technologies and around 70 products (although this number reduced slightly as some products proved not to be suitable and were withdrawn).

More than 2,100 households have received some form of intervention under this programme that has resulted in a positive impact on either their warmth and wellbeing, or on energy bill savings.

Technical monitoring and evaluation

NEA has been working with grant recipients to monitor the application of these technologies and assess performance, as well as understand householder experiences and impacts.

A sample of households from each TIF project was selected for monitoring purposes. Participation was entirely voluntary, and householders were free to withdraw at any time. This involved the installation of various monitoring devices within the home which collected data for analysis by NEA's technical team. Some residents were also asked to take regular meter readings. In some instances, a control group of properties that had not received interventions under TIF were also recruited and monitored.

The technical product evaluation was conducted alongside a social impact evaluation to inform our understanding of actual energy behaviour changes, perceived comfort levels and energy bill savings, as well as any other reported benefits. Householders were asked to complete a questionnaire both before and after the installation of the measures which captured resident demographic data including any health conditions. Small incentives in the form of shopping vouchers were offered to maintain engagement over the course of the evaluation period.

The HIP fund was principally designed to fund capital measures to be installed into fuel poor households. A small proportion of the funding enabled NEA to conduct limited research and monitoring of products installed and was restricted to ensure that the majority of funds were spent on the products. All products included in the trials were deemed to offer costs savings and energy efficient solutions as proposed by the delivery partners. The research and monitoring aimed to provide insights to inform future programme design and interested parties of the applicability of the product to a fuel poor household. We recognise that due to the limited number of households involved in the monitoring exercises and the limited period we were able to monitor a product's performance, we may recommend that further research is needed to better understand the application of these products in a wider range of circumstances over a longer period of time.

The research was conducted according to NEA's ethics policy, which adopts best practice as recommended by the Social Research Association (SRA) Ethical Guidelines 2002.

An accompanying programme of training and outreach work was also delivered to 292 frontline workers to increase local skills and capacity.

Individual project reports are being compiled and will be made available publicly on NEA's website from September 2017, along with a full Technical Innovation Fund Impact Report.

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Insuletics Ltd – EWI Manufacturer Supplier

Quietstone Ltd – Thermal Break / Below Damp Manufacturer / Supplier

Solarcrest Ltd – Demelec Softfoam Insulation / PIV / MVHR / Glazing Installer / Supplier

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Executive summary

Project overview

No-fines concrete houses are houses that have walls constructed from in-situ cast concrete that does not contain the fine aggregate that is usually mixed within the concrete. This means that the larger aggregate (gravel of 10-20mm in size) is bound by a cement slurry coating. As such, connected voids are found throughout the walls. The result of this is that these house types do not behave like other solid wall properties in relation to heat retention, air-tightness and resistance to moisture. This project seeks to address heat loss and air tightness issues in a group of such properties for The Riverside Group by testing an incremental set of retrofit measures in combination and measuring their impact on heat loss and airtightness, thereby developing a set of solutions that potentially reduces the incidence of fuel poverty. It also seeks to change the way retrofit projects are approached, delivered and monitored.

The project had the following aims;

- Secure a deeper understanding of the possible range of retrofit improvements that may be made to no-fines housing (an often-neglected typology for housing retrofit, due to their 'hard-to-treat' nature).
- Using a matrix of possible small measure improvements understand which difference combinations of products can be used to create a tailored retrofit approach to no-fines housing.
- To increase thermal comfort for residents and reduce their energy bills.

These aims will be tangibly demonstrated by trying to achieve the following targets:

- Reduce Air Change Rate from >16 $M^3/(H.M^2)$ to below 10 $M^3/(H.M^2)$ [1]
- Reduce Heat Loss, Damp and Cold Bridging through carful retrofit detailing
- Reduce fuel poverty and incidences of Asthma and other environment –related health issues
- Increase longevity of building fabric i.e. reduce maintenance legacy particularly with respect to damage caused through damp
- Produce a pattern-book of options for houses in different states of maintenance and retrofit within the typology.

1 The Building Regulations suggests that all new properties have an air tightness of less than 10 M3/(H.M2). The Energy Saving Trust suggest a standard of 5 M3/(H.M2) is desirable for naturally ventilated properties. We aim to improve our 'no-fines' properties to be better than minimum UK new build standards

Background Context

- There are approximately 200 no-fines concrete houses on the Glen estate in Halton. Around 40% are owned by Riverside and 60% are owner-occupied. This project seeks to improve 30 of these properties using a range of complementary measures in order to determine a pragmatic and cost-effective approach to improving the remaining properties.
- There are an estimated 300,000 no-fines concrete houses in the UK [2]. Assuming an average occupancy of 2.4 persons per household[3], this would equate to circa 700,000 inhabitants living in no-fines properties.
- According to the Centre for Sustainable Energy levels of fuel poverty amongst householders in no-fines concrete housing are estimated to be as high as 80% [4]
- The lead author has studied the retrofit of solid-wall and no-fines houses through the Retrofit for the Future Programme[5] and the S-impler Programme[6]. Prior knowledge from the outcomes of these programmes suggest that air-tightness plays a significant role in thermal performance of solid-wall properties.
- It is almost impossible to retain a good level of thermal comfort whilst these properties are unimproved because of heat loss due to thermal conduction and air leakage. This phenomenon is compounded by the properties generally being constructed in terraces as air moves within the party wall connections between adjacent properties.
- There are issues with access to funding from extended sources (e.g. Government mandated schemes) for the type of measures currently available and required to improve the combined building physics issues associated with cold and damp in this property type. This is because the funds are largely appropriated on the basis of predicted carbon savings made from reductions in modelled heat loss that do not take into account the complexity of air movement within the fabric of no-fines structures.
- Traditional EWI funded schemes are not particularly effective as they offer limited improvements to the air permeability that is inherent in ‘no-fines’ concrete housing.
- Moreover, these schemes tend to use calculation methods for funding that largely ignore heat loss due to air leakage. These properties are frequently side-lined as ‘hard to treat.’

Sample context

- Residents report regularly spending up to £5 per day on gas for heating, and report that the properties are rarely heated to a good level of thermal comfort, therefore the properties are generally heated to match affordability substantiated by tenant interviews and surveys (see qualitative survey data summary)
- The qualitative data reflects that amongst the sample group many suffered with health conditions exacerbated by living in a cold home including asthma, colds, joint pain / rheumatism / arthritis / chest complaints (see qualitative survey data summary)

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2 Ross, K. (2002) Non-traditional Housing in the UK – A brief review, Council of Mortgage Lenders, Bre, Watford.

3 https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/bulletins/familiesandhouseholds/2016#average-household-size-remains-stable-over-the-decade-to-2016

4 Baker, W. et al (2005), Fuel Poverty and Non-Traditional Constructions. Centre for Sustainable Energy, Bristol.

5 https://retrofit.innovateuk.org accessed 20th November 2017

6 https://www.bre.co.uk/news/The-SIMPLER-way-to-insulate-solid-wall-homes--932.html accessed 20th November 2017

The technology

External Wall Insulation with Spray Foam detailing and Thermal Break components

External wall insulation (EWI) is a common intervention used to improve the thermal performance of solid-wall properties. The problem with using EWI on no-fines concrete properties is that the small connected void spaces present in the concrete walls means that heat loss predominantly occurs through air movement, potentially negating the benefits from the EWI. The careful application of spray-foam insulation at junctions identified as problematic can prevent such air-loss, and as a complimentary technology may therefore be beneficial. Heat loss also occurs through conduction at key thermal bridging points such as where the solid ground floor slab meets the external wall, and in voids around window units. Thermal-break components that have been specifically developed for this project are introduced at these key detail areas. Two types of EWI were trialled: A solid insulation and a dynamic insulation with a hollow core. The dynamic insulation is linked to a ventilation system such that the air brought into the property via the hollow core is passively pre-warmed. Both types of EWI used in this project were enhanced with a range of complimentary junction details that reduce thermal bridging and air leakage.

Passive input Ventilation and Mechanical Ventilation with Heat Recovery

Increasing the air-tightness of the properties can also be achieved by removing existing passive wall vents and mechanical vents from kitchens and bathrooms then closing up the penetrations. By incorporating a whole-house ventilation system, it is possible to control the input and extract via a central unit, thus replacing the existing fixed / mechanical ventilation. One of the insulation types (dynamic) trialled includes a passive input ventilation unit (PIV) as part of its installation that inputs pre-warmed air via the ventilation system. Other properties in the project have mechanical ventilation and heat recovery (MVHR) systems installed instead. MVHR ventilation systems use heat exchangers to remove heat from expelled air and introduce it back to the input air, reducing heat loss due to ventilation.

The project

The project seeks to demonstrate the most efficient approaches to improving both thermal comfort and affordable warmth within this property type. Due to the movement of air from and between these properties, the industry approach to external wall insulation –cladding only the majority of clear expanses of elevations – has limited benefits in comparison to its use in other solid wall properties. A series of interventions have been derived and the goal is to test a combination of solutions such that the most appropriate range of measures can be specified in future projects. The application of these would depend upon available funding, and existing conditions and be complementary to any previous improvements that the properties may have already benefitted from.

The project trialled 30 properties organised across 4 groups. The properties are all terraced properties and each group has a spread of house types (2 and 3 bedrooms with differing internal arrangements). The houses all have gas central heating although many residents supplement the central heating with electric heating units in individual rooms.[7] The groups were arranged in terms of improvement measures employed as follows:

Group 1. Installation of air tightness measures without using external wall insulation
Group 2. Installation of solid external wall insulation
Group 3. Installation of dynamic external wall insulation
Group 4. Installation of thermal break technologies with window or glazing replacement and potentially Internal Wall Insulation (IWI)

Within each group, a series of complementary details were applied in an attempt to identify the efficacy of different improvements.

Initially, 35 households agreed to the trial, although ultimately only 30 households received works due to individual reasons such as health and change in employment or other personal circumstances. 5 properties agreed to act as control properties, receiving no improvement measures and acting as a comparison with improved properties.

Before and after installation measurements were undertaken as follows:

- Standard Assessment Procedure (SAP) for assessing the Energy Rating of each property
- EcoDesigner Star Environmental modelling software to assist with thermal bridge detailing
- Air Tightness Testing to BS EN 13829 for measuring the improvement in air tightness
- Thermography to BS EN 13187 to identify critical locations of heat loss
- Half hourly / hourly temperature readings in bedrooms, bathrooms, and living spaces using Hobo data loggers
- Half hourly / hourly humidity readings in bedrooms, bathrooms, and living spaces using Hobo data loggers
- Energy usage for gas from utility bills before and after installation
- A tenant questionnaire before installation and a follow-up questionnaire after installation.

7 Observed from visual inspections of each property

Summary of findings

Energy costs

• The average energy (gas) cost before installation was £698 per annum. However, 76% of those who responded in interview reported that their house didn't retain heat and 38% reported that they couldn't keep warm. This suggests that the cost for heating was limited by affordability or accentuated by excessive heat loss from the building fabric.

• After installation, the average cost was reduced by 31.5% to £475 and over 70% of respondents now report both being able to keep warm and that the houses retain heat.

Damp and humidity

• Before installation, 62% reported damp issues within the property. Visual surveys coupled with thermograph confirmed that the major damp issues were caused by condensation at key junctions. These issues were largely eradicated by controlling thermal bridging and reducing air movement within the walls. Less than 10% of occupants reported damp problems after installation.

• It is possible that after a suitable period of 'drying out', further long-standing damp issues will be resolved

Thermal comfort and resident satisfaction

• Around 25% or respondents reported perceived improvements in health. This is significant as almost 50% reported physical or mental health concerns attributable to the condition of their housing before installation began. Given that the post installation surveys were conducted only 6 months after completion, further health improvements in residents would be expected

• 50% of respondents reported saving energy as a benefit of the installation, whilst 70% reported savings on energy bills and between 80% and 90% reported improvements in the general warmth of the home, the speed at which the house warms up, the building fabric's retention of heat and an improvement in the 'quality' of the home

  - 25% of respondents recognised that the reduction in energy use within their properties could contribute to decelerating climate change

• Less than 10% of respondents reported no improvement in the quality of their homes, the building's ability to retain heat and a reduction in energy bills

Conclusions and recommendations

Conclusions

- It was possible to reduce the air leakage in no-fines housing by up to 50% by careful installation of External Wall Insulation & accompanying detailing
- There was a marginal thermal performance difference between Dynamic and Classic insulation when applied to this type of wall construction. The air leakage rate was reduced

by 38% using the classic insulation and 30% when using the dynamic insulation
- Installing spray foam insulation at key identified junctions and thermal breaks around windows and where external walls meet the ground was an effective way to reduce air leakage, with an average reduction of 30%
- Poorly fitted windows contribute to heat loss due to gaps around frames. Thermal break inserts reduce heat loss around frames as demonstrated by the before and after thermography
- Glazing replacement coupled with external thermal break detailing negates the need to replace full window units as the combined U-value was improved to 1.1 W/M^2K. This makes for less disruption compared to a full unit replacement.
- Below damp course insulation is extremely effective at reducing cold-bridging in solid floor properties
- Residents expressed great improvements in health and wellbeing
- External wall insulation alone has little impact on reducing air loss in no-fines housing
- The incidence of fuel poverty has been reduced / eliminated across the project, with an average increase in temperature during the heating season of 5°C
- The incidence of damp has been greatly reduced as identified through the post-installation tenants' surveys
- A pattern book has been produced for use by stakeholders (see appendix 3,4,5)
- Stakeholders should engage a design-led retrofit programme with in-construction and in-use monitoring to ensure a fit for purpose specification is complimented by construction quality control and tenant feedback

Recommendations

- Survey each property in order to optimise retrofit measures, use thermography, interview the residents; consider air tightness. Look at historic maintenance issues
- Look at incidence of voids, strategise accordingly, consider insulating full terraced blocks rather than individual units, even when owner-occupied units are included.
- Refer to the Pattern Book (in appendix 3,4,5) for specifications that relate to the existing conditions and opportunities relevant to the site
- Consider supplementary measures that are not necessarily covered by funding as part of a deeper maintenance strategy
- Check efficacy of works post-installation through empirical metrics and qualitative interviews
- Feed back to stakeholders and funders, disseminating successes and sharing findings

Project overview

1.1 Introduction

The project seeks to demonstrate the most efficient approach to improving the thermal comfort and affordable warmth within this no-fines concrete housing. Due to the movement of air from and between these properties, traditional approaches to installing external wall insulation have limited benefits in comparison to when installed in other solid wall properties. In order to better address the air permeability of their external envelopes, a series of constructional interventions have been derived. The goal was to test differing combinations of solutions such that the most appropriate range of measures can be specified in future projects. The solutions can then be provided dependent upon existing conditions, available funding and in complement to any previous improvements that the properties may have already undergone, thus reducing waste and minimising the disruption to tenants during works.

The project partners were The Riverside Group, Constructive Thinking Studio Architects, Caribou Construction, Insuletics & Solarcrest, using Jablite, Demelec, Quietstone, Envirovent and Pro-air products.

1.2 Aims

The project had the following aims;

- The project offers NEA and partners a deeper understanding of the possible range of retrofit improvements that may be made to no-fines housing, an often-neglected typology for housing retrofit, due to their 'hard-to-treat' nature. The key aim is therefore to test a range of measures in differing combinations in order to determine the most appropriate retrofit specification for any given scenario. The project employs and tests a matrix of small improvement measures and the project will reveal different combinations of products that can be used to develop a better retrofit approach to no-fines housing
- The project aims to reduce heat loss through the building fabric by reducing cold bridging and improving air tightness.
  - This will be achieved by incrementally testing a range of carefully detailed interventions that address key building fabric issues that were identified during pre-installation testing and environmental building information modelling
- The improvement in insulation, coupled with smaller, complimentary measures aims to show an increase in thermal comfort for residents and a reduction in their energy bills.
  - It is of interest to discover whether any improvement in thermal comfort and performance within the property is recognised through the householder feedback
- To provide stakeholders with a means to specify the most effective retrofit for no-fines properties.

o This will be achieved through the application of a design-led approach to retrofit specification outlined in a pattern book that has been developed and arranged to complement the existing conditions of differing properties – see Appendix 3,4,5

These aims will be tangibly demonstrated by trying to achieve the following targets:

- Reduce Air Change Rate from >16 $M^3/(H.M^2)$ to below 10 $M^3/(H.M^2)$ [8]
- Reduce Heat Loss, Damp and Cold Bridging through carful retrofit detailing
- Reduce fuel poverty and incidences of asthma and other environment related health issues
- Increase longevity of building fabric i.e. reduce maintenance legacy particularly with respect to damage caused through damp.
- Produce a pattern-book of options for houses in different states of maintenance and retrofit within the typology

1.3 Context

No-fines houses were constructed across Britain between the 1950's and 1970's. Based on a Wimpy formula, these properties were a rapid build, in situ concrete solution to housing shortages.[9] The basic construction consisted of 'no-fines' concrete cast into re-usable timber framework. The concrete is externally rendered and the undulating interior walls are finished with plasterboard on tanalised batten or parge plaster. Constructive Thinking and Riverside have identified that these properties are some of the coldest, dampest properties within their stock [10] and are seeking to find affordable retrofit solutions that will improve thermal comfort for tenants, reduce fuel poverty and provide an exemplar strategy for others to use.

The walls in no-fines concrete housing were formed using in-situ cast concrete that does not contain the fine aggregate that is usually mixed within the concrete. This means that the larger aggregate – gravel of 10-20mm – are bound only by a cement slurry coating. As such, connected voids are found throughout the walls. The result of this is that these house types do not behave like other solid wall properties in relation to thermal mass heat retention, air-tightness and resistance to moisture as air moves readily through and within the walls and their junctions. This project seeks to address heat loss and air tightness issues in a group of such properties for Riverside Housing Group by testing an incremental set of retrofit measures in combination and measuring their impact on heat loss and airtightness, thereby potentially reducing fuel poverty.

This project sought to address the difficult heat loss and damp issues prevalent within no-fines concrete housing. Riverside elected to retrofit 30 no-fines concrete houses in Runcorn. The team recognised that no-fines concrete houses are extremely difficult to retrofit in a cost effective way so

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8 The Building Regulations suggests that all new properties have an air tightness of less than 10 M3/(H.M2). The Energy Saving Trust suggest a standard of 5 M3/(H.M2) is desirable for naturally ventilated properties. We aim to improve our 'no-fines' properties to be better than minimum UK newbuild standards

9 The structural condition of Wimpey no-fines low-rise dwellings. BRE Report 153, 1989.

10 Ascertained from Riverside Group maintenance record review.

we trialled 4 different sets of measures in differing combinations. Monitoring took place before (baseline) and after the installation of each set of measures. Improvements were aggregated within sets in order to appraise the best combination of 'marginal gains'. The aim of the results is to inform Riverside and other stakeholders, offering a costed and measured strategy for incremental retrofit improvements for no-fines housing that can also be linked to available funding streams.

There are over 300,000 no-fines concrete houses in England and Wales and a further 6,000 in Northern Ireland [11]. As a separate exercise, we are establishing how many of The Riverside Group's stock are of this construction typology. Many of these properties are not on the gas network and are located in areas with high levels of fuel poverty. The properties inherently suffer from penetrating damp, condensation-induced damp, and coldness due to thermal heat loss through the building fabric and through air leakage. It is widely accepted that these properties are not easily improved using standard EWI solutions, and is the focus of an ongoing study in collaboration with BRE, Carillion Energy Services and other key partners[12]. Moreover, it is difficult to affectively calculate heat loss from these properties, as the density of the in-situ concrete varies from property-to-property[13].

As the main structure of the walls is very porous and air permeable, proprietary external wall insulation alone will offer limited reduction in energy use in comparison to its relatively high cost as a retrofit approach. This is because heat loss from the internal spaces into the envelope fabric is not fully contained by the external insulation, but is lost through convection / air movement within the connected voids that are present in the no-fines walls, through to the roof space, to neighbouring properties and to outside. It can therefore be demonstrated that air leakage is the principle cause of heat loss for this kind of property. A recent study[14] is expected to show that little improvement is made to air leakage using a standard EWI approach, meaning that the air within these houses needs to be reheated often. From a fuel poverty point of view, even a 25% improvement in air leakage alone will be unlikely to reduce fuel costs as many of the occupants are not currently reaching acceptable levels of thermal comfort. [15]

Given that a proprietary full EWI approach with window replacement, is likely to cost in excess of £20,000 per property[16], and cannot demonstrably improve heat loss to desired levels, it is timely to derive a different solution.

The careful design and implementation of small retrofit interventions might deliver greater improvements for reduced cost. As there is an air-percolation effect within the no-fines walls, it is not realistic to use standard heat loss calculations or SAP protocol to capture the existing challenge or test the efficacy of improvement measures. The measures trialled include: a spray-foam warm roof solution that seals the gable / party walls; Below Damp insulation; Positive Input ventilation; Passive/mechanical Ventilation and Heat recovery; Minimal EWI or thermally efficient

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11 Ross, K. (2002) Non-traditional Housing in the UK – A brief review, Council of Mortgage Lenders, Bre, Watford.

12 Results from the S-Impler Project, Carillion and BRE Consortium https://bre.co.uk/page.jsp?id=3236

13 Sommerville, J. et al, (2011) "No-fines concrete in the UK social housing stock: 50 years on", Structural Survey, Vol. 29 Issue: 4, pp.294-302

14 Results from the S-Impler Project, Carillion and BRE Consortium Consortium https://bre.co.uk/page.jsp?id=3236

15 www.eci.ox.ac.uk/research/energy/downloads/40house/chapter04.pdf

16 Sweett Group (2014) Retrofit for the Future – analysis of cost data. Innovate UK. (Extrapolated from cost per square metre)

render; Bespoke thermal break boards for new window installation; Internal Insulation Panels; Sealed Pike Party Wall Detailing.

1.4 Project timeline

This timeline sets out the timescales of the project, the technologies being tested, how they were monitored, and results and conclusions of this, resulting in overall findings regarding whether the technology is suitable for use in similar schemes tackling fuel poverty.

Figure 1 Project timeline

From March to May 2016, householders who had subscribed to the scheme were interviewed and data-loggers recording temperature and relative humidity were installed into the properties. Initial meter readings were taken and pre-commencement interviews were undertaken. During this period the properties were surveyed (measured and condition), digitally modelled using ArchiCAD[17] Building information Modelling software and assessed for thermal performance using EcoDesigner[18] software. During this period, one of the properties became vacant. It was not therefore possible to collect before and after data based upon continued occupancy and use patterns. The team thus decided to use this house as a pilot scheme to optimise installation methods for installing a range of technologies and to act as a showcase to demonstrate the technologies to the residents. The main works took place between May and September 2016 and the key post-installation monitoring period ran until May 2017.

30 houses were selected for the monitoring group and 5 control properties were also monitored.

17 http://www.graphisoft.com/archicad/ [Accessed 20.01.18]

18 http://www.graphisoft.com/archicad/ecodesigner_star/ [Accessed 20.01.18]

1.5 Attracting beneficiaries and establishing a monitored group

The Glen, Halton, is an estate of 'no-fines' concrete houses built in the 1970's using the Wimpy no-fines in situ concrete system. The Riverside Group and Constructive Thinking identified this type of housing as particularly in need of measured research for the following reasons:

• Constructive Thinking's work with BRE on the S-Impler Project (12) highlighted the need to develop a design-led approach to simultaneously addressing heat loss through air leakage and cold bridging in these typologies
• Riverside identified that they were receiving continuing reports from residents within this type of property regarding lack of affordable warmth along with dampness and maintenance issues.
• The cost of retrofit measures nationally for this typology were historically high due to the poor general condition of the building fabric that is inherent within damp properties
• Air leakage issues between properties in mixed tenure estates needs to be assessed as the potential solutions cannot easily be coordinated across different tenure types.
• Energy modelling using Elmhurst Design SAP software together with EcoDesigner suggested that by reducing air leakage, less overall insulation would be required to improve thermal comfort.

The Riverside Group identified The Glen, a 200+ house estate that had minimal prior retrofit. Riverside Group own around 40% of the stock. The remaining 60% are owner-occupied. [See map in Appendix 2]
Having selected the estate and identified the properties under The Riverside Group's control, we wrote to residents asking for expression of interest. From the response, we compiled a list of properties and Constructive Thinking / Riverside visited the residents and explained the scope of the scheme. These approaches aimed to carefully explain that the project would be testing a range of measures. Most residents asked for EWI (external wall insulation) as some of the properties on the estate had undergone similar retrofit and were visually improved. The team explained that other measures might return improved thermal comfort. The potential benefits were ultimately demonstrated to the tenants through visits to the pilot house, as outlined below.

From the 40 interested respondents we selected 35 properties from a range of 3 differing layouts and mid / end terrace positions under various orientations. The selections were separated into 7 groups with different key measures (ultimately aggregated to 4 groups). The 5 remaining respondents were reserved as a 'control' group for comparison purposes.

The retrofit interventions and measurement processes were discussed with tenants and the groupings were adjusted to accommodate factors such as:

• Excessive damp – these properties were identified as preferential for ventilation control
• Interior intervention – where tenants expressed a wish for no interior intervention, their properties were designated to groups where external works only were carried out
• Raised ground / gardens – where altering landscaping was not permissible, we designated these properties as not to receive below-damp insulation.

Just prior to the commencement of the works, one of the monitored properties became vacant (void). In the first instance this allowed us to trial a whole range of measures on an unoccupied property. We were able to conduct building forensic investigations that would not have been possible in occupied properties (such as lifting floorboards, stripping out window trims and undertaking smoke tests), taking periodic air pressure tests, opening up service risers, removing windows and panels to confirm construction and conducting smoke tests to ascertain air movement paths.

Using this property, we also trained the contractors in how to install the new technologies, ensuring that the manufacturers / suppliers were fully involved in disseminating best practice

All tenant participants were made aware of the need to keep data loggers in place in their own properties, take meter readings, complete questionnaires and allow access for air-pressure tests.

1.6 Factors affecting the planned evaluation methodology

Issue	Description and mitigation
Size of monitoring group	The monitoring group was initially to be 35 properties, aggregated into 7 groups of 5. 2 of the groups were to have internal wall insulation installed. Following 2 drop outs from ill health and some subsequent refusals for internal wall insulation (IWI) we re-arranged the properties into 4 groupings + control. See appendices 4 & 5 for the matrix overview. A pilot property was introduced following one property becoming void. This was really useful on two counts. Firstly, it enabled us to hone installation techniques. Secondly it was possible to showcase the property to the other participants.
Identification of the monitored group and control group	The project team identified the wider monitoring group in December 2015 and then the defined group in January 2016. Initially data loggers were installed into a group of 10 control properties in order to provide a 'reserve' list to cover dropouts. The pilot project helped with engagement, but also served to dissuade some tenants from window replacement and internal wall insulation due to the potential for disruption to interiors
Start of monitoring	Installations were phased between May and September due to a change in programme from inclusion of the pilot property. This was, however, helpful in shortening the contract period by a month as we reduced each individual installation from 6 to 4 weeks.
Monitored group	Recruitment of residents for the control group was not difficult as they were originally candidates for works who for personal reasons were not able or willing to have the works done at the time. The architect and the landlord's tenant liaison officer explained the value of the 'control' element of the monitoring and most residents approached were happy to take part. However, it was difficult to obtain regular utility meter readings from some of the tenants due to access issues.

System performance	The system(s) performance throughout was positive, The project team demonstrated to tenants how to use the control system for the Mechanical Ventilations and Heat Recovery Systems (MVHR), together with correct use of the existing central heating thermostat. This helped the tenants understand that they did not need to heat the house to the same temperatures that they were aiming for pre-installation, as the control is more nuanced and the rate of cooling is slower.
Meter readings	Many of the residents did not always take regular meter readings, but The Riverside Group was proactive in obtaining meter readings (including historic) wherever possible. This was achieved by tracking reporting and by undertaking regular tenant visits
Monitoring equipment	The monitoring equipment installed were Onset Hobo data loggers measuring temperature and relative humidity at prescribed intervals.
Other factors	A number of factors were identified by NEA through the course of the trials which impacted on the original methodology. NEA was able to adapt the programme to accommodate the introduction of the pilot property. This, in turn, enabled additional air pressure tests, thermal modelling and minor improvements in detailing to be introduced, enriching the overall outcomes. Several data loggers failed due to premature battery failure, and some were misplaced by the residents during the course of the study. These were replaced where identified.

Social evaluation and impacts

A sample of 40 properties were identified from the estate containing 96 Riverside Group owned properties. 5 of these properties were used as a 'control' group of unimproved properties used for comparison purposes, and 35 were identified for works. The table below identifies the property type, number of bedrooms and position within the terrace, together with the applicable group of retrofit measures to be applied to the improved properties.

Project Leader **Jon Moorhouse**

Group	Description/address	House Type	Number of Bedrooms	Terrace Type	Internal Floor Area
Group 1	**Ceiling treatment, no wall insulation**				
1	T-11	B	3	End Terrace	108m2
2	T-04	C (Handed)	3	End Terrace	110m2
3	T-03	A	2	Mid Terrace	101m2
4	T-08	B	3	End Terrace	108m2
5	T-09	B	3	End Terrace	108m2
6	T-07	A	2	Mid Terrace	101m2
7	T-14	A	2	Mid Terrace	101m2
8	T-15	B	3	End Terrace	108m2
9	T-24	B	3	Mid Terrace	108m2
10	T-12	A	2	Mid Terrace	101m2
11	T-13	B	3	End Terrace	108m2
Group 2	**External wall insulation + loft with mechanical ventilation**				
12	T-16	B	3	Mid Terrace	108m2
13	T-25	A	2	Mid Terrace	101m2
14	T-18	B	3	End Terrace	108m2
15	T-19	A	2	End Terrace	101m2
16	T-20	A	2	End Terrace	101m2
Group 3	**External wall insulation with a cavity + loft insulation with Positive Input Ventilation**				
17	T-21	C (Handed)	3	Mid Terrace	108m2
18	T-22	A	2	Mid Terrace	101m2
19	T-23	B	3	End Terrace	108m2
10	T-17	C	3	Mid Terrace	110m2
21	T-05	C (Handed)	4	End Terrace	110m2
22	T-26	C	3	Mid Terrace	110m2
23	T-27	A	2	Mid Terrace	101m2
24	T-28	B	3	End Terrace	108m2
25	T-29	B	3	End Terrace	108m2
26	T-30	A	2	End Terrace	101m2
Group 4	**Window replacement with thermal break**				
27	T-02	B	3	End Terrace	108m2
28	T-31	B	3	End Terrace	108m2
29	T-01	A	2	Mid Terrace	101m2
30	T-10	A	2	End Terrace	101m2
31	T-06	C (Handed)	3	Mid Terrace	108m2

Figure 2 House Types in Groups

The properties are a mixture of 2 & 3 bedroom units and are either orientated NW/SE or NE/SW. House type A is a 2 bedroom property whilst types B & C are 3 bedroom properties with differing arrangements. The properties are either end-terraced or mid-terraced. In order to protect the privacy of the residents, data in the study has been anonymised, each being allocated an identification number. The numbers 1-31 are the identifications following (T) in the technical reference numbers. The group sizes differ due in part to the rearrangement of groups part way through the projects, but also to reflect the range of differences in issues to be investigated. For example, there are more combinations of measures in Group 3 than Group 1. Group 4 is small because of the refusal by participants to accept internal wall insulation due to the potential impact on their interiors.

Figure 3 Typical ‘No fines’ terraced property, indicating the terraced and stepped nature of many of the properties together with the impact of outriggers on the front / rear of properties.

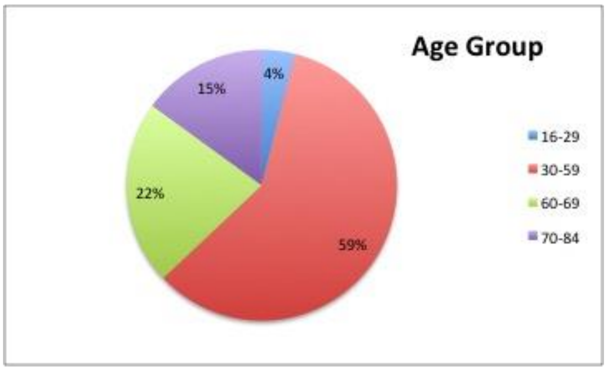
Figure 4 Extract of site layout showing arrangements of terraced blocks. Note the block sizes, stepped arrangements and outrigger positions.

2.1 Qualitative feedback from initial questionnaire

The residents were interviewed via qualitative questionnaires before and after the installation. The interviews were led by The Riverside Group and NEA. Responses to questions regarding householder demographics, residents' views, their acceptance of the technology, together with responses to questions regarding immediate findings and changes, are set out in the sections below. All graphs are derived from the compilation of pre-installation or post-installation survey responses.

Householder demographic details

The majority of interviewed householders in the monitored group were between the ages of 30 and 59. Over a third (37%) were over 60 years old (Figure 5). The survey did not capture the age of other residents within the properties. Figure 6 shows that just under half (48%() of respondents were in full time work. The next largest group were retired at 38% with 14% either unemployed or not working.



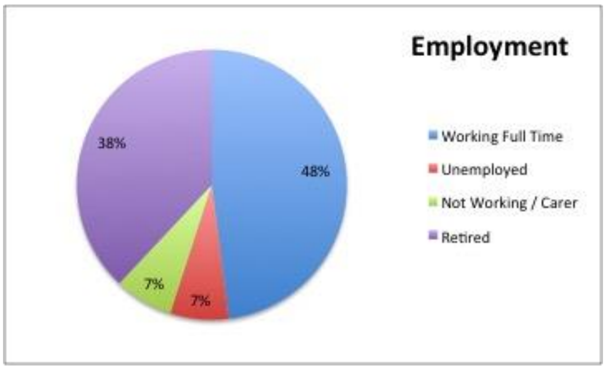
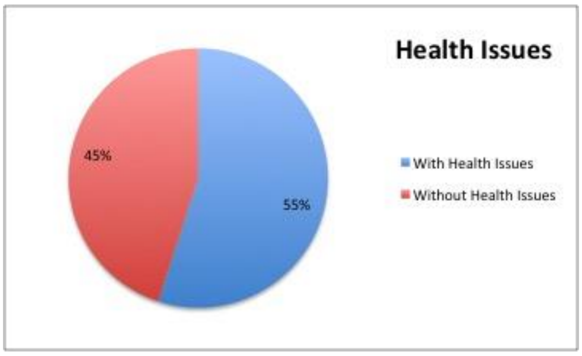


Figure 5 Age brackets of respondent occupants

Figure 6 Employment status of respondents.

Over half of respondents reported health issues and 37% of all respondents reported that their health issues are affected by the cold. (Figures 7 & 8)



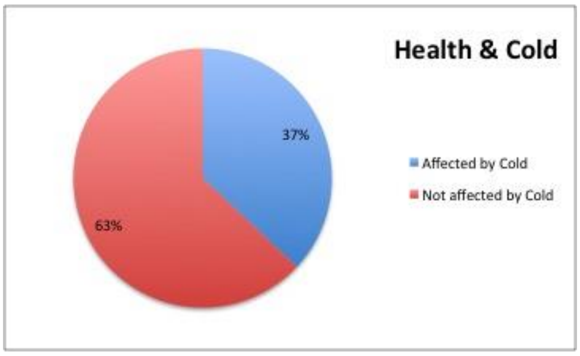


Figure 7 % of Respondents reporting health issues

Figure 8 % Respondents reporting effect of the cold.

Almost two thirds of the properties with survey respondents had 3 bedrooms, whilst a third of the properties had 2 bedrooms and just 1 property had 4 bedrooms. Most properties had 1, 2, 3 or 4 occupants, with 1 property having 6 occupants and 1 with 7. Almost half of the properties were only occupied by 1 or 2 people, with just under a third occupied by 3 people.

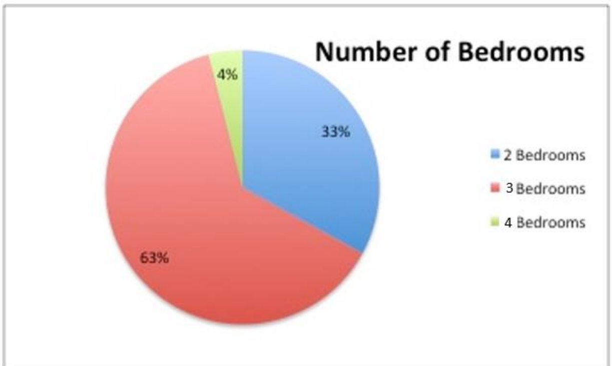


Figure 9 Number of bedrooms in the properties

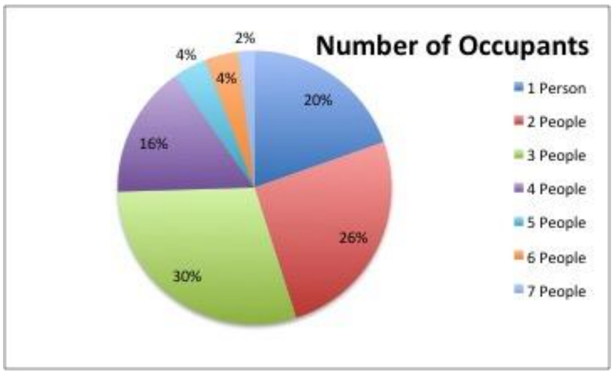


Figure 10 Reported occupants per property

2.2 Affordability of energy bills

19% of occupants had their Gas Central Heating running permanently, whilst a further 23% used their heating all day. 29% used their central heating morning and evening with 10% evening only. (Figure 11)

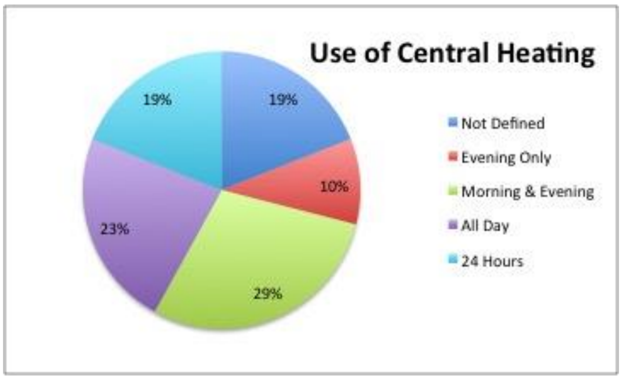


Figure 11 Times of use of Gas CH prior to installations

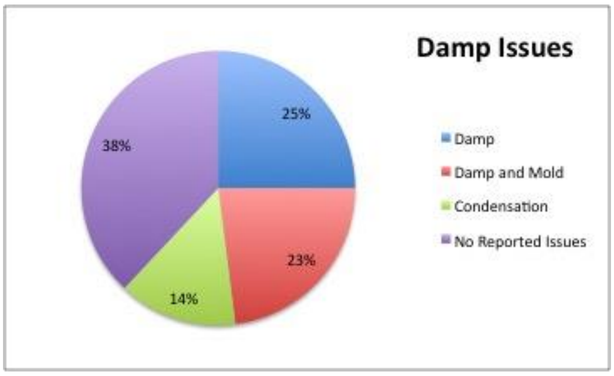


Figure 12 Reported damp issues before works

The majority of residents reported some kind of damp-related issues regardless of occupancy level; almost half of the respondents reported damp issues with a quarter also reporting incidence of mould. 14% separately reported condensation with just 38% reporting no moisture issues (Figure 12). The absence of damp appears to correlate with the all-day use of heating (Figure 11) with the only exceptions being T29 and T30, who reported both extensive heating use and damp issues.

Qualitative feedback given pre-installation of the ventilation and insulation measures

Pre-installation, 62% of residents reported that they could keep warm, and 38% reported that they could not keep warm (Figure 13). Similarly 60% related that they were satisfied they could keep the house warm during periods of cold weather, whereas 40% could not (Figure 14). Only a third of respondents were satisfied with the way in which the building fabric retained heat, whereas two thirds expressed dissatisfaction.

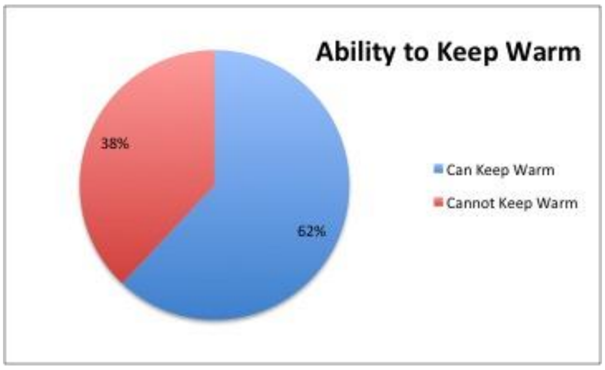


Figure 13 Reported warmth issues before installation

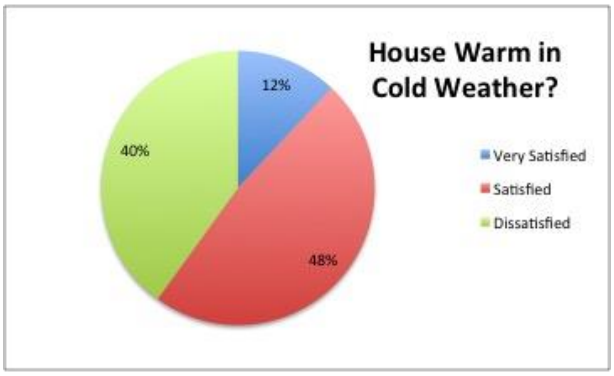


Figure 14 Warmth in cold weather before installation

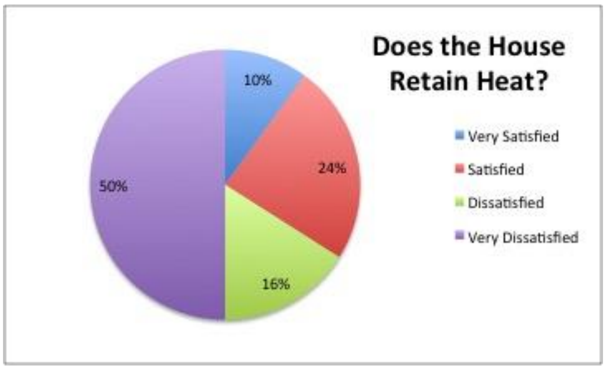


Figure 15 Building fabric warmth issues before installation

Figure 16 suggests that almost half of the respondents reported that maintenance and repair issues cause concern. According to the Riverside Group (maintenance log data) and to the residents (interview data) many of the maintenance issues are chronic and related to cold and damp ingress. That is to say issues, such as re-decoration and re-plastering, tend to be required periodically. As outlined in the section above, the questionnaire results bear out this finding. Furthermore 25% of respondents reported that their inability to keep warm affected their mental health whilst 35% reported that the cold affected their physical health. 60% of households reported that they worried about paying fuel / utility bills and a similar number kept their heating lower than they would like in order to reduce the cost of bills. 60% of households also indicated that paying fuel bills impacts on the amount of money available for purchasing food.

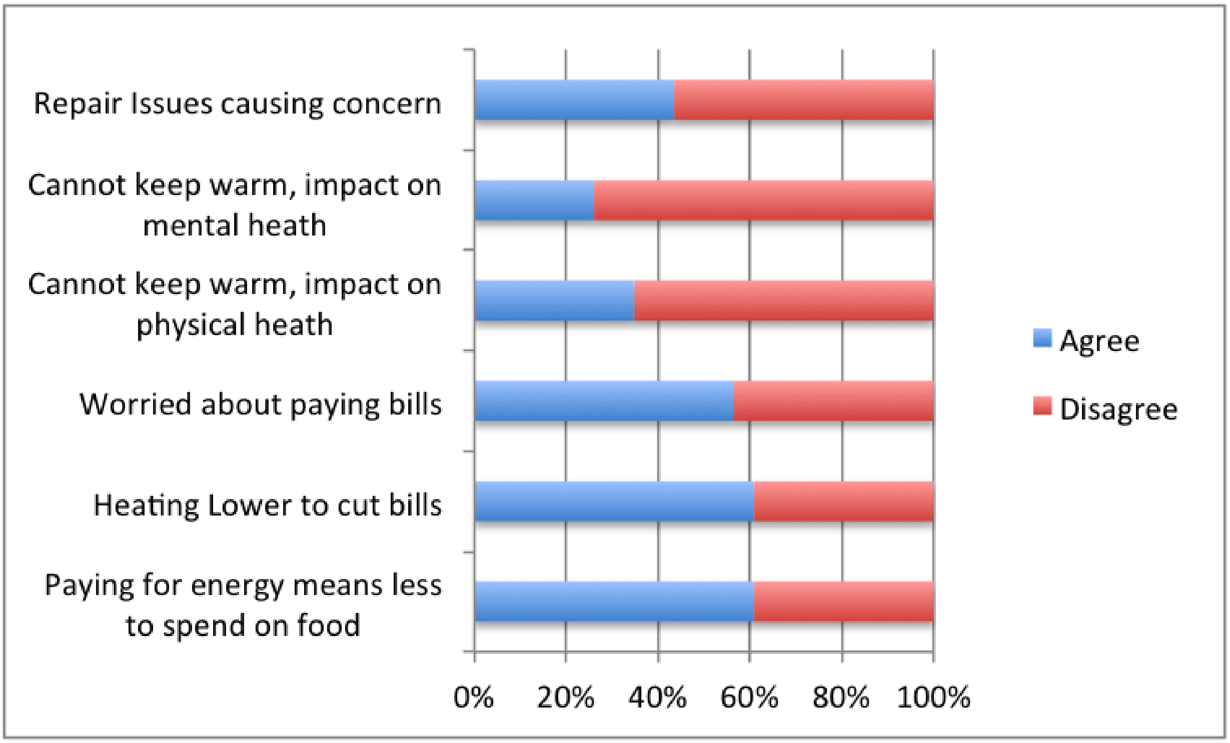


Figure 16 Comparative Impact of warmth issues on occupants before works

Whilst the information collected through the survey cannot accurately assess the prevalence of fuel poverty due to the absence of income data, the patterns of heating use, lack of ability to keep the houses warm, reporting of damp issues and the suggestion that paying for energy means less to spend on food suggests that high fuel poverty levels exist within the sample.[19]

19 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/639118/Fuel_Poverty_Statistics_Report_2017_revised_August.pdf [Accessed 20.01.18]

2.3 Resident acceptance and satisfaction

After completion of the works, over half the households (54%) reported that their houses were less damp (Figure 17). This is in fact more than reported damp issues in the initial survey (Figure 12). One of the respondents reported an increase in damp which could be accounted for by the reduction in air permeability and a lifestyle previously compatible with an extremely draughty property, or potentially not using the ventilation system properly.

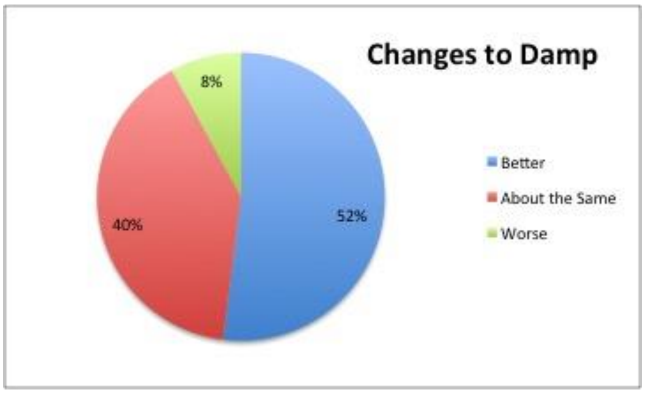


Figure 17 households reporting change incidence of damp after works

84% of occupants report being able to keep warm (increased from 62% before measures were installed), 16% reported not being able to keep warm and were dissatisfied with the performance of the property. Interestingly, of the 4 who responded in this way, (T02, T04, T06, T15) none had benefitted from EWI installation and only had received measures designed to reduce air-tightness, and therefore the need to reheat air.

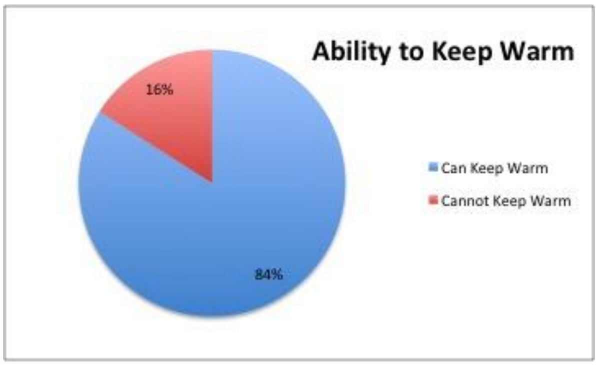


Figure 18 Keeping warm after installation installation

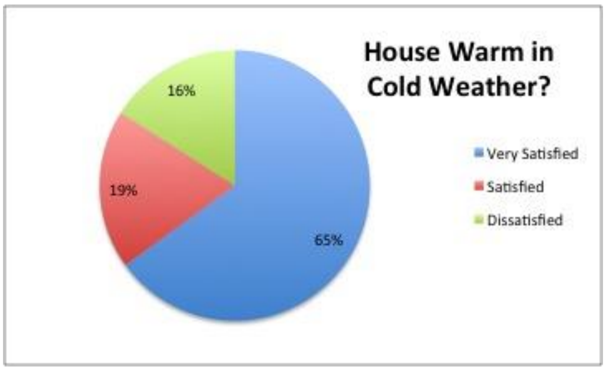


Figure 19 Satisfaction with warmth during cold weather after

96% responded that the heating system was easy to use with only 4% being dissatisfied with the installation (Figure 20)

Over three quarters of residents (76%)now consider that the house adequately keeps the heat in (Figure 21). This is in comparison to 34% pre-installation. (Figure 15)

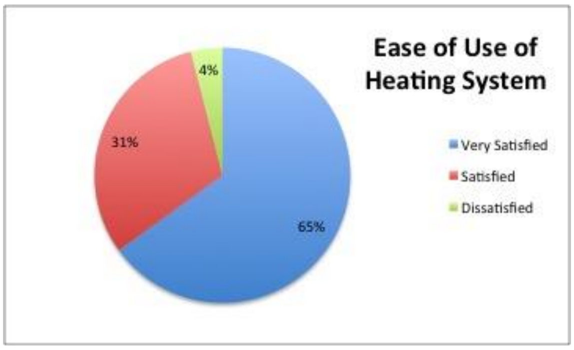


Figure 20 Use of heating control after installation

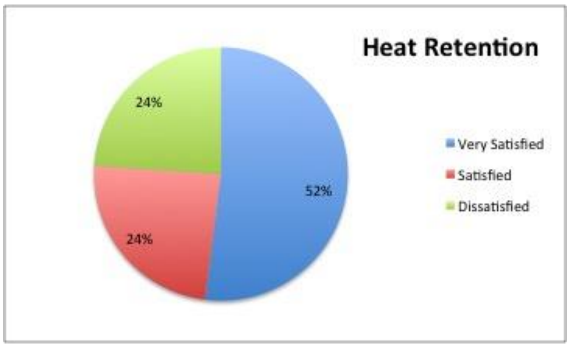


Figure 21 Perceived Heat retention after installation

2.4 Ease of use and reliability

78% of respondents now consider the cost of running the heating system to be acceptable (Figure 22), up from 30% prior to installation. This is significant as it suggests that 78% of households are achieving affordable warmth levels. It does not necessarily correlate that the remaining 22% of households do not experience affordable warmth as this was not the framing of the question, but they remain dissatisfied with the cost of their heating which could suggest a lack of affordable warmth, more detail would need to be gleaned to be conclusive on this point.

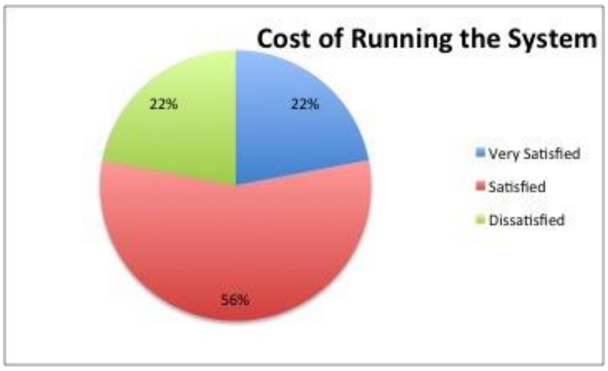


Figure 22 Cost of running the system after installation

2.5 Perceived comfort and benefits

Post installation (Figure 23), a similar proportion of respondents used their central heating all day in cold weather (30% as before). This appears to correlate with those that were not working and are at home in the day time (pre-installation questionnaire). The largest section of respondents now only used the central heating 'as needed'. 77% stated that they adjusted the central heating on a daily basis (Figure 24). 65% now set their thermostat to between 18 & 21°C (World Health Organisation Recommendations[20]), which appears to demonstrate that the systems are working as

20 http://www.eci.ox.ac.uk/research/energy/downloads/40house/chapter04.pdf [Accessed 20.01.18]

intended i.e. to increase thermal comfort within the residents homes. (Fig. 26)

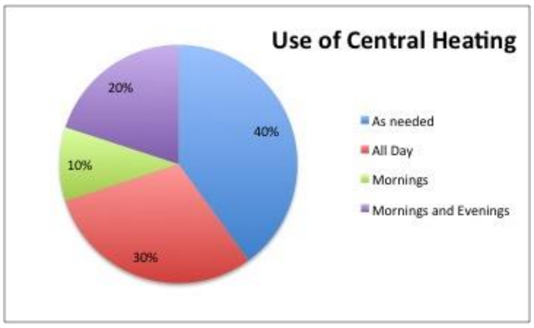


Figure 23 Use of central heating

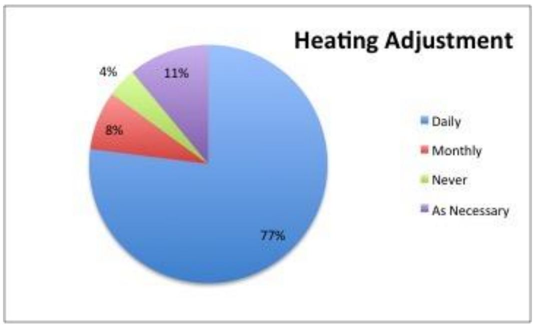


Figure 24 Cold weather adjustment of central heating

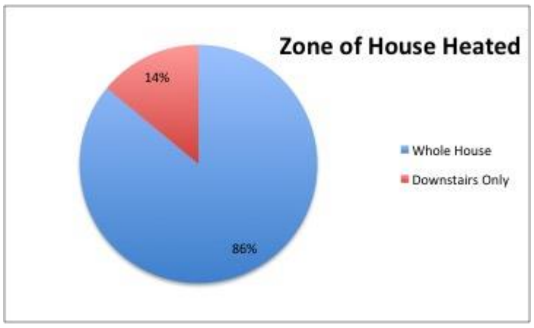


Figure 25 Zone and temperature settings

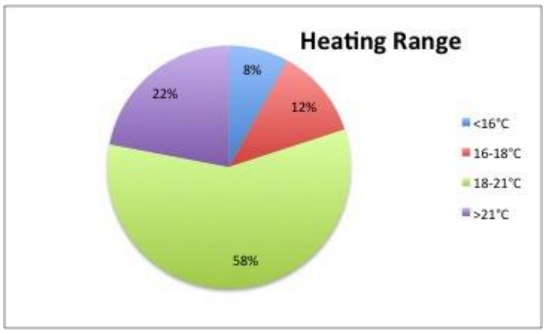


Figure 26 TLR setting temperature range

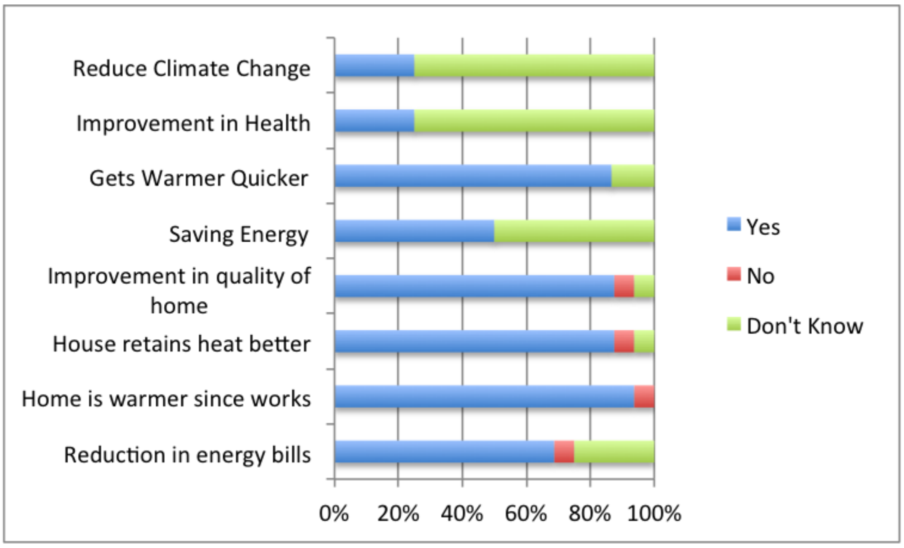


Figure 27 Perception of benefits post installation

25% of respondents recognised that the reduction in energy use within their properties could contribute to decelerating climate change. (Figure 27) Around 25% or respondents also reported perceived improvements in health. This is significant as almost 50% reported physical or mental health concerns attributable to the condition of their housing before installation began. 50% of respondents reported saving energy as a benefit of the installation, whilst 70% reported savings on energy bills and between 80% and 90% reported improvements in the general warmth of the home, the speed at which the house warms up, the building fabric's retention of heat and an improvement in the 'quality' of the home. Less than 10% of respondents reported no improvement in the quality of their homes, the building's ability to retain heat or a reduction in energy bills.

Again, in terms of measuring a reduction in fuel poverty, whilst we are unable to conclusively state whether (by definition) fuel poverty has reduced, 90% of respondents suggested that their homes are warmer since the works and 82% now suggest that paying for energy does not influence food purchase (improved from 40%) suggests that at least we have enhanced residents ability to keep affordably warm.

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Technical evaluation and results

3.1 Overview of technology

The careful design and implementation of small retrofit interventions might deliver greater improvements for reduced installation cost when compared to current costs of larger stock improvement schemes. As there is an air-percolation effect within the no-fines walls, it is not realistic to use standard heat loss calculations or SAP protocol to capture this existing challenge or to test the efficacy of improvement measures. Instead, a combination of thermal modelling, thermography, air pressure tests and recording of temperature, relative humidity and energy usage have been employed.

The retrofit measures include: a spray-foam insulation warm roof solution that seals the gable / party walls; Below Damp insulation; Positive Input ventilation; Passive/mechanical Ventilation and Heat recovery; Minimal EWI or thermally efficient render; Bespoke thermal break boards for new window installation; Internal Hemp Insulation Panels; Sealed Panel Party Wall Detailing. Implementing these measures to complement the existing dwelling condition addresses the challenges of heat loss through conduction when combined with heat loss due to air percolation.

Technologies:

Demelec Sprayfoam Insulation [DEMILEC APX® 1.2][21]
Demelec Sprayfoam is a non-polyurethane (PU) soft-foam open-cell insulation with a declared thermal resistivity of 0.039 W/M^{2}K R-value that expands on application to provide an airtight but vapour permeable barrier to 'hard to treat' areas. This product was applied to the underside of roof, into the eaves, across gables and part walls within roof voids.   Demelec is relatively new to the UK market and is not yet widely recognised for its air tightness qualities. It has a water vapour resistance factor of 6[22]

Figure 28 Installing Demelec Insulation

21 Demelec APX 1.2 is a two part semi-rigid water-blown foam system http://www.demilec.com/documents/Tech-Library/Demilec-APX-1-2/Update/Demilec-APX-1.2-TDS.pdf

22 The Water Vapour Resistance Factor is a dimensionless unit that measures a material's reluctance to let water vapour pass through it in comparison to air. Here we seek a balance of water-vapour permeability and airtightness.

Q-Clad below damp insulation plinth

Q-Clad Plinth is a pre-finished foamed-glass bead insulation board specifically designed by Quietstone [23] for below-damp course applications. Research from the Building Research Establishment (BRE) suggests that un-insulated below damp walls are a significant cause of heat loss. These areas of the external envelope are frequently ignored in EWI schemes as installation is difficult and there are concerns about vertically bridging a damp course causing rising damp. Q-Clad is a new technology designed to address this issue. Q-Clad, a derivation of Quietstone Light, is manufactured from recycled foamed glass beads and has an R Value of 0.08 W/M^2K and is a Class 0 fireproof product.[24] It is not damaged by moisture and can be pre-finished to assist installation. Difficulty in fixing and rendering below damp insulation is the reason for its omission on many schemes.

Q-Clad Cold Bridge Thermal Break

It has been observed through site measurements that the window apertures in 'no-fines' concrete houses are rarely uniform, differing by as much as 30mm in width and height across the same opening. Moreover, they often vary in size from front to back. Window replacement on larger stock schemes tend to use standardised units for economic and logistic reasons. This implies that the smallest regular aperture size across a group is used for frame sizing. The residual gaps – often up to 40 mm when combined across a dimension, tend to be covered by uPVC trims. This means that the windows are very draughty and that the efficacy of the frame and glass are compromised. The detail developed for this issue has been to introduce a slender thermal break from the outside wall retuning into the frame edge, and then foaming into the remaining gap. This measure is combined with replacing the glazing with a high performance double glazed unit (U-value 1.1 W/m2K), leaving the frame and internal decoration intact.

Q-Clad Thermal Break is a structural foamed glass bead insulation board developed by Quietstone[(19)] for uses as a thin profile window liner. Its purpose is to provide a thermal break to solid wall window replacement installations without reducing the area of glazing. The required slenderness of the retrofit measure necessitates use of a structurally stable material that does not fracture during installation. The product is a new technology designed to address this issue.

Figure 29 Quietstone Q-Clad Pre-rendered below damp insulation & Window thermal break board

23 http://www.quietstone.co.uk/product/quietstone-expanded-glass-beads/ accessed 28/12/2017

24 A Class 0 fireproof product meets the Class 1 resistance to surface spread of flame together with BS476 Part 6 against fire propagation – limiting the amount of heat a material adds to a fire.

Jablite Dynamic External Wall Insulation

Jablite Dynamic EWI[25] [26]is a two layer vented insulation product that uses the heat energy conducting through the walls to warm air that is brought in through a channel at the bottom of the insulation. The air is brought into the property via a Passive Input Ventilation System connected to an air plenum at eaves level. The input air temperature is naturally raised by 7°C when the external temperature is more than 10° below the internal air temperature. The benefit of this measure is that ventilation is pre-warmed and the thickness of EWI required is significantly reduced. This insulation is to be installed in conjunction with Insuletics Render Systems, inclusive of thermal break treatments for satellite dishes, porch canopies and meter boxes. Jablite Dynamic with Envirovent PIV[(23)] is a new technology particularly suitable for a retrofit installation that improves air tightness.

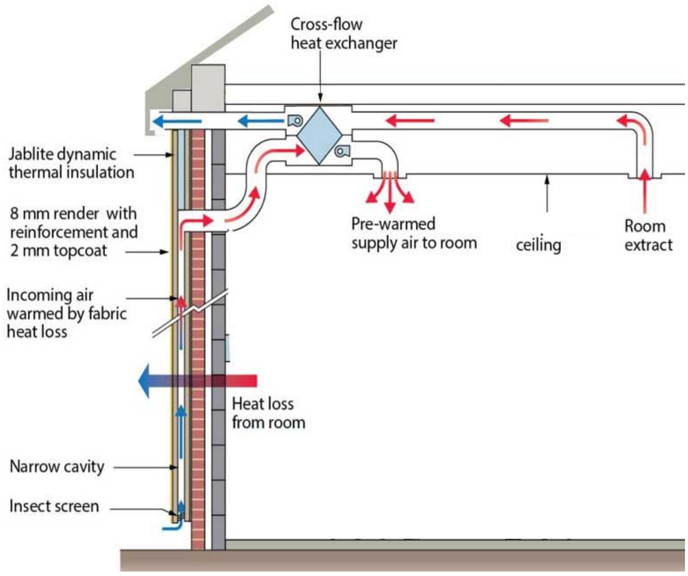


Figure 30 Jablite Dynamic Insulation Installation & ventilation regime diagram

Jablite Classic EWI

Jablite EWI is a standard, cost effective EWI system. It has been specified as a control comparison for installation within this project as it is in keeping with the majority of standard EWI installations. It is used on Group 2 houses. This insulation is to be installed in conjunction with Insuletics Render Systems using the same render products as the Dynamic system described above.[27]

25 https://www.jablite.co.uk/news/jablite-dynamic-insulation-cpd-materials-2017/ accessed18th September 2017

26 https://www.jablite.co.uk/news/jablite-dynamic-insulation-cpd-materials-2017/ accessed 28th December 2017

27 https://www.jablite.co.uk/application/jablite-external-wall-insulation/

Figure 31 Jablite Classic Insulation Board

EnviroVent PIV[28]

EnviroVent Positive Input Ventilation (PIV) is a centrally-located, loft mounted unit that supplies filtered air at a controlled rate. This technology compliments the Jablite Dynamic insulation as the input air is pre-warmed. The input air for the unit is connected to the eaves collection plenum for the insulation system and the associated input an extract ductwork is ducted through the central store / cylinder cupboard and adjacent ceilings.

Figure 32 Envirovent MVHR unit and installation diagram showing typical location of vents

EnviroVent MVHR [29]

Envirovent Mechanical Ventilation and Heat Recovery (MVHR) is a whole house ventilation system suitable for retrofits with increased air tightness. The ability to mechanically preheat input air in

28 http://www.envirovent.com/specifier/products/positive-input-ventilation/

29 http://www.envirovent.com/specifier/products/heat-recovery-systems/

addition to reusing heat exchanged from the output air will assist with overall thermal performance. Two types of unit were trialled. The larger type included outputs to the bedrooms and key living spaces and intakes from the kitchen and bathrooms. The simpler type removes air from the utility spaces and inputs to the hall and landing. This simpler type, whilst costing less, is ideal for where minimal disturbance to decoration is required by the tenant. Installation cost of the simpler unit is significantly less.

Pro-Air MVHR [30]

Pro-Air MVHR units are designed for larger / colder properties and provide an alternative to Envirovent MVHR in terms of flexibility and efficiency.

Figure 33 Pro Air MVHR

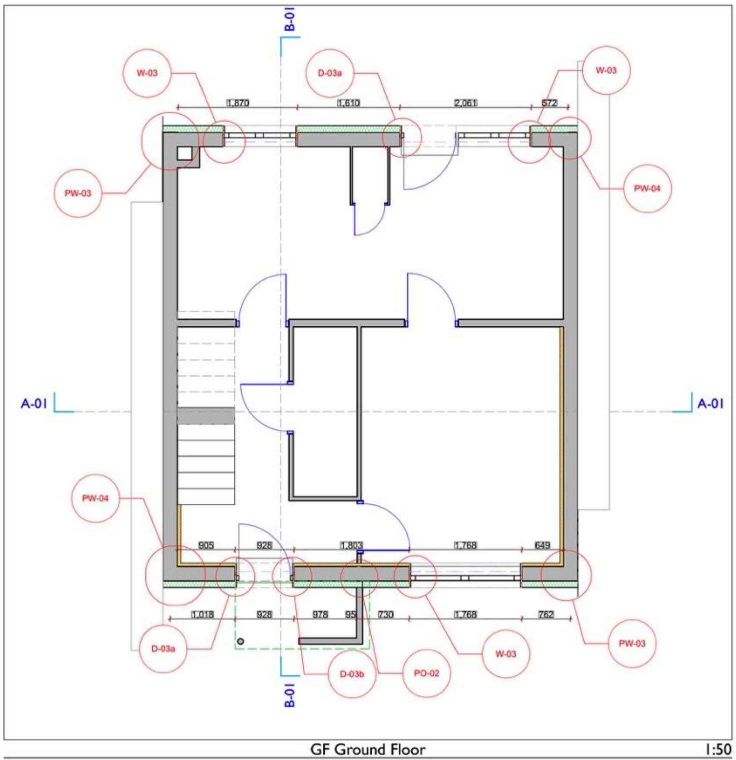
Glazing

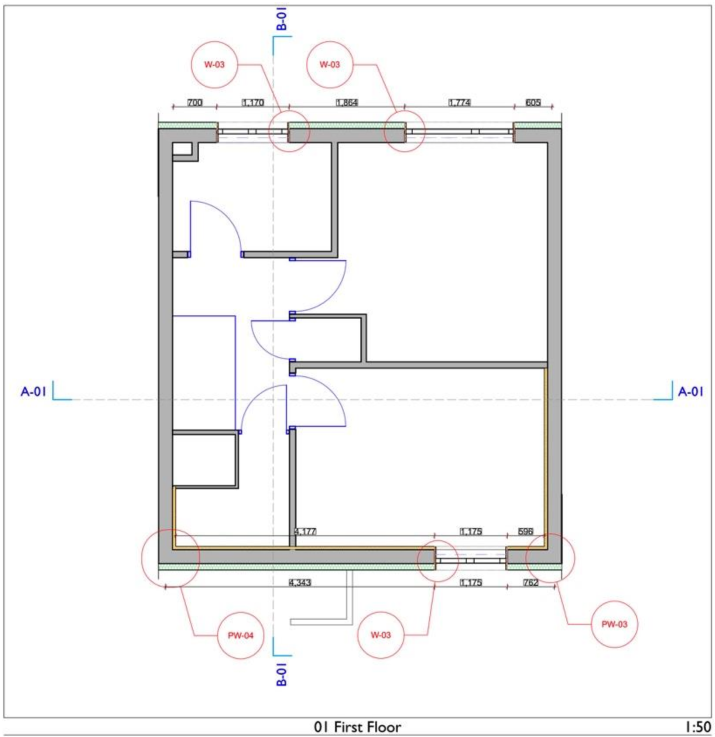
Units with an estimated Uw Value of 2.0 W/M^{2}K were replaced with units offering 1.1 W/M2K. In situation where the frames could not be replaced, the glazing alone was replaced providing a reduction to 1.4 W/M^{2}K for the glass only, but a Uw of 1.4 W/M^{2}K when the frame and thermal break complementary technology is taken into account.

Appraising Technological Challenges

Cold-bridging issues occur in no-fines properties where solid floors meet the solid walls below the Damp Proof Course (DPC). Steel angles joist supports and denser concrete at chamber level also create cold bridging, as do the solid reveals around windows and doors. These areas are particularly susceptible to condensation and damp. Air movement through the connected voids – spaces between the aggregate that is the main structure of the concrete (see fig 37 below) within the solid walls means that warm air from interior spaces percolates rapidly into the loft void above the existing insulation at ceiling level.

30 http://www.proair.ie





Details

D-03	Vertical Door reveal thermal break
W-03	Vertical Door reveal thermal break
PW-03	Vertical Party Wall detail
PW-04	Vertical Party Wall detail
PO-02	Porch Junction Detail

Figure 34 Type 'A', 2 bedroom mid terrace floor plans. (Key cold bridge details that were identified using thermography are highlighted by red circle marks and illustrated in the appendices)

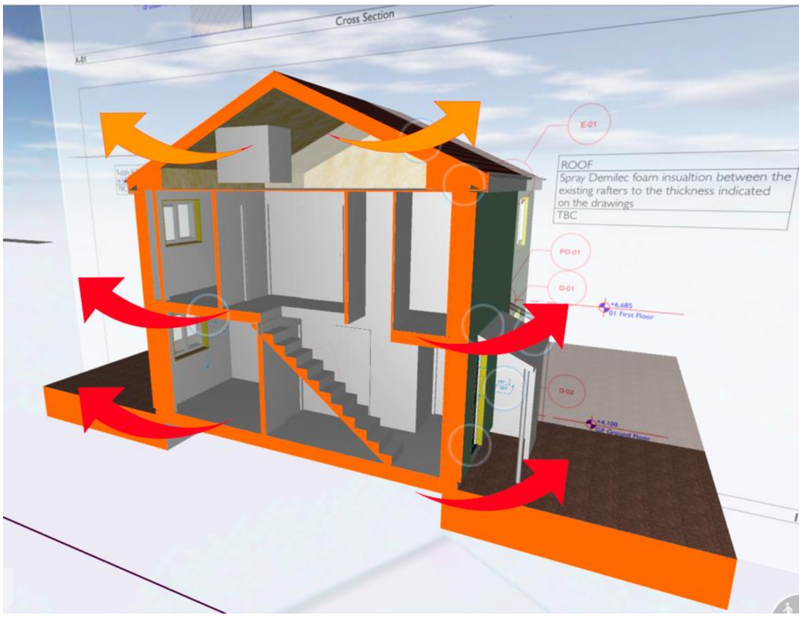


Figure 35 Section showing key areas of heat loss at cold bridge points identified through thermography

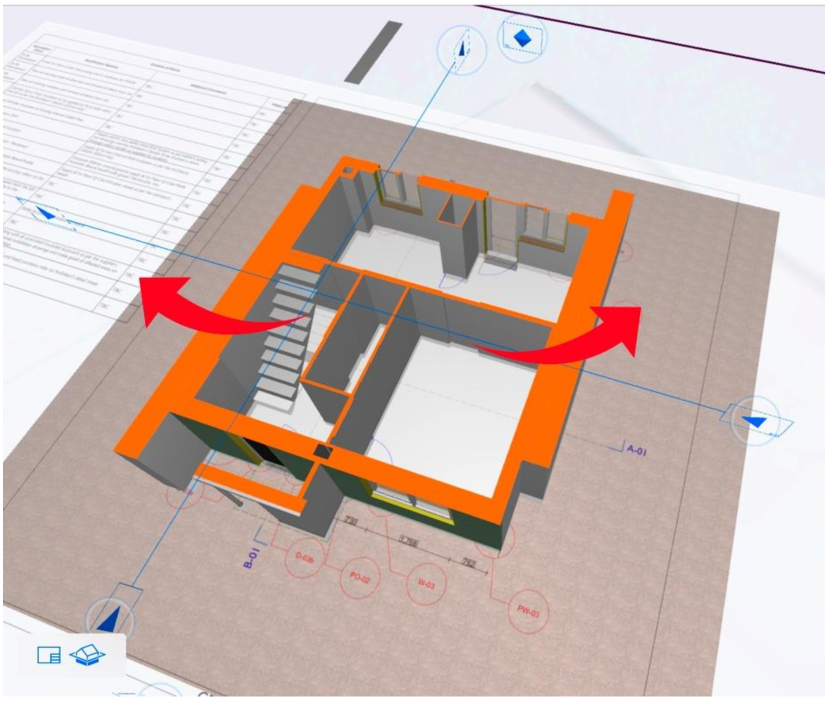


Figure 36 Plan showing key areas of lateral heat transfer to neighbouring properties identified through thermography and modelling

The majority of properties have parge-plaster coats to the interior of external concrete walls within the habitable spaces. However, air leaks into the walls through sockets and other apertures and, together with air heated through conduction, percolates through to adjoining properties as well as to outside. The party walls in the loft spaces tend to be bare concrete meaning that any air escaping into the walls from heated rooms, or via conduction-convection transfer, can easily leak into the roof space. This increases air transfer between properties.

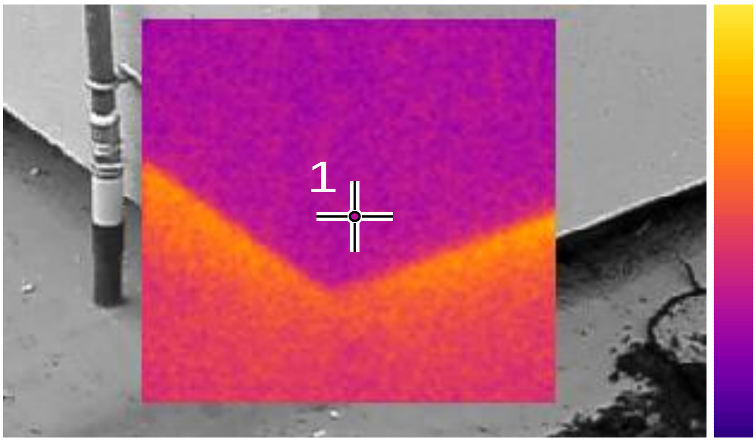


Figure 37 No Fines concrete exposed in the wall

Figure 38 Thermo-graphic image showing area of cold bridging below the DPC. The band of colour at the side denotes temperature from warm at the top (yellow) to cooler at the bottom. In this instance there is an overall temperature difference of 3.5°C

3.2 Technological monitoring

The core monitoring strategy was developed to provide parity with other NEA projects from this scheme. This included:

• A series of qualitative surveys collected by interviews with householders both before and after the installation
• Data loggers reading temperature and relative humidity were installed prior to works and remained for a period beyond completion
• Gas meter readings were taken throughout the duration of the project and monitoring period to capture central heating fuel usage

Supplementary monitoring was included to assist developing and optimising the detailing and measuring of the key changes in heat loss and air tightness. This included:

• 3D scanning of the building form to capture dimensional anomalies
• Parametric Computer Modelling for energy assessment and 'on the fly' optimisation of cold bridge / thermal break detailing
• Thermography
• Air Pressure testing

Baseline and Post Installation Monitoring

Monitoring was conducted in order to establish the efficacy of each range of measures, and their individual / combined effect on heat loss and air tightness.

All properties were to be evaluated in the current condition and modelled to provide a baseline for research. Each of 3 property types and their variants were surveyed using ArchiCAD BIM software[31] (see Appendix 3). As the software is fully parametric, each construction element could be imbued with thermal performance data, allowing us to model heat flow, dew-points and cold-bridging as required. Current thermal performance was then modelled using EcoDesigner [32] and compared data with our SAP modelling and will ultimately compare data from utility (energy) bills. Thermographic surveys were undertaken on all properties and performed air pressure tests on 10-15 properties across the sets before and after installation. Data loggers were used to record temperature and humidity in 3 locations (master bedroom, bathroom and living room) within each property, capturing changes before and after installations.

Using the methodology above it was possible to capture a comprehensive data set of current building performance in order to inform the design of each alternative measure whilst setting a baseline to measure empirical improvements. The team thence undertook *qualitative* surveys to establish existing thermal comfort and fuel usage / occupancy patterns and attitudes from the tenants' perspectives. The primary aim of the overall monitoring methodology was to measure incremental improvements in thermal comfort, heat loss reduction, and incidence of damp, air tightness and fuel use. Data logger results, utility costs, air pressure tests and thermography were used in conjunction with post-completion qualitative surveys to build a picture of outcomes.

Monitoring equipment & thermal modelling

A sequence of before and after construction-monitoring strategies were used to assess energy use, heat loss, air tightness, cold bridging and detailed design. The following monitoring equipment was used on the project:

Thermal data loggers

Onset's HOBO MX1101 Dataloggers[33] were used to record the temperature and humidity inside the property every hour. Three thermal loggers were installed in each of the monitored homes, with one placed in the kitchen, one in the main living space and one in the bathroom. The data from the loggers then enabled comparison of room temperature and relative humidity in rooms before and after the installation works.

31 ArchiCAD is a Building Information Modelling authoring software for architectural design.

32 EcoDesigner is an 'add-on' for ArchiCAD that facilitates on-the-fly environmental optioneering, allowing the optimisation of detailing to minimise cold bridging and overall heat loss.

33 http://www.onsetcomp.com/products/data-loggers/mx1101

Figure 39 Onset Hobo Data Logger

Thermography

A Flir B50[34] thermal imaging camera was used according to BS EN 13187 to identify thermal bridges, air flow within the walls and areas at risk from condensation, mould and damp. Details identified through this process were modelled and addressed using Graphisoft's ArchiCAD[35] Building Information Modelling Authoring Software and Ecodesigner[31], a software add on to enhance energy modelling capabilities. The ArchiCAD (BIM) and EcoDesigner (Energy Modelling) outputs were calibrated with baseline Air Pressure tests and Thermography. The empirical results could thence form a basis to inform decision making for this and future stock improvements in a way that could be strategised to incorporate progressive maintenance that can respond to funding and policy opportunities.

Figure 41 Flir B50 Thermal Imaging Camera in action

Thermal Modelling

The surveyed properties were modelled in ArchiCAD BIM authoring software in order to produce drawings, details and schedules. EcoDesigner software was used to test the thermal properties of the junction details identified through the initial thermography highlighted in Figure 34. Figure 41 illustrates the software in action, whereby a window reveal detail is optimised by careful positioning

34 http://www.flir.com/legacy/view/?id=52337 accessed 1st January 2018

35 http://www.graphisoft.com/archicad/ accessed 1st January 2018

of insulation and thermal break boards. The left-hand detail is the wall in its original state showing the cold (blue) penetrating through the wall to the interior. The next two details show the effect of insulation in making the wall a useful thermal store and minimising the cold-bridging at the window junction.

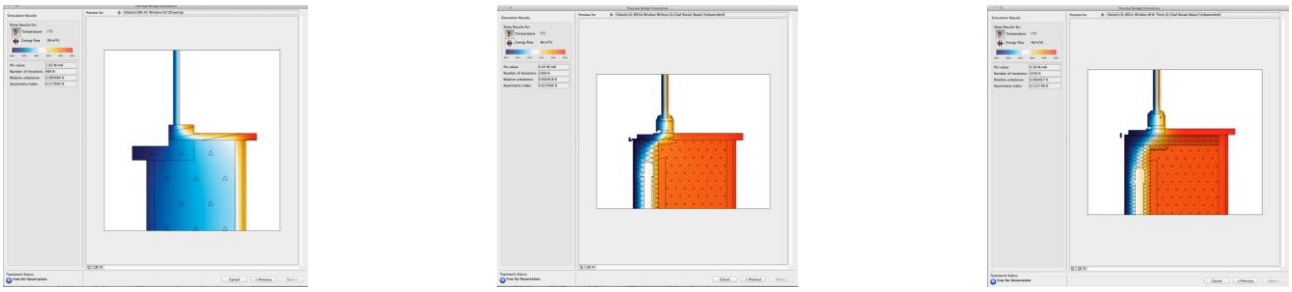


Fig.40 Modelling proposals for insulated window sill details in EcoDesigner – Optimising the design 'on the fly'.

Air Pressure Tests

A sample of properties had air pressure tests carried out before and after the installation of measures. Peak Acoustics[36] carried out the key tests in accordance with ATTMA TS1[37]. The properties are de-pressurised to create an air pressure differential of 50 Pascal (50N/m2) between the inside and outside. The air leakage rate per hour per square metre of building envelope area at the test reference pressure differential is then measured. It is possible during these tests to identify the main location of air infiltration / leakage as the pressure differential causes noticeable airflow. The tests were carried out across 15 properties with interim testing on the first trial (pilot) property to assist with optimising detail installation, in particular the spray-foam insulation.

Figure 42 Air Pressure test equipment showing the door seal and depressurisation fan

Meter Readings

36 https://www.acousticsurveys.co.uk/air-testing/ accessed 11th December 2017

37 https://www.attma.org

Gas and Electricity meter readings were taken throughout the duration of project and for a period after completion. As the central heating in all properties was gas-fuelled, analysis of gas usage has been used to assess the fuel savings made. Residents were asked to record meter readings on a fortnightly basis. Where this did not take place, The Riverside Group obtained data from the relevant utility companies with permission from the residents. Several residents had smart meters installed during the project. Energy use was adjusted using degree day data to compensate for different climatic conditions between the before and after measure heating periods, using accepted analytical techniques.

Property Type	Monitoring Equipment	Number of properties
Monitored	Hobo Thermal data loggers – three for each monitored property	30
Monitored	Thermography (before and After)	20
Monitored	Air Pressure Tests Before and After	12
Monitored	Air Pressure tests during construction	1
Control	Hobo Thermal data loggers – three for each control property	5
Control	Thermography	5
Control	Air Pressure Tests	3

Figure 43 Table of monitored properties

1 of the 30 properties became vacant before work began. Whilst this meant that we would be unable to interview the same tenant before and after renovation, it did allow us to retrofit this property as a pilot and perform air pressure tests and thermography during the works, thus optimising some of the details before they were carried out on other properties.

Monitoring results – Measured as installed, following review of pilot void property

The trial properties were divided into four groups according to the types of measures applied. Traditionally these properties would be retrofit using external wall insulation. The four groups are arranges to explore complementary or alternative approaches centring on improving air-tightness.

Originally, 7 groups had been proposed with the aim of increased incremental testing of ancillary and complementary details alongside the key component measures within each group. The base metrics quickly demonstrated that it would be difficult to determine the efficacy of individual measures in this way due to the massive air leakage coupled with the differing occupancy patterns within the dwellings. The opportunity to trial a raft of measures on a pilot property meant that we could increase the frequency of air pressure tests during construction as work proceeded on this house, offering a richer insight into the incremental benefits of combined details. The tenants also refused internal wall insulation (IWI) due to the intrusive nature of the install. This also influenced the regrouping of houses.

Group 1

The first group trialled measures that sought mainly to address air-tightness without the inclusion of EWI. These details include installing spray foam insulation at key junctions (Figure 34) where initial airtightness tests suggested that air leakage was prolific. Application locations included eaves level - where the tops of the no-fines concrete walls were open; underneath the roof plane, or above first floor ceiling level; at gables and at party pike-walls. These walls were generally left as exposed concrete following construction. MVHR with ductwork to each room was trialled; a reduced MVHR system was also trialled with extracts in the key utility spaces (kitchen and bathroom) and inputs in the circulation spaces only; and a Positive Input Ventilation system

Group	Description/ID	Plot	House Type	External Treatment	Air Tightness Measures	Complimentary Tech	Seal @ Eaves	Internal Gable Pike Treatment	Window Treatment
Group 1	Ceiling treatment, no wall insulation								
1	T-11	2	B	Existing Render Only	Ceiling Level Demelec Sprayfoam	MVHR (full system)	TRUE	Render	Replace Glazing Only
2	T-04	3	C (Handed)	Existing Render Only	Ceiling Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	Render	None
3	T-03	4	A	Existing Render Only	Ceiling Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	None	None
4	T-08	2	B	Existing Render Only	Rafter Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	Inject Demelec Sprayfoam	None
5	T-09	2	B	Existing Render Only	Rafter Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	Inject Demelec Sprayfoam	Replace Glazing Only
6	T-07	4	A	Existing Render Only	Rafter Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	None	None
7	T-14	1	A	Existing Render Only	Ceiling Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	Demelec Sprayfoam	Replace Glazing Only
8	T-15	2	B	Existing Render Only	Ceiling Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	Demelec Sprayfoam	Replace Glazing Only
9	T-24	5	B	Existing Render Only	Ceiling Level Demelec Sprayfoam	MVHR (reduced ductwork)		None	None
10	T-12	4	A	Existing Render Only	Ceiling Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	None	None
11	T-13	3	B	Existing Render Only	Ceiling Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	Demelec Sprayfoam	None

3.1.1 Matrices of properties grouped in terms of measures – Group 1

Group 2

Group 2 sought to trial measures combined in group 1 with Jablite Classic external wall insulation and insulated render system. This facilitates a direct comparison in results between retrofit with and without EWI systems. Similar ventilation systems to group 1 were used.

Group 2	External wall insulation + loft with mechanical ventilation								
12	T-16	4	B	Jablite Classic	Rafter Level Demelec Sprayfoam	MVHR (reduced ductwork)		None	None
13	T-25		A	Jablite Classic	Rafter Level Demelec Sprayfoam	MVHR (reduced ductwork)		None	None
14	T-18	3	B	Jablite Classic	Rafter Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	Inject Demelec Sprayfoam	None
15	T-19	3	A	Jablite Classic	Rafter Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	Inject Demelec Sprayfoam	Replace Glazing Only
16	T-20	1	A	Jablite Classic	Rafter Level Demelec Sprayfoam	MVHR (full system)	TRUE	Inject Demelec Sprayfoam	Replace Glazing & Fit Insulated Reveal Liner

3.1.2 Matrices of properties grouped in terms of measures – Group 2

Group 3

Group 3 also sought to trial measures combining group 1 but with Jablite Dynamic external wall insulation, whereby intake air is drawn in through the insulation cavity and passively pre-warmed before being distributed via a passive ventilation system. Only PIV is used as a means of ventilation in this group as it is a complimentary technology to the dynamic insulation.

Group 3	External wall insulation with a cavity + loft insulation with Positive Input Ventilation								
17	T-21	5	C (Handed)	Jablite Dynamic	Rafter Level Demelec Sprayfoam	PIV		None	None
18	T-22	4	A	Jablite Dynamic	Rafter Level Demelec Sprayfoam	PIV	TRUE	None	None
19	T-23	3	B	Jablite Dynamic	Rafter Level Demelec Sprayfoam	PIV	TRUE	Demelec Sprayfoam	None
10	T-17	2	C	Jablite Dynamic	Rafter Level Demelec Sprayfoam	PIV	TRUE	Demelec Sprayfoam	Replace Glazing Only
21	T-05	5	C (Handed)	Jablite Dynamic	Rafter Level Demelec Sprayfoam	PIV	TRUE	Demelec Sprayfoam	Replace Glazing & Fit Insulated Reveal Liner
22	T-26	5	C	Jablite Dynamic	Ceiling Level Demelec Sprayfoam	PIV		None	None
23	T-27	4	A	Jablite Dynamic	Ceiling Level Demelec Sprayfoam	PIV	TRUE	None	None
24	T-28	3	B	Jablite Dynamic	Ceiling Level Demelec Sprayfoam	PIV	TRUE	Inject Demelec Sprayfoam	None
25	T-29	2	B	Jablite Dynamic	Ceiling Level Demelec Sprayfoam	PIV	TRUE	Inject Demelec Sprayfoam	Replace Glazing Only
26	T-30	1	A	Jablite Dynamic	Ceiling Level Demelec Sprayfoam	PIV	TRUE	Inject Demelec Sprayfoam	Replace Glazing & Fit Insulated Reveal Liner

3.1.3 Matrices of properties grouped in terms of measures – Group 3

Group 4

Group 4 was similar to group 1, with no external wall insulation used, but including installation of a thermal break system around window and door reveals as this was another area of extreme leakage identified by the pre-trial air pressure and thermography tests.

Group 4	Window replacement with thermal break								
27	T-02	2	B	Existing Render Only	Internal Wall Insulation	None		None	Replace Glazing & Fit Insulated Reveal Liner
28	C2	1	B	Existing Render Only	Internal Wall Insulation	None		None	Replace Glazing Only
29	T-01	P	A	Jablite Classic	Internal Wall Insulation	MVHR (full system)	TRUE	Demelec Sprayfoam	Replace Window & Fit Thermal Break
30	T-10	1	A	Existing Render Only	Rafter Level Demelec Sprayfoam	MVHR (reduced ductwork)	TRUE	Inject Demelec Sprayfoam	Replace Glazing Only
31	T-06	1	C (Handed)	Existing Render Only	Ceiling Level Demelec Sprayfoam	MVHR (reduced ductwork)		None	None

3.1.4 Matrices of properties grouped in terms of measures – Group 4

3.3 Cost

Analysis using gas meter readings and energy bills

Gas meter readings were recorded by households during the study. Consumption data was also obtained from bills prior to the monitoring period. These meter readings allowed the gas consumption of households to be compared before and after the installation of air tightness and insulation measures. Meter readings from the 'before' period were in the range January 2016 to September 2016. Those used in the 'after' period were typically from the earliest meter reading after all measures were complete (September 2016) to the date of the final interviews in April 2017. The frequency of gas meter records varies from household to household. In many cases, only historic data from utility companies was available. In others, fortnightly meter readings have been taken. As smart meters were not fitted as part of the project, the energy uses data for nuanced analysis is not available. However, sufficient data across a relatively large field has been collected in order to demonstrate the effects of the retrofit works.

Table 3.3.1 shows records for the 'before works' periods. The properties are arranged into the four groups arranged in terms of retrofit typology, together with a control sample. The differing record periods are shown, predominantly focussing on the heating period. Where the intervals in readings are for periods that are longer than the heating period, these have been used. The readings are in cubic meters and have been converted to KWH using a conversion factor for the supplier area (11.14) which takes account of the calorific value of the gas and its temperature and atmospheric conditions[38]. Costs per 30 days, together with estimated annual cost is also shown, using a standard gas price of £0.05 / KWH

In order to properly analyse energy use for space heating, account must be taken of the weather.

[38] https://www.theenergyshop.com/advice-guides-how-to-convert-gas-units-to-kWh#.WtXsiy7waUk

For example, it is poor practice to compare the heating costs for 2 periods without compensating for different outdoor temperatures. An external temperature of 15.5°C is accepted by energy professionals as the outside temperature below which heating will be required, and above which no heating is necessary. The heating requirement for a building is proportionate to the number of heating degree days (HDD) i.e. the number of degrees below 15.5°C that the average temperature is on each day during the period. When the average outside temperature drops to 14.5°C, this is classed as 1 degree-day, for example. Degree days are added together for the required period to give the total number of degree days for the period. Different periods can then be compared for their energy consumption and the results used to predict energy consumption on a normalised basis taking into account the outside temperature for those different periods[39]. Good quality temperature data was available from weather stations nearby (Liverpool Airport, 7 miles away) for a period of 3 year preceding and including the study[40] . An average of the number of degree days per year over a 20-year period was only available on a regional basis, which was used to normalise the savings which can be expected in the following analysis. In this case, 2223 degree days, the value for the West Pennines region was used as the households around Halton were located in this area[41].

The number of degree days for each period of record is shown, together with the number of KWH/Degree Day. The annual cost has been estimated from multiplying the 20 Year Average degree days (2201 for Liverpool) by the number of KWH/degree day at a rate of £0.05 / KWH.

Table 3.32 Shows the records for gas consumption after installation of the retrofit measures. Similar data arrangements are shown as for the 'before' period, with the addition of a column to show the cost difference between the estimated annual bills and the percentage difference between these estimates. In this way, results (changes) between the different groups of retrofit measures can be averaged and compared. The 'after' period data is generally taken over a more consistent period (heating period from mid-September 2016 to April 2017) as this data has largely been collected by the monitoring team.

Prior to the retrofit measures being installed, the estimated average cost of gas for Group 1 was £592 with a range of £117 to £1014 and a field of 9 properties. The estimated average cost of gas for Group 2 was £392 with a range of £92 -£716 and a field of 4 properties, whilst he estimated average cost of gas for Group 3 was £651.60 with a range of £456 - £936 across a field of 6 properties. Only 1 property was reported in Group 4, suggesting an average annual cost of £379.60. The overall average annual cost of gas was £559.48.

5 of the interviewees whose costs were below average, and 2 of the respondents whose bills were above average, reported not being able to heat their properties to an adequate temperature.

39 https://www.carbontrust.com/resources/guides/energy-efficiency/degree-days/ [Accessed 20/03/2017 M. Hamer]
40 www.degreedays.net [Accessed 22/06/2017}
41 http://www.vesma.com/ [Accessed 05/05/2017]

Type	Group	Tech Ref	Period From	Period to	Days	Cost/M3	Volume M3	cost/30days	conversion M3:KWH	KWH used	Degree days	KWH/DD	Estimated Annual Cost
Before Period													
Group 1 Ceiling Treatment, No Wall Insulation													
A	1	T-03	14.09.2015	01.04.2016	199	0.58	504	35.94	11.14	5614.56	1354	4.15	£461.02
A	1	T-12	11.01.2016	20.09.2016	244	0.58	667	47.56	11.14	7430.38	1151	6.46	£717.73
A	1	T-14	20.11.2015	07.06.2016	200	0.58	894	77.78	11.14	9959.16	1428	6.97	£775.39
C	1	T-04	11.01.2016	20.09.2016	244	0.58	526	37.51	11.14	5859.64	1151	5.09	£566.01
B	1	T-08	27.02.2016	20.09.2016	231	0.58	109	8.21	11.14	1214.26	1151	1.05	£117.29
B	1	T-24	25.09.2015	05.05.2016	223	0.58	432	33.71	11.14	4812.48	1571	3.06	£340.58
B	1	T-13	24.09.2015	24.03.2016	182	0.58	1030	98.47	11.14	11476.00	1258	9.12	£1,014.23
B	1	T-09	11.01.2016	05.05.2016	115	0.58	346	52.35	11.14	3854.44	1003	3.84	£427.25
B	1	T-15	11.10.2015	05.05.2016	207	0.58	1111	93.39	11.14	12376.54	1513	8.18	£909.47
			Average Annual Cost										£592.11
Group 2 Classic External Wall Insulation													
A	2	T-20	11.01.2016	20.09.2016	244	0.58	288	20.54	11.14	3208.32	1151	2.79	£309.91
A	2	T-25	11.01.2016	15.08.2016	217	0.58	414	29.52	11.14	4611.96	1134.00	4.07	£452.17
B	2	T-18	27.02.2016	01.05.16	63	0.58	85	6.06	11.14	946.90	1134.00	0.84	£92.84
B	2	T-16	11.01.2016	24.10.2016	278	0.58	740	46.32	11.14	8243.60	1279	6.45	£716.59
			Average Annual Cost										£392.88
Group 3 Dynamic Wall Insulation													
C	3	T-24	11.01.2016	29.04.2016	217	0.58	414	33.20	11.14	4611.96	970	4.75	£528.62
C	3	T-17	11.01.2016	20.09.2016	244	0.58	813	57.98	11.14	9056.82	1151	7.87	£874.84
A	3	T-22	11.01.2016	20.09.2016	253	0.58	561	38.58	11.14	6249.54	1151	5.43	£603.67
A	3	T-27	11.01.2016	20.09.2016	244	0.58	870	62.04	11.14	9691.80	1151	8.42	£936.17
C	3	T-21	11.01.2016	20.09.2016	244	0.58	474	33.80	11.14	5280.36	1151	4.59	£510.05
C	3	T-26	11.01.2016	20.09.2016	244	0.58	424	30.24	11.14	4723.36	1151	4.10	£456.25
			Average Annual Cost										£651.60
Group 4 Window Replacement with Thermal Breaks													
A	4	T-01											
C	4	T-06	11.01.2016	24.10.2016	278	0.58	392	24.54	11.14	4366.88	1279	3.41	£379.60
			Average Annual Cost										£379.60
Control Group													
A	3	C-1	08.09.2015	23.12.2016	472	0.58	1029	37.93	11.14	11463.06	2377	4.82	£536.16
B	2	C-2	01.10.2015	15.04.2016	198	0.58	974	85.59	11.14	10850.36	1402	7.74	£860.44
			Average Annual Cost										£698.30

3.3.1 Cost of gas before installation

Type	Group	Tech Ref	Period from	Period to	Days	Cost/m3	Volume M3	cost/30 days	Conversion	KWH Used	Degree Days	KWH/DD	Estimated Annual Cost	Saving	Saving %
			After Period												
			Ceiling Treatment. No Wall Insulation												
A	1	T-03	29.09.2016	02.05.2017	215	0.58	493	39.90	11.14	5492.02	1629	3.37	£374.83	£86.19	18.70
A	1	T-12	20.09.2016	21.04.2017	213	0.58	840	68.62	11.14	9357.60	1577	5.93	£659.72	£58.01	8.08
A	1	T-14	20.09.2016	21.04.2017	213	0.58	863	70.50	11.14	7068.00	1577	4.48	£498.30	£277.09	35.74
C	1	T-04	20.09.2016	30.01.2017	133	0.58	446	58.35	11.14	4968.44	1006	4.94	£549.10	£16.91	2.99
B	1	T-08	20.09.2016	05.04.2017	197	0.58	199	17.58	11.14	2216.86	1490	1.49	£165.42	-£48.13	-27.24
B	1	T-24	24.10.2016	21.04.2017	179	0.58	389	37.81	11.14	4333.46	1539	2.82	£313.06	£27.52	8.08
B	1	T-13	20.09.2016	21.04.2017	213	0.58	155	12.66	11.14	1726.70	1577	1.09	£121.73	£892.50	27.24
B	1	T-09	20.09.2016	21.04.2017	213	0.58	865	70.66	11.14	9636.10	1577	6.11	£679.35	-£252.10	-37.11
B	1	T-15	20.09.2016	21.04.2017	213	0.58	1218	99.50	11.14	13568.52	1577	8.60	£956.59	-£47.13	-5.18
			Average Annual Cost & Saving										£479.79	£112.32	
			Group 2 Classic Wall Insulation												
A	2	T-20	20.09.2016	21.04.2017	213	0.58	137	11.19	11.14	1526.18	1577	0.97	£107.60	£202.31	65.28
A	2	T-25	16.08.2016	21.04.2017	248	0.58	371	26.03	11.14	4132.94	1591	2.60	£288.81	£163.36	36.13
B	2	T-18	20.09.2016	21.04.2017	213	0.58	630	51.46	11.14	7018.20	1577	4.45	£494.79	-£401.95	-432.97
B	2	T-16	24.10.2016	07.05.2017	195	0.58	641	57.20	11.14	7140.74	1539	4.64	£515.86	£200.73	27.24
			Average Annual Cost & Saving										£351.76	£41.11	
			Group 3 Dynamic Wall Insualtion												
C	3	T-24	20.09.2016	21.04.2017	213	0.58	561	45.83	11.14	6249.54	1577	3.96	£440.60	£88.02	16.65
C	3	T-17	20.09.2016	21.04.2017	213	0.58	647	52.85	11.14	7207.58	1577	4.57	£508.14	£366.70	41.92
A	3	T-22	20.09.2016	21.04.2017	213	0.58	770	62.90	11.14	8577.80	1577	5.44	£604.74	-£1.07	-0.18
A	3	T-27	20.09.2016	21.04.2017	213	0.58	714	58.33	11.14	7953.96	1577	5.04	£560.76	£375.41	62.19
C	3	T-21	20.09.2016	21.04.2017	213	0.58	489	39.95	11.14	5447.46	1577	3.45	£384.05	£126.00	24.70
C	3	T-26	20.09.2016	21.04.2017	213	0.58	473	38.64	11.14	5269.22	1577	3.34	£371.49	£84.76	18.58
			Average Annual Cost & Saving										£478.30	£173.30	
			Group 4 Window Replacements With Thermal Breaks												
A	4	T-01	20.09.2016	21.04.2017	213	0.58	274	22.38	11.14	3052.36	1577	1.94	£215.19		
C	4	T-06	24.10.2016	21.04.2017	179	0.58	246	23.91	11.14	2740.44	1447	1.89	£210.56	£169.04	44.53
			Average Annual Cost & Saving										£212.88	£169.04	
Control Group			Control Group												
A	3	C-1	23.12.2016	30.04.2017	129	0.58	470	45.69	11.14	5235.80	1018	5.14	£571.82		
B	2	C-2	01.10.2016	30.04.2017	212	0.58	1116	108.48	11.14	12432.24	1618	7.68	£854.27		
			Average Annual Cost										£713.05		

3.3.2 Cost of gas after installation

Following retrofit the lowest reported annual cost was £107. This household was also the lowest cost before retrofit and the survey showed that the property had limited occupancy periods. The highest annual cost was £957 and was also the second highest cost before retrofit. Whilst the lowest cost reported a saving after the works, the highest reported a minor increase in cost of 5%. The average annual cost was reduced to £475, an average saving of 32%. 4 properties showed increases in gas consumption however, respondents from the two highest of these properties reported using supplementary electric heating prior to the works. The percentage savings are shown above in table 3.3.2

After retrofit measures being installed, the estimated average cost of gas for Group 1 was £479, down from £592 (an average saving of 19%) with a range of £121 - £957 and a field of 9 properties. The estimated average cost of gas for Group 2 was £351 with a range of £107 - £515 and a field of 4 properties giving an average saving of 11%. T18 showed a 400% increase in cost which is likely to be due to a change in gas meter that has been incorrectly recorded. When T18 is removed from the calculation, the saving increases to 35%. The estimated average cost of gas for Group 3 was £478 with a range of £371 - £604 across a field of 6 properties. This group returned a saving of 26%. Only 1 property was fully reported in Group 4, suggesting an average annual cost of £210 (a saving of 46%).

The savings in energy bills largely correlate with the level of measures included in the retrofit. Group 1 had the least amount of work carried out and averaged a 19% saving. There was little measurable difference between the two groups that had EWI in addition to air tightness measures, the 'classic' system slightly out-performing the dynamic system, returning 35% and 26% savings respectively. Interestingly, just installing air tightness measures together with thermal breaks around fenestration led to an average saving of 46%, although with just one fully recorded property in this group, it could reasonably be compared to the best results in the other 3 groups returning 35% (Group 1), 65% (Group 2) and 62% (Group 3).

The control group showed an average cost of £713 compared to £698 before the study, underlining the benefit of using 20 year degree day averages to allow for changes in weather over similar calendar periods.

Figure 44 below plots the percentage cost saving on fuel bills for each group alongside the reduction in air leakage by percentage. Groups 1, 2 & 3 closely correlate. Group 4 shows the closest relationship between cost and air-tightness, but it should be noted that the analysis only presents 1 property in this group as the other properties did not have 'before' cost data due to void status.

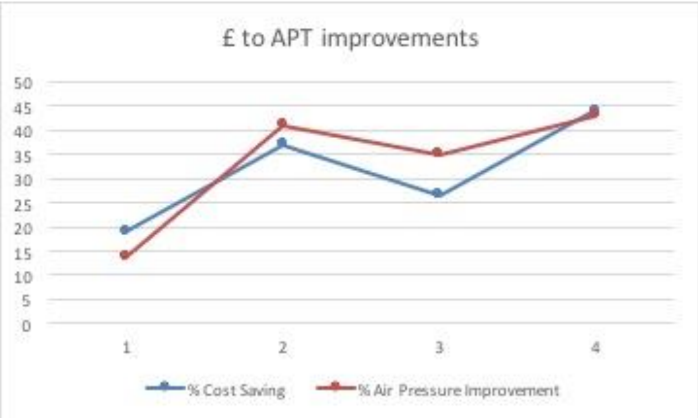
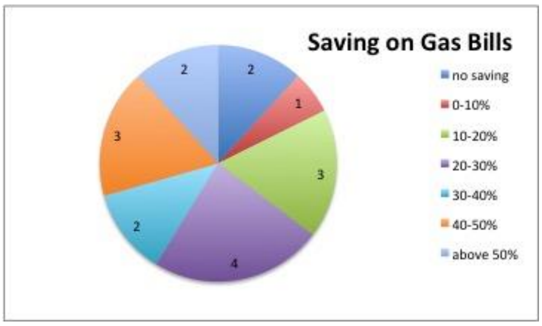


Figure 44 Graph of energy savings by percentage and air tightness improvements by percentage.

Percentage savings by number of properties were on gas costs in 10% increments are shown in Figure 45a and the average percentage savings on energy bills are shown by group in Figure 45b.



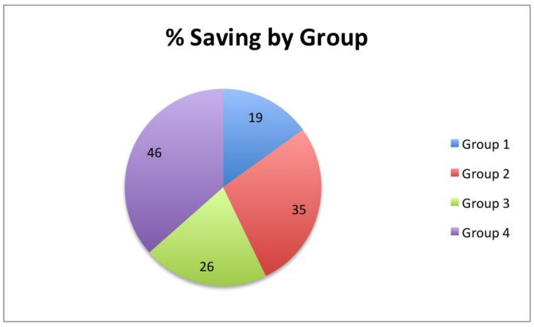


Figure 44a Percentage saving on gas bills (10% increments)

Figure 45b Percentage savings by group

It is useful to consider energy savings before and after installation in conjunction with average internal temperatures. If a household has been experiencing fuel poverty, it is likely that any improvement in the thermal performance of the building fabric is not fully reflected in savings on utility bills. This is because the occupant may elect to heat the interior spaces to a higher temperature and maintain the same heating budget. This phenomenon is highlighted by the outcomes described below:

T-03, a group 1 property, showed an average increase in temperature of 5°C after installation and a cost saving of 19% on energy bills. The air leakage rate was reduced by 1.6 m^3/m^2h.

T-16, a group 2 property, showed an average increase in temperature of 3°C after installation and a cost saving of 27% on energy bills. The air leakage rate was reduced by 4.9 m^3/m^2h.

T-27, a group 3 property, showed an average increase in temperature of 9°C after installation and a cost saving of 62% on energy bills.

T-06, a group 4 property, showed little increase in temperature after installation and a cost saving of 43% on energy bills. The air leakage rate was reduced by 1.2 m^3/m^2h.

A potential correlation therefore exists which has the effect of reducing the potential savings on heating due to a better level of thermal comfort being reached for the same energy cost. This is supported by tenant feedback regarding improvement in thermal comfort and the ability to keep warm / for the property to retain heat (Figures 18-22).

3.4 Temperature and thermal comfort

Data loggers

Onset Hobo temperature recording data loggers were placed in the living rooms, main bedrooms and bathrooms of trial and control properties. The data loggers recorded at intervals of 30 minutes / hourly intervals. As the trial begin in January 2016 and finished in May 2017, the heating periods from January to April in 2016 (before retrofit) and January to April 2017 (after retrofit) were compared, with May of each year included for comparison beyond the heating season.

Property CP779-03 returned an average temperature of between 15°C and 16°C before retrofit, only increasing to World Health Organisation recommendations of 18-21° in April and May 2016. The temperature range after removing statistical outliers was 10-18°C. After retrofit, the mean temperature was 20°C to 22°C with a range of 18°C to 24°C. The increase in mean temperature after retrofit suggest that the property was under heated prior to retrofit. Figure 46 maps the temperature before and after installation across a 5 month period in consecutive years. Figure 47 isolates 3 days from 1st to 3rd March 2016 (before installation) and shows the localised changes in relative humidity and temperature. As the heating is turned off at night, the temperature drops from 20°C to 12°C and the Relative Humidity spikes from 65% to 80%, possible as moist air penetrates through the porous walls.

Property CP779-03 is a Group 1 property. The works included airtightness measures, glazing replacement and ventilation control only.

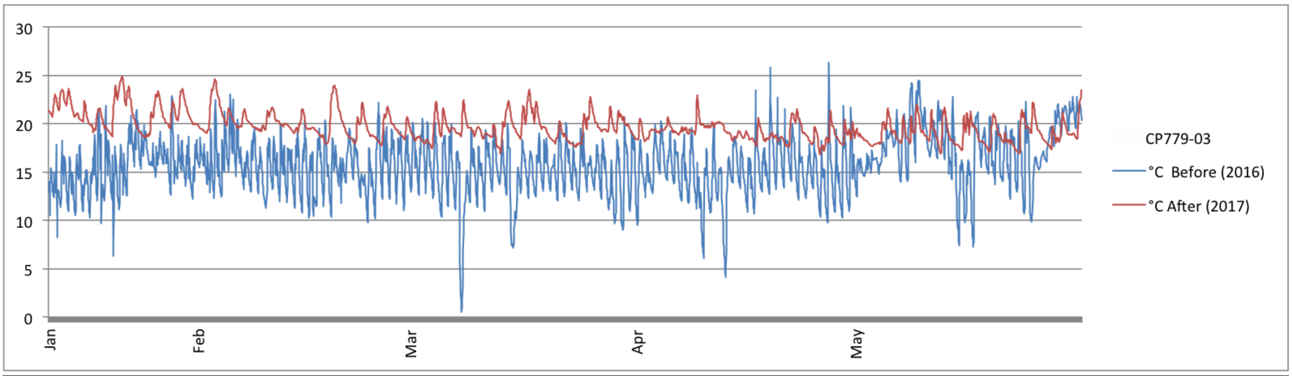


Figure 46 before and after temperatures for property CP779-03

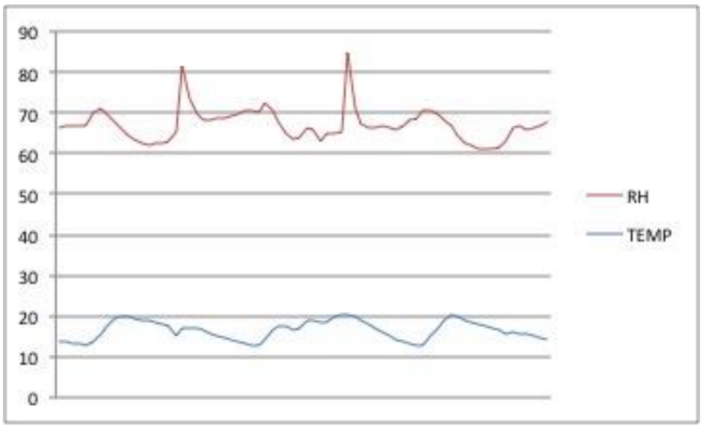


Figure 47 Relative Humidity and Temperature from 1st to 3rd March 2016

Property CP779-00 returned an average temperature of between 10°C and 22°C before retrofit, reaching the World Health Organisation recommendations of 18-21° in all measured months in 2016. After retrofit, the mean temperature was 20°C to 22°C with a range of 16°C to 25°C. The graph pattern before and after retrofit is consistent with periodic (twice daily) heating patterns as reported in the questionnaire. The temperature fluctuation was reduced after retrofit, suggesting that the building fabric retained heat better than before retrofit.

Property CP779-00 is a Group 2 property. The works included airtightness measures and External Wall Insulation.

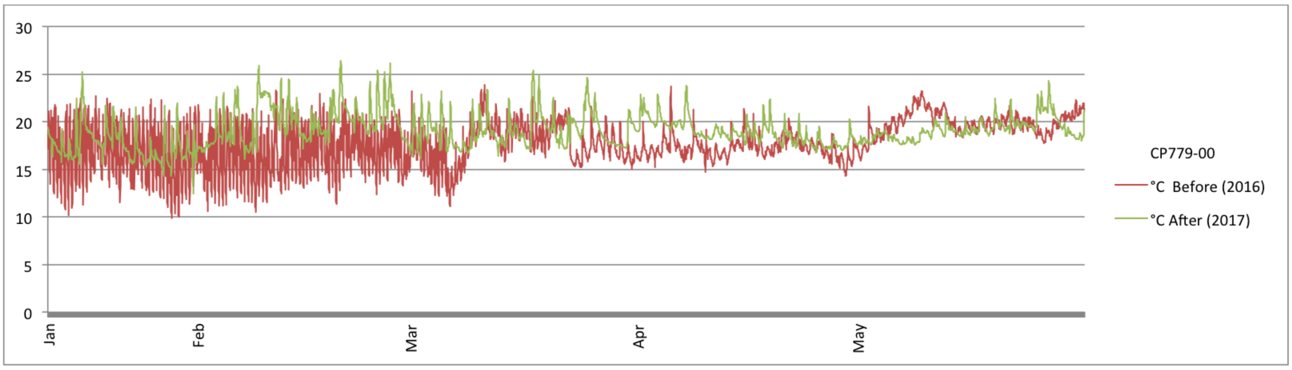


Figure 48 before and after temperatures for property CP779-00

Property CP779-22 returned an average temperature of between 16°C and 18°C before retrofit, only increasing to World Health Organisation recommendations of 18-21° in April and May 2016. The temperature range after removing statistical outliers was 15-22°C. After retrofit, the mean temperature was 19°C to 22°C with a range of 18°C to 25°C. The mean temperature was raised by 3°C after the works.
Property CP779-22 is a Group 3 property. The works included dynamic external wall installation airtightness measures, glazing replacement and ventilation control.

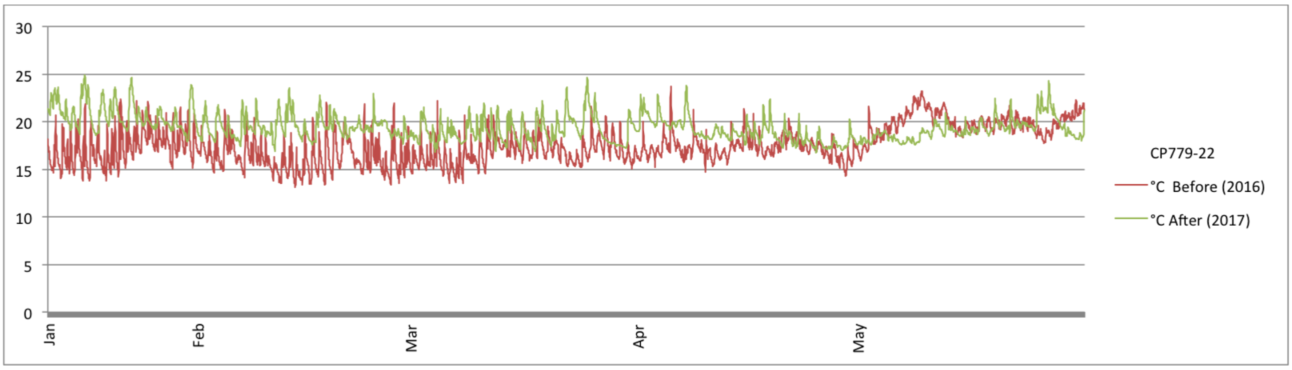


Figure 49 before and after temperatures for property CP779-22

Property CP779-27 returned an average temperature of between 16°C and 18°C before retrofit, reaching World Health Organisation recommendations of 18-21° throughout the measured period in 2016. The temperature range after removing statistical outliers was 15-20°C. After retrofit, the mean temperature was 22°C t 23°C with a range of 20°C to 25°C.
Property CP779-27 is a Group 3 property. The works included dynamic external wall installation airtightness measures, glazing replacement and ventilation control.

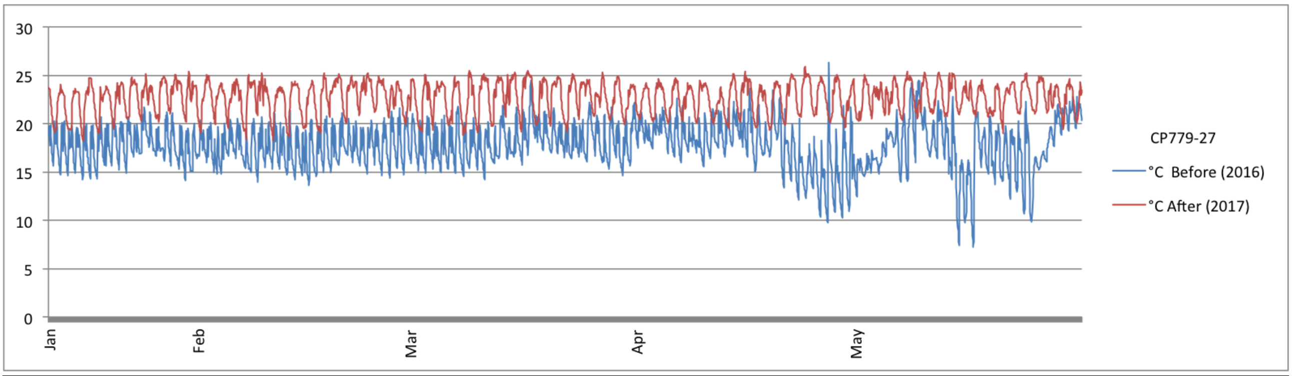


Figure 50 before and after temperatures for property CP779-27

Property CP779-06 returned an average temperature of between 17°C and 18°C before retrofit, maintaining World Health Organisation recommendations of 18-21° throughout the measured period in 2016. The temperature range after removing statistical outliers was 15-21°C. After retrofit, the mean temperature was 18°C t 21°C with a range of 16°C to 22°C.
Property CP779-06 is a Group 4 property. The works included airtightness measures, glazing replacement, thermal breaks around fenestration and ventilation control only.

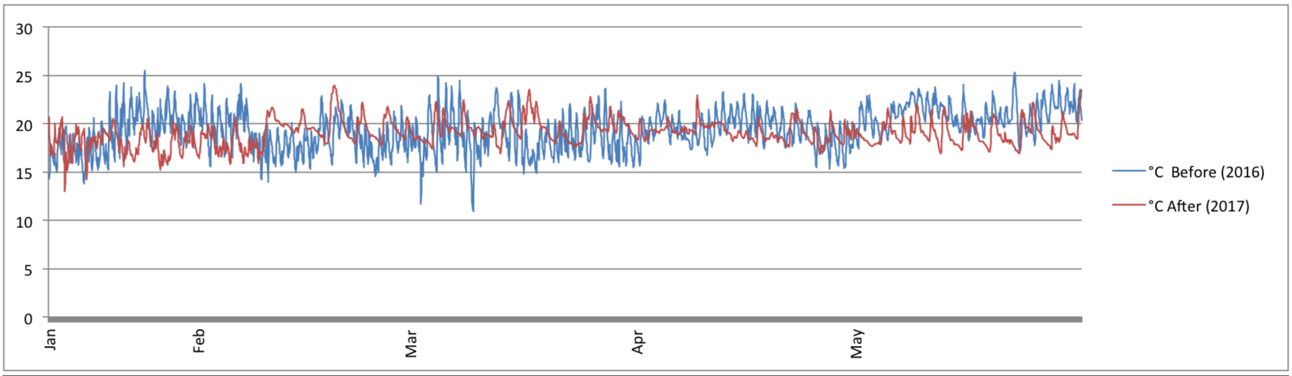


Figure 51 before and after temperatures for property CP779-06

In many of the properties where periodic temperature data was collected prior to the works, it was apparent that the properties cooled rapidly when the heating was turned off. This was especially noticeable in properties where heating was used in mornings and evenings. In Figure 51, below, the temperature for T22 was compared for the same 1-week period in January 2016 (before the works) and January 2017 (after the works). Degree days are shown for the two periods. It is apparent from comparing the graphs that after the works there is a reduction in temperature drops when the heating is off. This suggests that the property is now retaining heat for longer.

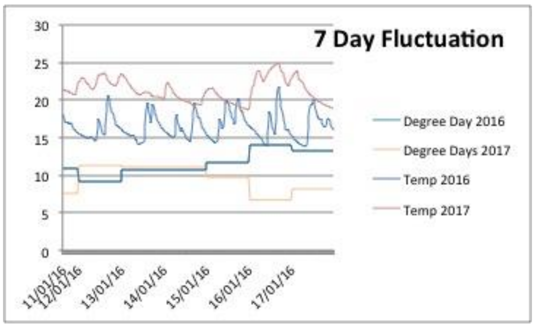


Figure 52 before and after localised fluctuations in temperatures for property CP779-22

3.5 Humidity

The automated data-loggers record both temperature and relative humidity (RH) at regular intervals across the study properties. RH is a ratio (expressed as a percentage) of the amount of moisture present in the air at each logging point, relative to the amount that would be present if the air were saturated. Since the latter amount is dependent on temperature, relative humidity is a function of both moisture content and temperature. Relative Humidity is derived from the associated Temperature and Dew Point for the indicated sample. The higher the value of RH, the more water vapour is contained in the air. High values are problematic, and can cause damage to building fabric and furnishings, and can cause mould growth and the health problems associated with this high humidity. From the Building regulations part F[42]; the suggested average monthly maximum humidity levels for domestic dwellings during the heating season is 65%.

Onset Hobo relative humidity recording data loggers were placed in the living rooms, main bedrooms and bathrooms of trial and control properties. The data loggers recorded at intervals of 30 minutes / hourly intervals. As the trial begin in January 2016 and finished in May 2017, the heating periods from January to May in 2016 (before retrofit) and January to May 2017 (after retrofit) were compared.

Property CP779-03 returned an average relative humidity of 60% before retrofit. The humidity range after removing statistical outliers was 50% & 70%. After retrofit, the mean relative humidity was 60% with a range of 55% to 65%. There was a slight reduction in fluctuation after retrofit. Property CP779-03 is a Group 1 property. The works included airtightness measures, glazing replacement and ventilation control only.

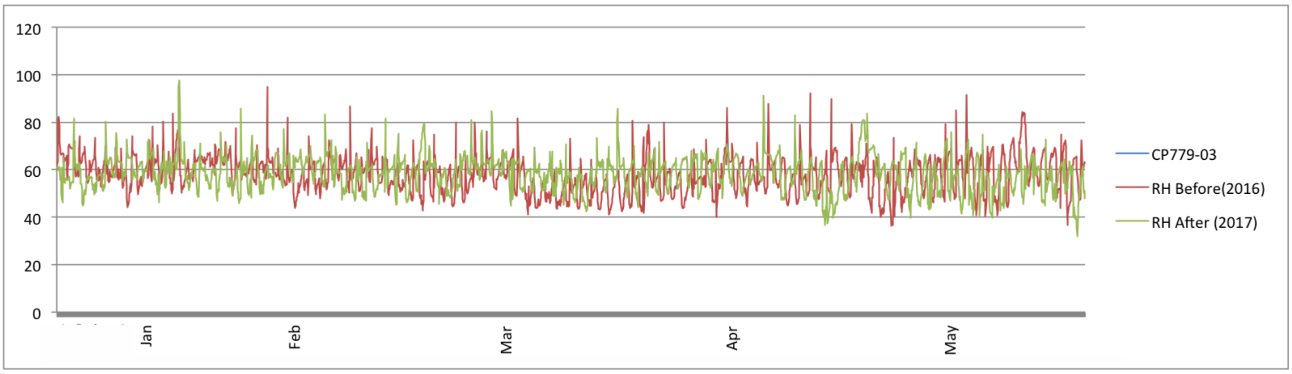


Figure 53 before and after relative humidity for property CP779-03

Property CP779-00 returned an average relative humidity of 65% before retrofit. The humidity range after removing statistical outliers was 40% to 100%. After retrofit, the mean relative humidity was 53% with a range of 35% to 65%. There was a large reduction in fluctuation after retrofit. Property CP779-00 is a Group 2 property. The works included airtightness measures and External Wall Insulation.

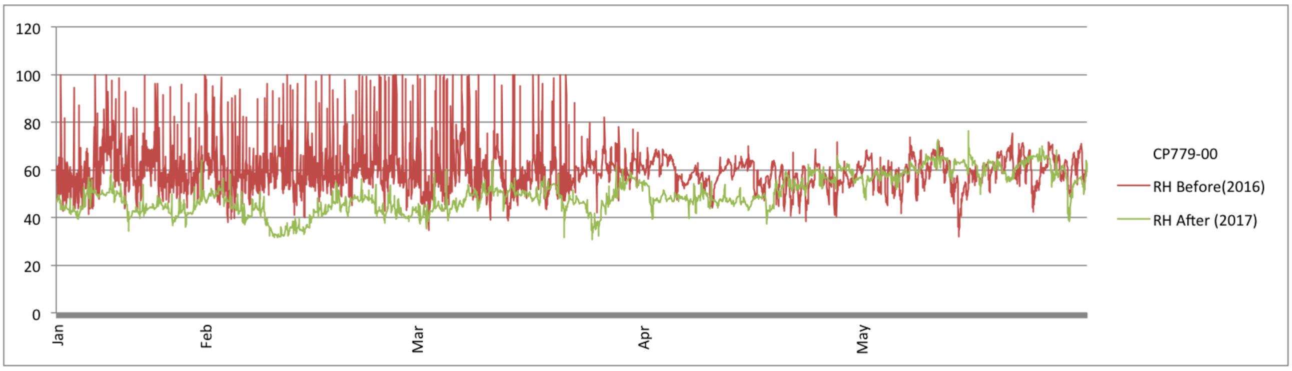


Figure 54 before and after relative humidity for property CP779-00

[42] Approved Document F. Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/468871/ADF_LOCKED.pdf [Accessed 02/01/2018]

Property CP779-22 returned an average relative humidity of 62% before retrofit. The humidity range after removing statistical outliers was 45% to 70%. After retrofit, the mean relative humidity was 54% with a range of 45% to 65%. There was a marked reduction in fluctuation after retrofit. Property CP779-22 is a Group 3 property. The works included dynamic external wall installation airtightness measures, glazing replacement and ventilation control.

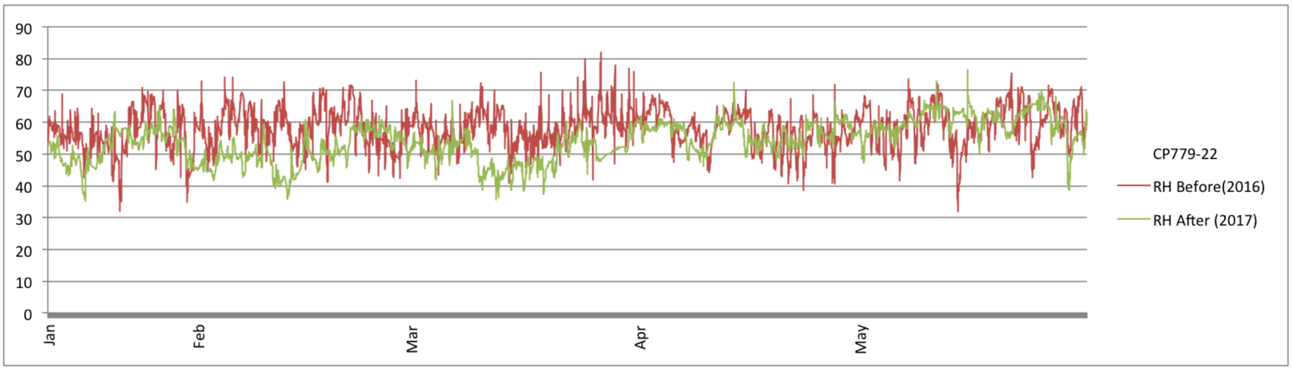


Figure 55 before and after relative humidity for property CP779-22

Property CP779-27 returned an average relative humidity of 60% before retrofit. The humidity range after removing statistical outliers was 50% to 70%. After retrofit, the mean relative humidity was 47% with a range of 35% to 58%. There was little reduction in fluctuation after retrofit. Property CP779-27 is a Group 3 property. The works included dynamic external wall installation airtightness measures, glazing replacement and ventilation control.

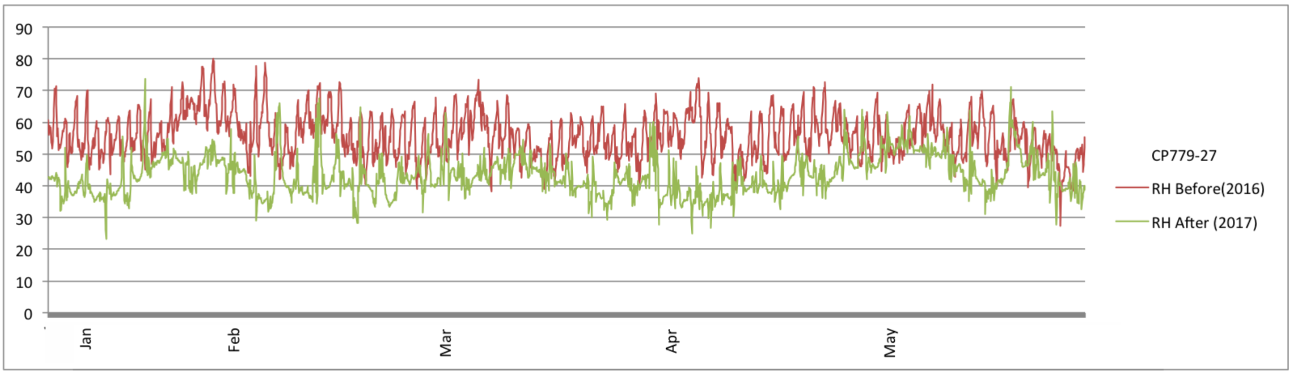


Figure 56 before and after relative humidity for property CP779-27

Property CP779-06 returned an average relative humidity of 55% before retrofit. The humidity range after removing statistical outliers was 45% to 65%. After retrofit, the mean relative humidity was 54% with a range of 40% to 67%. There was no reduction in fluctuation after retrofit. Property CP779-06 is a Group 4 property. The works included airtightness measures, glazing replacement, thermal breaks around fenestration and ventilation control only.

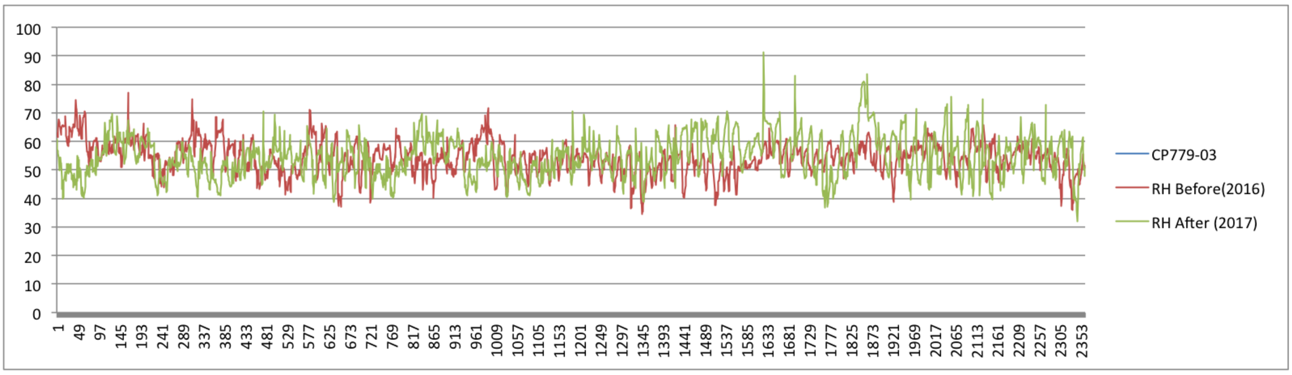


Figure 57 before and after relative humidity for property CP779-06

Figure 58 below illustrates the optimum humidity levels as cited by Arundel et al[43] The study concludes that maintaining relative humidity levels between 40% and 60% would minimise adverse health effects relating to relative humidity. It can be seen that in all of the cases recorded in the project, the average relative humidity range lies within this optimum zone after completion of the works (Figures 53-57). Whilst many of the properties were close to the optimum range both before and after installation, it can be seen from the graphs that the relative humidity was lowered and stabilised in all measured properties.

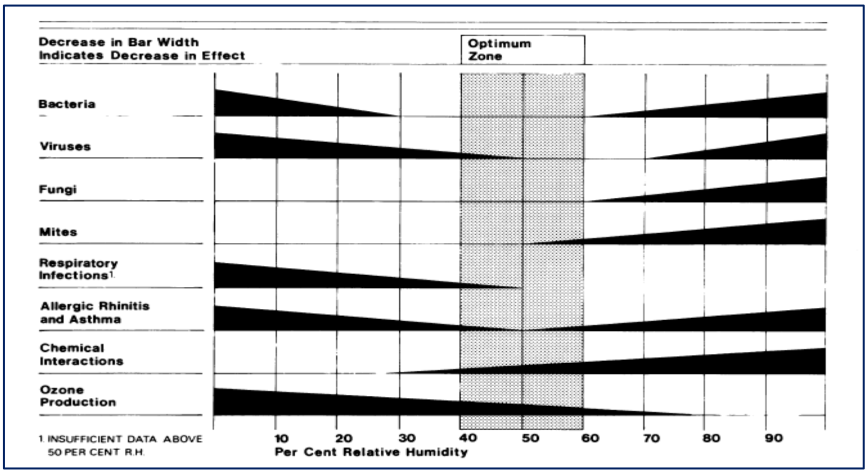


Figure 58 Optimum humidity levels to reduce indirect effects from pathogenic organisms or chemicals

Air Pressure Test Results

Air pressure tests were undertaken before and after works on 15 properties. 11 of those properties were included for both before and after tests, representing all groups (see table below).

The average overall air leakage rate before retrofit was 13.22 $m^3/(h.m^2)$ The average overall air leakage rate before retrofit was 8.55 $m^3/(h.m^2)$.

For the comparable properties (those that underwent before and after tests), the average overall air leakage rate before retrofit was 12.47 $M^3/(h.m^2)$. The average overall air leakage rate before

43 Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/468871/ADF_LOCKED.pdf [Accessed 02/01/2018]

retrofit was 8.33 $M^3/(h.m^2)$.

Group 1 returned the smallest improvements. This result was expected as the properties received the least number of air tightness details, in particular excluding window and below DPC treatments. Groups 2 and 3 returned excellent results, reflecting the careful peripheral detailing that complement the external wall insulation. T-05, a group 3 house, produced a lower than expected improvement at 2.6$m^3/h.m^2$, although the property did begin from a relatively low leakage rate.

Air Pressure Test Results					
Technical Reference	Group	Before	After	Difference	Unit
CP779#3	1	10.02	8.45	1.57	m3/(h.m2)
CP779#12	1	13.64	12.08	1.56	m3/(h.m2)
CP779#14	1	10.83	9.4	1.43	m3/(h.m2)
CP779#16	2	13.33	8.44	4.89	m3/(h.m2)
CP779#25	2	12.89	8.41	4.48	m3/(h.m2)
CP779#27	3	13.33	9.25	4.08	m3/(h.m2)
CP779#17	3	14.61	8.62	5.99	m3/(h.m2)
CP779#5	3	11.01	8.41	2.6	m3/(h.m2)
CP779#30	3	14.62	9.7	4.92	m3/(h.m2)
CP779#6	4	11.19	10.06	1.13	m3/(h.m2)
CP779#1	4	13.84	7.97	5.87	m3/(h.m2)

Figure 59 Comparison of Air Pressure Test Results across the four groups

Group 1 returned an average improvement in air-tightness of 24%. Group 2 returned an average improvement in air-tightness of 38%. Group 3 returned an average improvement in air-tightness of 31%, Group 4 returned an improvement in air-tightness of 29%. Although the Group 4 results should not be averaged as T-1 was the pilot property and was the recipient of several air pressure tests during the work in order to optimise installation performance. The control property air leakage rates were between 13 $^{m3/h.m2}$ and 14 $^{m3/h.m2}$ were similar to the starting point for T-1. T-1 returned an air leakage rate of 9.10 after the spray-foam detailing and 8.80 after the window replacement, thermal break detailing and MVHR, with an improvement to 7.97 after all of the works. It is likely that the internal wall insulation to the front rooms assisted with this improvement. No effect on air tightness was noted following the introduction of plinth insulation, but this would be expected as this was a detail to combat thermal bridging.

These results suggest that significant improvements in air tightness can be made without the installation of EWI, however the inclusion of EWI within the retrofit scheme does generally improve air-tightness and also improves the thermal performance (and appearance) of the properties.

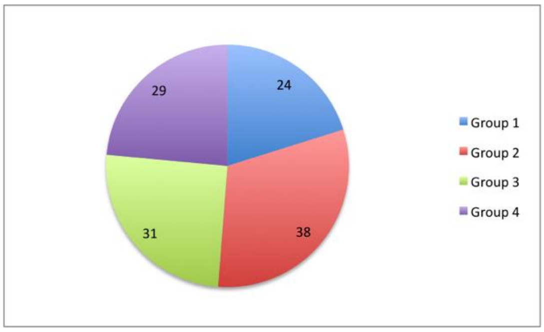


Figure 60 Comparison of Air Pressure Test Results – percentage improvements by group.

The effect of air-leakage on energy performance in dwellings is significant. In the table below, a study by the Low Carbon Hub[44] demonstrates the effect of air permeability on returned Design Emission Rate in SAP assessments. Each change in air permeability of 3 $m^3/h.m^2$ equates to approximately 90Kg/annum of CO^2 emissions. The permeability and connectivity of walls within no-fines housing increases the influence of air permeability on energy performance.

SAP assessments for a semi-detached house with a 80 m² floor area				
Target Emission Rate	23.19 kg/m² floor area per annum			
Design air permeability value (m³/h.m² at 50 Pa)	7	7	7	7
Measured air permeability value (m³/h.m² at 50 Pa)	7	10	15	3
Design Emission Rate (kg/m² floor area per annum)	23.14	23.70	25.01	22.65
CO_2 emissions increase from design	–	Increased by over 90 kg/annum	Increased by over 100 kg/annum	Saving over 90 kg/annum
Pass/fail	Pass	Fail	Fail	Pass
Remedial action required?	None: No need for any further action	Improve: airtightness and/or improve insulation of envelope. Install higher efficiency boiler or install renewable energy source	Improve: airtightness	None: No need for any further actions (check ventilation is adequate)

Figure 61a the effect of air leakage on SAP assessments (Low Carbon Hub)

Figure 61b below sets out the results of SAP 2012 calculations relating to annual energy cost in Pounds Sterling, modelled for the three property types at the Glen. SAP modelling was run for three different Air Tightness levels in order to be able to compare the actual benefits of improving air-tightness with those predicted through the Standard Assessment Procedure that is widely used when preparing funding bids. The SAP calculations do not take into account the differing behavioural patterns of householders on energy use, or the effects of fuel poverty on the ability to heat a house to an acceptable standard, but they do provide a benchmark that is useful for comparisons across different properties. The second grouping of figures takes the average actual energy costs for each property type before and after the works were carried out. These figures are extracted from Tables 3.3.1 and 3.3.2. The control figures were not included. The average Air

44 http://www.zerocarbonhub.org/sites/default/files/resources/reports/A_Practical_Guide_to_Building_Air_Tight_Dwellings_NF16.pdf [Accessed 20th December 2017]

Leakage rate before the works were carried out was 12.8 $M^3/(m^2.hr)$@50Pa and the average Air Leakage rate after the works were carried out was 9.2 $M^3/(m^2.hr)$@50Pa (Figure 67).

At 15 $M^3/(M^2.hr)$, - the default level for SAP - the predicted energy costs are higher than the actual recorded averages seen in the project. The actual average annual energy costs for a Type A before improvement (Table 3.3.1) - where the air leakage rate most closely aligns with the SAP default is £608 whereas the predicted cost was £1001. The actual average annual energy costs for a Type B property before improvement (Table 3.3.1) is £516 but the predicted cost is £933. The actual average annual energy costs for a Type C property before improvement (Table 3.3.1) is £552 but the predicted cost is £1457. The difference in SAP results when compared to actual results is more pronounced for the end terraces. This may be accounted for by the SAP calculations giving more weight to heat loss through the fabric of the surface area of the building envelope than actually takes place, and by the unaffordability of heating the end-terrace properties.

Using an air leakage rate of 7 $M^3/(M^2.hr)$ in the SAP calculations most closely reflects the best achieved rate within the project. The predicted energy costs are around double the actual recorded costs seen in the households through the project, that approach this level of air permeability. Type A and B properties have predicted annual energy costs of £877 and £820 respectively. Type C properties have predicted annual energy costs of £1290. Table 3.3.2 shows that the average annual energy costs after the works have been completed are £414 for Type A, £464 for Type B and £410 for Type C. Again, the additional external envelope area on Type C properties has little effect on actual energy costs.

In actuality, the predicted energy costs at 3 $M^3/(M^2.hr)$ most closely relate to the actual energy costs seen at the Glen after the works, albeit at a much higher actual air permeability. These predicted costs are £458 for Type A, £446 for Type B and £562 for Type C.

The trends in improvement do align however, suggesting that the SAP results return a greater accuracy in trends than actual energy costs when projects monitor a varying cross section of energy behaviours and other variables. Factors that could account for this difference could be an under appreciation of the effects of air-tightness on heat loss in SAP calculations, and limitations in the calculations in terms of occupancy behaviour; the effects of fuel poverty on actual energy use.

This study suggests that air-tightness has a much greater effect on heat loss than SAP allows for in No Fines Concrete Housing. Moreover, in properties with high levels of air leakage, the influence of additional building fabric present in end-terrace properties is unduly skewed. This might be significant when using SAP calculations to support funding bids.

Property Type	Standard Assessment Procedure 2012 Version - Predicted Annual Heating Costs at Differing Air Leaking Rates			Actual Annual Energy Costs before the works commenced, where the average Air Leakage Rate is 12.8	Actual Annual Energy Costs After the works were commenced, where the average Air Leakage Rate is 9.2
	Air Tightness Test Results m3/(m2.hr)@50Pa			Air Tightness Test Results m3/(m2.hr)@50Pa	
	15.0 (default)	**7.0**	**3.0**	**12.8**	**9.2**
Type A Mid Terrace	1001.00	877.00	458.00	608.00	413.74
Type B Mid Terrace	933.00	820.00	446.00	516.89	463.82
Type C End Terrace	1457.00	1290.00	562.00	552.00	410.66

Figure 61b the predicted effect of air leakage on annual energy cost (£) obtained through SAP 2012 modelling

Thermo-graphic Imaging

Thermo-graphic imaging was taken before and after the works. In addition to demonstrating the efficacy of the systems employed, they serve to highlight air movement between terraces after completion and to assist with perfecting installation techniques during construction.

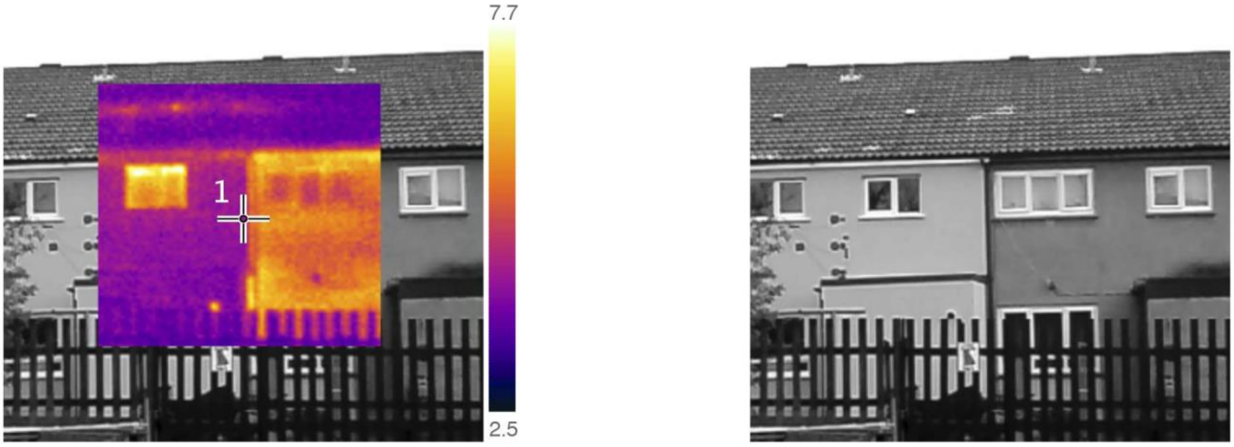


Figure 62 Thermographic images showing insulated property on left and unimproved property on right

Figure 62 shows an improved property on the left and an unimproved property on the right. In addition to showing a much colder external surface (less heat loss) on the improved property, it also shows thermal bridging at roof and wall ventilation points

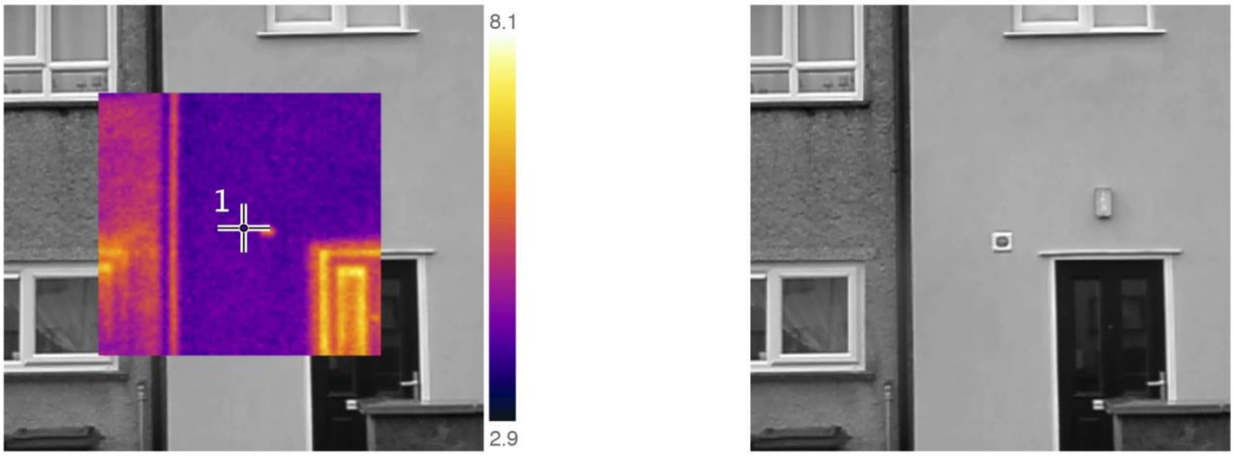


Figure 63 Thermographic images Thermal bridging around door and at party wall

The improved property on the right of figure 63 shows a marked improvement on the unimproved property on the left. The bright orange vertical line at the party wall suggests that warm air within the walls of the improved property is moving to a cold bridge at the junction with the neighbouring house.

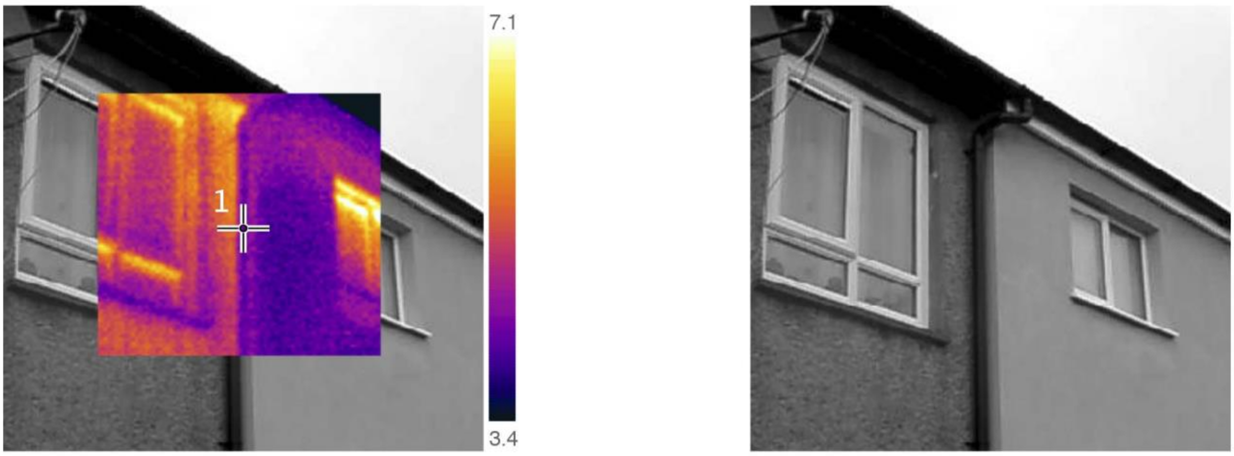


Figure 64 Thermographic images heat movement (cold bridging) around windows

The party wall cold bridge is also highlighted here. A marked improvement in terms of heat retention can be seen at the eaves of the right hand property. However, we can see the effect of not installing a significant thermal break around the window. Figure 65 shows a property without plinth insulation. Significant cold bridge heat loss occurs where a solid ground floor meets an uninsulated external wall. This heat loss is compounded by hard landscaping as it increases conducted heat flow away from the building.

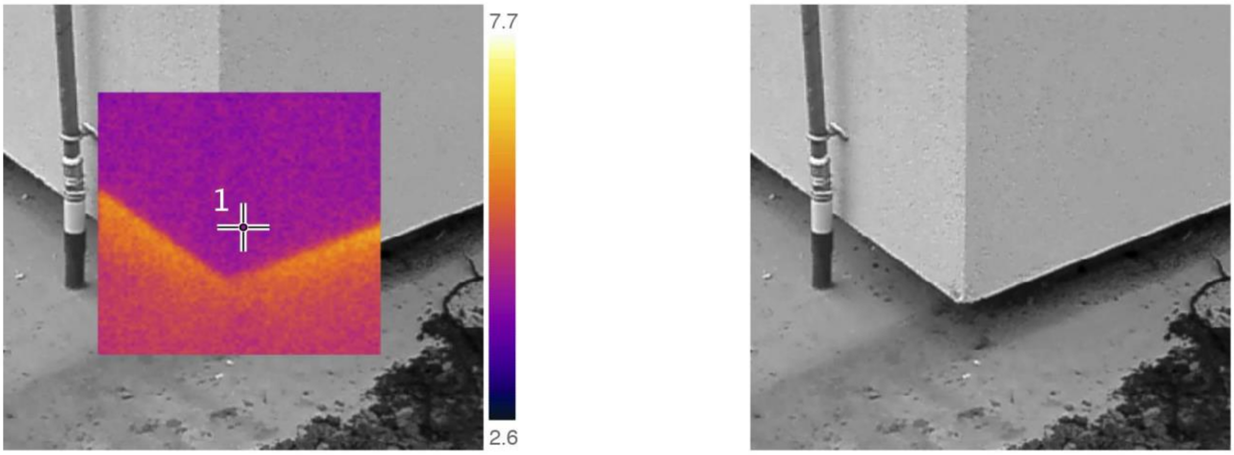


Figure 65 Thermographic images heat movement at below-damp detail

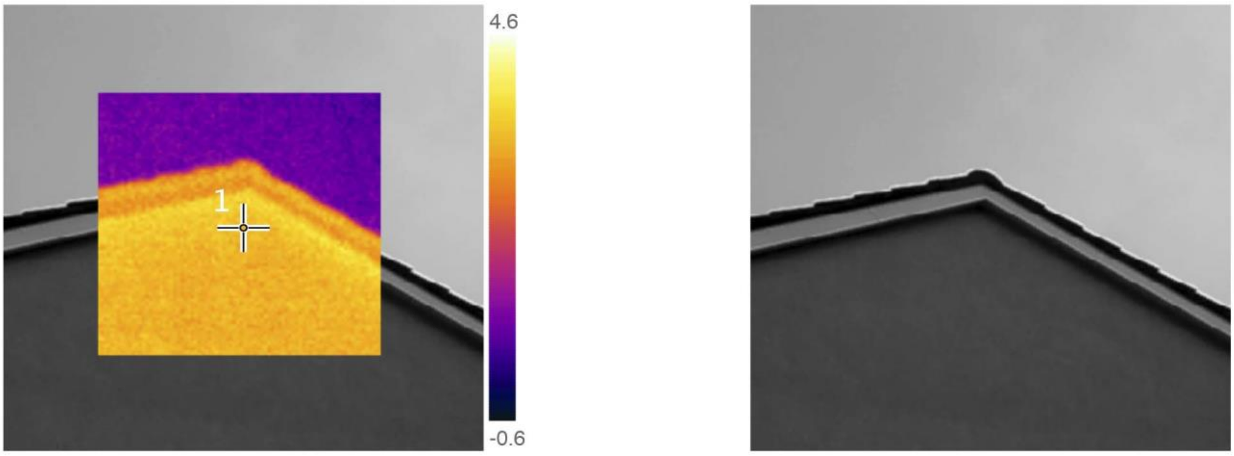


Figure 66 Thermographic images – heat movement at verge detail

Significant heat loss due to air escaping from the unsealed no-fines concrete wall tops, has been reduced by spraying insulation into the verges from inside the roof space. This effectively seals the top of the open wall. Where this seal is introduced on party walls, the potential for smoke to move between properties is reduced.

Thermography has been beneficial in helping to identify areas of heat loss through air leakage and cold bridging prior to retrofit, and for measuring the effects of detailing post-construction.

Incremental Improvements

The project sought to measure incremental improvements due to small measures within each main group. The unexpected baseline difference in air-tightness, combined with the difference in occupancy behaviour and the issue of widespread fuel poverty meaning that many residents did not heat their houses to an adequate level of thermal comfort meant that nuanced improvements due to incremental detailing could not be isolated, patterns are apparent when the groups are compared as a whole.

	Works	APT Before	APT After	Air Pressure Test Improvement	Energy Cost Before	Energy Cost After	Percentage Energy Saving	Average temperature before works during heating period	Average temperature After works during heating period	Average relative humidity Before works during heating period	Average relative humidity After works during heating period
Group 1											
T-12	Loft Insulation	13.64	12.08	1.56	£717.73	£659.72	8	22	23	62	58
T-3	Loft Insulation and MVHR	10.02	8.45	1.57	£461.22	£374.83	19	16	20	55	54
T-14	Loft Insulation, MVHR and Peripherals	10.83	9.4	1.43	£775.39	£498.30	36	17	20	57	44
Group 2											
T-16	Insulation, Sprayfoam loft, MVHR	13.33	8.44	4.89	£716.59	£515.86	28	23	24	42	37
T-25	Insulation, Sprayfoom loft, MVHR	12.89	8.41	4.48	£452.17	£288.81	36	17	17	44	42
Group 3											
T-27	Insulation and Sprayfoam	13.33	9.25	4.08	£936.17	£560.76	40	17	23	57	43
T-17	Insulation, sprayfoam and glazing	14.61	8.62	5.99	£874.84	£508.14	42	22	24	47	39
T-30	Insulation, sprayfoam, glazing and peripherals	14.62	9.7	4.92	£662.28	£463.17	30	18	21		44
Group 4											
T-6	Sprayfoam Detailing, windows, therma break and reduced MVHR	11.19	10.06	1.13	£379.60	£210.56	45	20	19	53	44
T-1	External and Internal EWI, [Pilot]	13.84	7.97	5.87		£173.13			21		46

Figure 67 A comparison of empirical monitoring data across groups

In terms of air-tightness generally, the baselines ranged from 10.02 – 14.62 $m^3/h.m^2$. This highest air leakage rate approximates that expected across similar stock. The lower rates may be where tenants have made attempts to minimise leakage (additional loft insulation, removal of vents), their position within a terrace, exposure to prevailing wind, or where previous works such as window replacement have been carried out to a higher standard. Notwithstanding, improving the air leakage rate to around 10 $m^3/h.m^2$ is achievable with peripheral spray-foam and thermal break detailing (all houses except T-12). The general trend is that the more details undertaken, the better the improvement, with the inclusion of EWI consistently offering 30-40% improvements (T-16; T-25; T-20; T-27; T-17; T-30). T-1 shows an improvement of over 40% and potentially makes a case for conducting air pressure tests during the works to ensure optimised detailing.

The energy cost savings do not always correlate to reduction in air leakage, although whilst those with reductions of over 30% in air leakage do consistently show energy savings of over 30%, the properties have also benefited from EWI. This suggests that a combination of improvement in air tightness and insulation contributes to energy reduction (as expected). T-14 is notable in achieving a 30% reduction in energy costs without the need for EWI.

In all cases there is an improvement (reduction) in relative humidity to within the range of recommendations. There are less fluctuations once MVHR / PIV is introduced. This is potentially because the system is ‘whole house’ and tends to run in the background. Most significantly, despite the reduction in air permeability across the range, relative humidity is reduced. This suggests that the damp & condensation in the unimproved properties contributes more to the relative humidity than the occupancy behaviour. This is reflected in the feedback from the interview questionnaires.

All properties reach WHO minimum temperature ranges of 18-21°C after works. T3 and T14 show an average rise of 3°C with energy cost reductions of 11% and 30% respectively. These properties have not had external wall insulation introduced.

The significance of improving air-tightness is shown to improve thermal comfort, temperature, relative humidity and reduce fuel bills. Whilst these improvements are not captured using the RD SAP tool, using full SAP where air-tightness can be factored begins to highlight potential improvements and is therefore of more use in assisting with the design of similar projects (see figure 68 below).

Housetype	End Terrace baseline	Upgrade scenario 1	Upgrade scenario 2	Upgrade scenario 3
Floor Area (m^2)	97.7	97.7	97.7	97.7
Wall type	Uninsulated no fines wall	100mm EWI no fines wall	130mm EWI no fines wall	180mm EWI no fines wall
U-value	1.23	0.28	0.23	0.18
Floor type	Solid slab	Solid slab	Solid slab	Solid slab
U-value	0.59	0.60 (not improved)	0.60 (not improved)	0.60 (not improved)
U-value	0.16	0.14 (250mm Sprayfoam @ Rafter Level)	0.11 (350mm Sprayfoam @ Rafter Level)	0.1 (400mm Sparayfoam @ Ceiling Level)
Whole window U-value and glass WER g-value	4.80, 0.60	1.1 (whole window)	1.1 (whole window)	1.1 (whole window)
Doors	3.00	1.1	1.1	1.1
Detailing	Calculated y-value 0.116	0.09	0.09	0.09
Airtightness	Default	9.00	7.00	5.00
Ventilation fans	2	MVHR	MVHR	MVHR
Boiler	Ideal Logic system 89.6% efficient	Ideal Logic system 89.6% efficient	Ideal Logic system 89.6% efficient	Ideal Logic system 89.6% efficient
Secondary heating	Electric fire	Removed	Removed	Removed
Controls	Programmer, room thermostat and TRV's	Honeywell System	Honeywell System	Honeywell System
Hot water storage insulation	50mm foam	Measured Loss 1KWh/day	Measured Loss 1KWh/day	Measured Loss 1KWh/day
Low energy lighting	83%	100%	100%	100%

Annual running costs	£1,457	£562	£536	£502
Improvement	(Updated Baseline – SAP 2009)	61.4%	63.2%	65.6%

Figure 68 Projected Saps with differing air-tightness values

Conclusions and recommendations

4.1 Conclusions

- No-fines concrete houses have unique building physics issues that must be taken into account before retrofit. Air-leakage in unimproved properties is in excess of 14m^3/m^2.h against a minimum acceptable level for new construction of 10m^3/m^2.h. This air leakage is of such significance that without being addressed will negate the benefits of typical external wall insulation schemes (see Figure 59 & Sap results in this section)
- Reducing air leakage by 4m^3/m^2.h can lead to a saving of over 90Kg of CO^2 emissions annually[45], which equates to energy and cost savings and more comfortable living environment for the householders.
- It was possible to reduce the air leakage by over 35% by optimising the combination of details and developing a best-practice and measured approach to installation. The expected air leakage for these properties before improvement is often 16 m^3/h.m^2. The significance of this is that improvements to the thermal performance of the fabric alone has limited benefit unless air-tightness is addressed (see table 67)
- There was little performance difference between Dynamic and Classic insulation. This was as a result of the pronounced effect of air movement within the walls of these no-fines concrete buildings which has a greater impact on the performance than heat transfer due to conduction.
- Installing spray foam insulation was the most effective trialled approach to reducing air leakage as the foam can be applied to building fabric junction details that are otherwise inaccessible (see table 67)
- Poorly fitted windows significantly contribute to heat loss. In no-fines concrete housing, the apertures are generally irregular in all three axes as the concrete walls are cast in situ. This means that voids are left around the windows during installation and covered with uPVC strips, virtually negating the thermal benefits of the window replacement scheme[46]. Thermal break inserts improve this situation without the need to replace windows.
- Glazing replacement coupled with external thermal break detailing negates the need to replace full window units meaning that interiors are not affected, saving time and expense.
- Below damp insulation is extremely effective at reducing cold-bridging in solid floor properties. This improves the efficacy of the external envelope insulation scheme and reduces the risk of condensation at floor/wall junctions (Figure 65)
- External wall insulation alone has little impact on reducing air loss in this property typology
- Residents expressed great improvements in health and wellbeing after completion of the works (see figure 19)
- Incidences of fuel poverty have been reduced and almost eliminated within this project and residents generally report that the properties stay warm for longer periods after retrofit
- The incidence of damp has been reduced in over 90% of properties
- A pattern book approach to retrofit has been developed for use by stake holders (see

45 http://www.zerocarbonhub.org/sites/default/files/resources/reports/A_Practical_Guide_to_Building_Air_Tight_Dwellings_NF16.pdf Accessed 1st January 2018

46 http://www.zerocarbonhub.org/sites/default/files/resources/reports/A_Practical_Guide_to_Building_Air_Tight_Dwellings_NF16.pdf Accessed 1st January 2018

appendices 3, 4 & 5)
- The matrix system of identifying the best fit specification and the subsequent application of the pattern book of details can lead to solutions that provide measurable benefits (appendix 5 & 6)
- A design-led retrofit programme with in-construction and in use monitoring ensures a meaningful retrofit
- Post installation monitoring should be employed, recorded and disseminated for future use

4.2 Recommendations for potential future installations

- Survey each property prior to specification in order to optimise retrofit measures. Use thermography, interview the residents and consider air-leakage / ventilation control. Look at historic maintenance issues and factor observations into the retrofit brief.
- Use nuanced predictors (detailed energy modelling, thermography, air-pressure tests) for energy improvements. Tools such as RD Sap are too crude to give a meaningful indication of likely issues and subsequent potential for improvement (use SAP as a minimum)
- Look at incidence of void properties to determine the value of retrofitting properties when empty. Strategise phasing accordingly and consider insulating full terraced blocks where possible, even if owner-occupiers need to be subsidised. This is particularly pertinent for no-fines properties where air moves readily between properties through the walls
- Refer to the Pattern Matrix to define specifications and ensure that overall design responsibility is borne by a qualified designer rather than by manufacturers or suppliers, as they tend to only take bear responsibility for their own systems rather than the holistic solution and interface details of differing product combinations
- Consider supplementary measures that are not necessarily covered by funding as part of a long term strategy. Whilst funding tends to target specific improvements, it may well be cost-effective and beneficial to the building performance and tenant’s well-being to introduce complementary measures into the scheme
- Always check efficacy of works post-installation through qualitative and quantitative surveying. Disseminate successes widely. Each scheme leaves a legacy.

4.3 Impact on fuel poverty

- Mean averaged temperatures were generally raised where pre-retrofit temperatures were below World Health Organisation thermal comfort recommendations
- Heat retention within the building fabric was improved by a combination of insulation and reduction of heat loss due to conduction and convection / air leakage (where a combination of external wall insulation and air-tightness detailing was introduced)
- Temperature fluctuation in the dwellings was moderated across the heating season
- Relative humidity was generally lowered and fluctuations were moderated
- Tenant feedback suggests a positive impact on fuel poverty and an improvement in health and well-being
- No households within the scheme remained in fuel poverty after the works were complete

4.4 Performance comparison against manufacturers' claims

- For no-fines concrete housing, there is no significant improvement in thermal performance when Jablite Dynamic insulation is used in preference to Classic external wall insulation
- Q-clad thermal breaks at window reveal and in below-damp proof course detailing returns significant improvements in the reduction of thermal bridging. There are limited viable alternatives to this technology at present
- Demelec Sprayfoam insulation, when used in conjunction with external wall insulation, returns a significant improvement in air-tightness
- A simple approach to whole house ventilation has a positive effect on control of air movement within the houses and is particularly useful when replacing stand-alone mechanical ventilation in kitchens and bathrooms

4.5 Economic business case for installation of measures

Economic business case for installation of measures.

Payback times against installation costs are presented below using a simple methodology of investment / energy savings. It should be noted that all of these property types will require some form of retrofit work to meet future legislation. The most likely retrofit of choice would be external wall insulation with a base cost in the region of £10,000 per property. If we assume that £10,000 would be needed as an investment to meet legislation and energy performance levels, the "adjusted" payback times for the measures are shown in bracketed italics (deducting £10,000 form the capital cost). Further work would be needed to establish more accurate baseline investments, but provided here as an indicative figure.

The average cost of works for Group 1 (Peripheral insulation and air-tightness works) was £8245.64
Taking the most effective combination from this group, the annual saving from Table 3.3.2 is £175.96, giving a payback time of 47 years *(reduced to 12 years after deducting baseline £10,000 required investment)*

The average cost of works for Group 2 (Classic EWI & Peripheral insulation and air-tightness works) was £15081.80
Taking the most effective combination from this group, the annual saving from Table 3.3.2 is £158.17, giving a payback time of 95 years
(reduced to 30 years after deducting baseline £10,000 required investment)

The average cost of works for Group 3 (Dynamic EWI & Peripheral insulation and air-tightness works) was £19903.60
Taking the most effective combination from this group, the annual saving from Table 3.3.2 is £299.84, giving a payback time of 66 years
(reduced to 33 years after deducting baseline £10,000 required investment)

The average cost of works for Group 4 (ad hoc) was £10328.33. Taking the most effective combination from this group, the annual saving from Table 3.3.2 is £130.37, giving a payback time of 79 years
(reduced to 12 years after deducting baseline £10,000 required investment)

Whilst the empirical payback time seems to be substantial, the benefits of lifting the tenants out of fuel poverty coupled with the likely reduction in maintenance legacy and potential increase in tenure length due to improved thermal comfort and affordability should be taken into account.

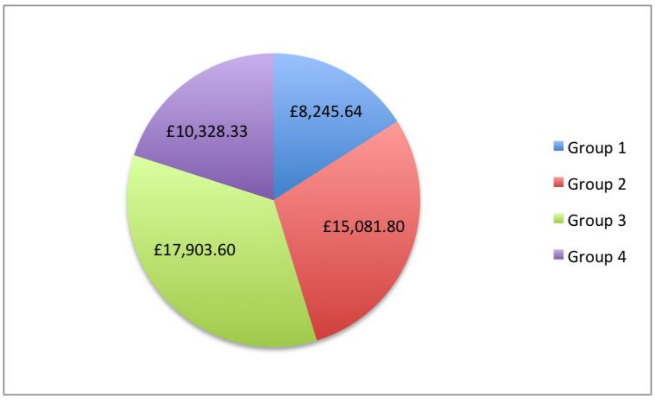


Figure 69 Average cost of measures by group

All sets of measures returned improvements in fuel costs for heating (gas), increased thermal comfort (temperature) in accordance with WHO guidance and a general reduction in and stabilisation of relative humidity. Little difference was noted between groups 2 and 3. Group 4 offered the best value retrofit, although thermal comfort was further improved with the introduction of external wall insulation.

Retrofit in line with Group 4 (T-1) therefore offered the best value in relation to improvements but would be further complemented with group 4 works. This suggests that a tailored approach to retrofit of no-fines concrete housing, whereby previous interventions are taken into account and incremental retrofit measures reflecting available funding is viable.

Taking the works in Group 2 as the ‘best fit’ value for money approach whereby the improvements in thermal comfort, reduction of incidence of damp and savings on energy bills are the key indicators, the payback time on energy saving alone averages 20 years. However, if reduction in the requirement for maintenance coupled with improvement in the health of occupants is taken into account, payback time would be considerably shorter.

3 Index to Appendix

Appendix 1 Glossary of terms

Appendix 2 Case studies
Site Plan
Case Study 1 CP779 29 The Glen
Case Study 2 CP779 21 The Glen

Appendix 3 Details of technologies:
Product Data sheets
Project Production Information: Building Information Model; Scheme Level Drawings; As-Built BIMx Maintenance File

Appendix 4 Matrix of measures for large stock roll-out

Appendix 5 Example of application to large stock roll out project

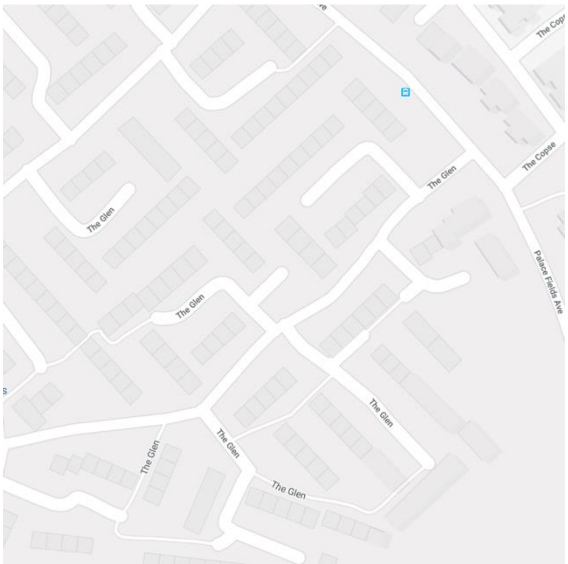
Appendix 6 Health and Innovation Programme 2015-2017

Appendix 1: Glossary of Terms

ATT	Air Pressure Test
DD	Degree Days
EPC	Energy Performance Certificate
EWI	External Wall Insulation
IWI	Internal Wall Insulation
HIP	Health and innovation Programme
MVHR	Mechanical Ventilation and Heat Recovery
NEA	National Energy Action – the National Fuel Poverty Charity
PIV	Passive Input Ventilation
PVHR	Passive Ventilation and Heat Recovery
RH	Relative Humidity
SAP	Standard Assessment Procedure (for assessing home energy efficiency)
TIF	Technological Innovation Fund
TRV	Thermostatic Radiator Valve

Appendix 2: Case Studies

The satellite image[47] and site plan showing properties at the Glen. Almost half are under control of The Riverside Group, but the majority are not located in contiguous blocks. This illustrates the terraced and stepped-terraced arrangement of houses. The rationale for retrofitting whole blocks is particularly pertinent for no-fines concrete houses due to the connected voids in the walls between adjacent properties. The potentially difficulty of organising whole-block refurbishment given the mixed tenure inherent on this estate is highlighted by the layout.



47 https://www.google.co.uk/maps Accessed 20th December 2017

Case Study 1 CP779 01

After the trial properties had been identified, but before work commenced, the residents of property CP779 01 moved house. This compromised the trial in terms of continuity of occupancy. It did however provide the opportunity to undertake study on a 'void' or empty property. In renovation of properties, a different approach can be taken to 'voids' as the level of disruption to tenants need not be taken into account. Indeed, one of the recommendations made for future works is to gauge the average turnover of properties in an area prior to determining the most effective approach to retrofit. If the turnover period is generally short, it may be pragmatic to wait until properties are empty before commencing renovation.

NB – Exploded images of the plans below are available on request from NEAs Technical Department

The team elected to work on the void property prior to commencement on the main scheme. The perceived advantages of this approach were as follows:

- It was possible to conduct building forensics to find additional voids, cavities and openings
- Additional thermography and air pressure tests were possible during the works, allowing us to optimise install techniques.
- It was possible to spend extensive time assessing the roof space and connections to neighbouring properties.
- The benefits of Internal Wall Insulation (IWI) were explored. IWI installations were refused

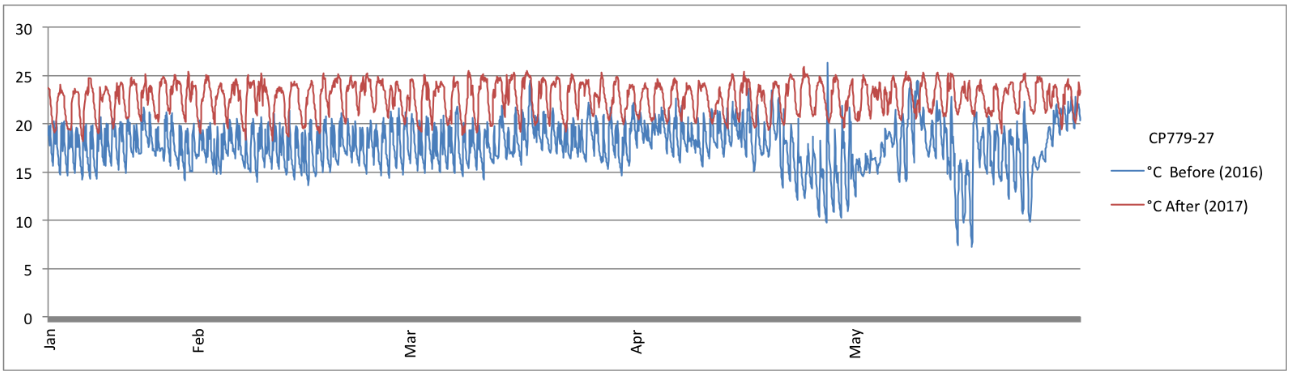
by all tenants as being too much of a disturbance to their interiors. IWI did prove to be a useful barrier to damp caused by condensation, and a good way to treat party walls to unimproved properties

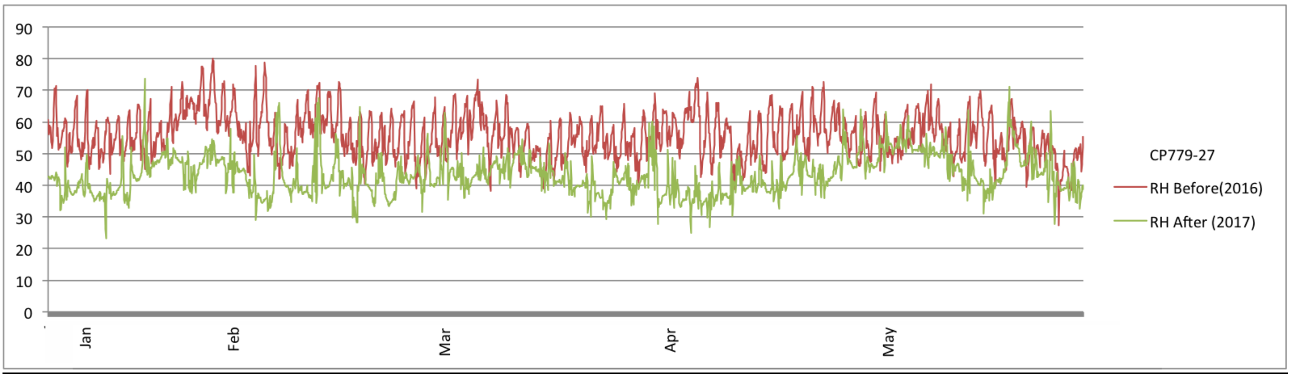
- Tenants were able to visit the property during and after the works. This was a useful tenant engagement tool and certainly assisted with uptake. It also helped to ensure good relations with the contractors, although many residents not uninvolved with the trial did express dissatisfaction about being excluded.
- The contractors were able to optimise their installations, and to plan further works in order to minimise disturbance to the tenants.
- Continued works to this property ultimately led to an air tightness of approximately 8 $m^3/h.m^2$

Case Study 2 CP779 27

CP779 27 is a mid-terraced property. The occupants are both retired and report ill-health due to dampness, particularly apparent in the hallway adjacent to the gable wall. The tenants reported excessive heating bills that meant they could only heat the house for 4 days each week during the winter.

The property received external wall insulation and a full set of air-tightness and thermal bridging improvements. The heating bill was reduced by £288/annum from £739 to £451. Average temperatures were raised from 17° to 23.5°. Relative humidity was reduced from an average of 65% to 45%. The tenants now feel more able to heat their home affordably, substantiated by the reporting of an absence of damp and satisfaction with the heat retention and thermal comfort within the home. .





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Client	Riverside
Project	NEA Halton 97 The Glen
Layout	Front and Rear Elevations
Drawings	Front Elevation, Rear Elevation

Drawing Number							Revision
654	CTS	97	ZZ	DR	A	4501	01 - WIP

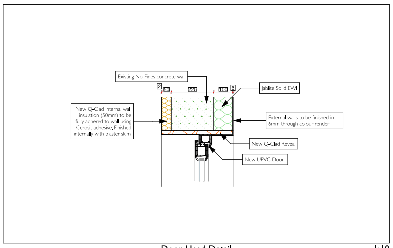
TECHNICAL INNOVATION FUND

NEA Action for Warm Homes

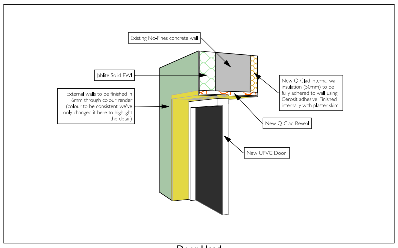
Appendix 3: Details of technologies:

The details below are a set of details output from the Building Information Model generated by the pattern book process used in conjunction with this project. (See also Appendices 4 & 5)

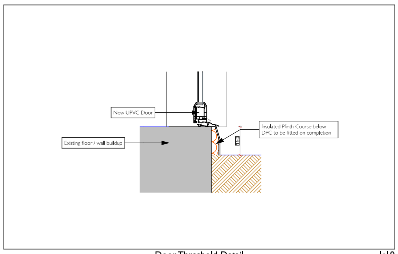
NB – Please contact NEAs technical Dept for source PDFs of the images below if required



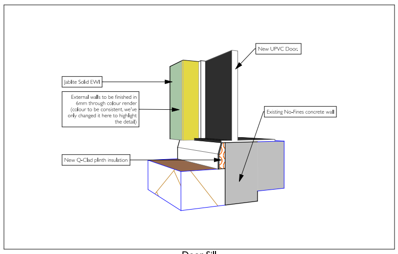
Door Head Detail 1:10



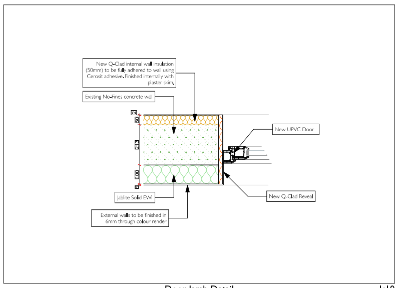
Door Head



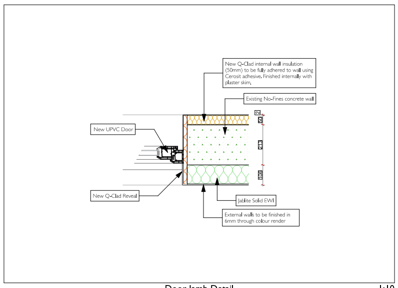
Door Threshold Detail 1:10



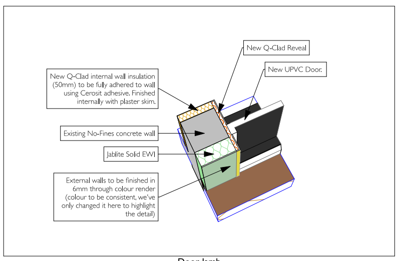
Door Sill



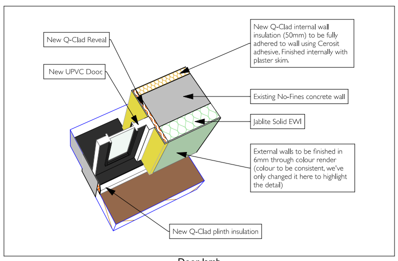
Door Jamb Detail 1:10



Door Jamb Detail 1:10



Door Jamb



Door Jamb

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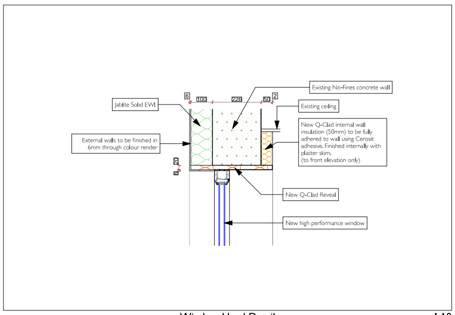
Client	Riverside
Project	NEA Halton 02 The Glen
Layout	Door Details
Drawings	Door Head Detail, Door Threshold Detail, Door Jamb Detail, Door Head, Door Sill, Door Jamb

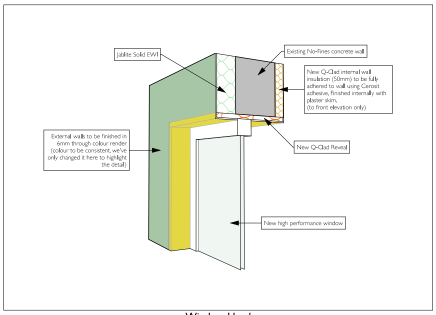
Drawing Number							Revision
654	CTS	002	GF	DR	A	4701	01

NEA Action for Warm Homes

TECHNICAL INNOVATION FUND



Window Head Detail 1:10



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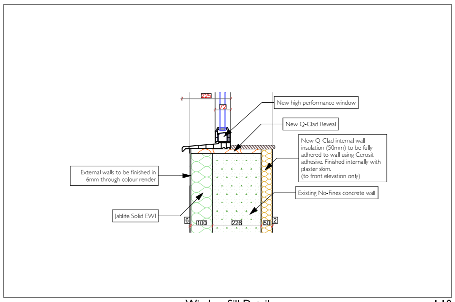
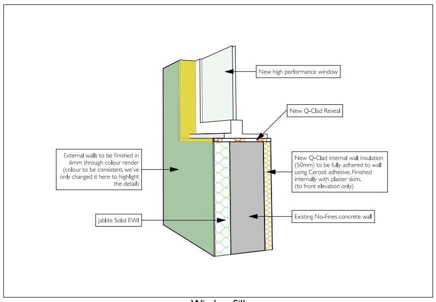


Window Sill Detail 1:10



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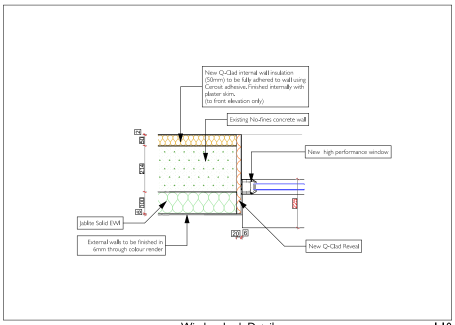
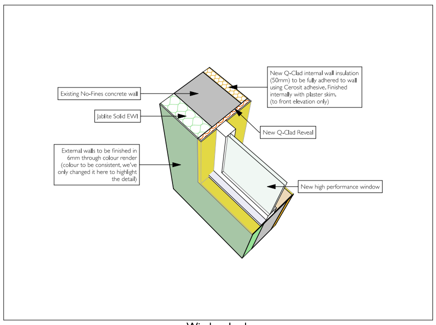


Window Jamb Detail 1:10



Window Jamb

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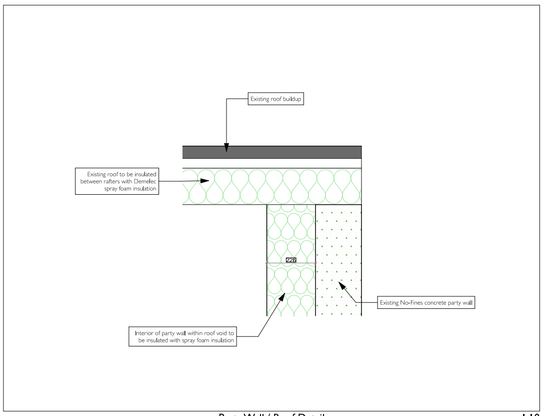
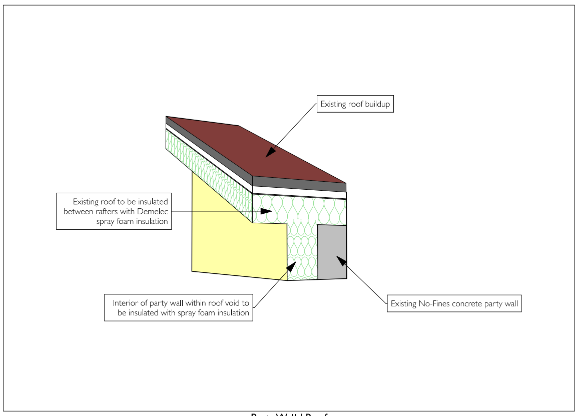
Client	Riverside
Project	NEA Halton 02 The Glen
Layout	Window Details
Drawings	Window Head Detail, Window Sill Detail, Window Jamb Detail, Window Head, Window Sill, Window Jamb

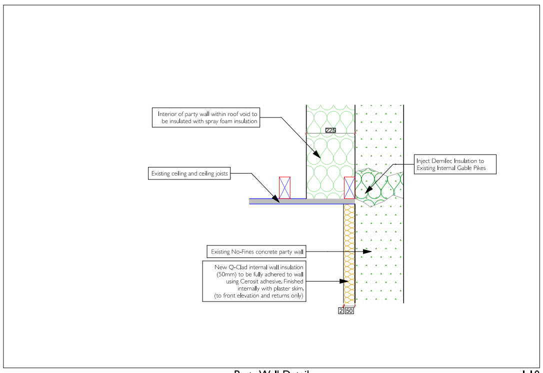
Drawing Number: 654 CTS 002 ZZ DR A 4702 — Revision: 01



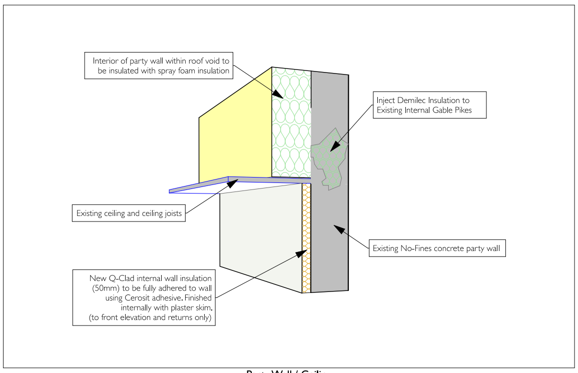
Party Wall / Roof Detail 1:10



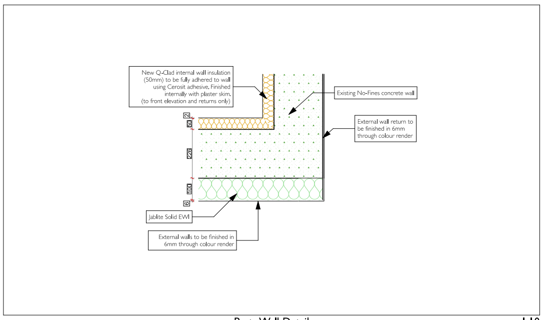
Party Wall / Roof



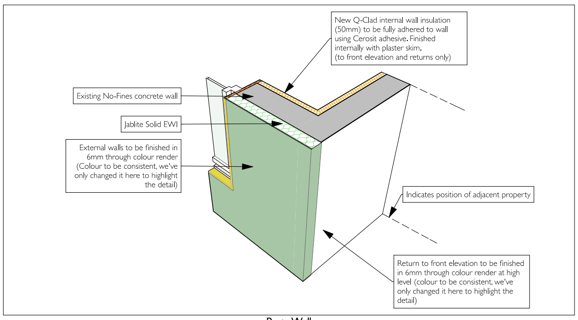
Party Wall Detail 1:10



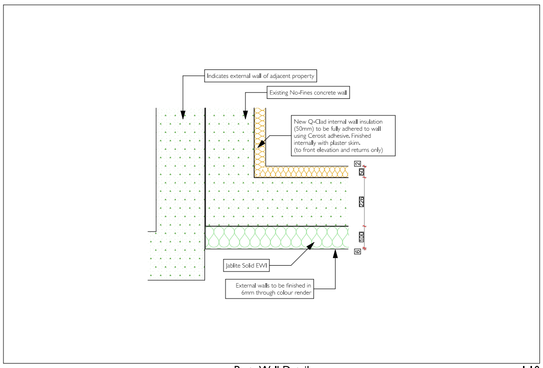
Party Wall / Ceiling



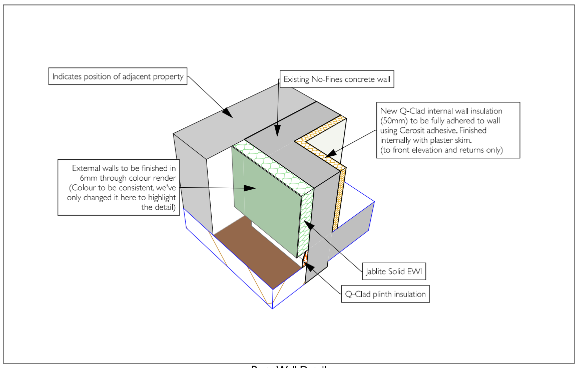
Party Wall Detail 1:10



Party Wall



Party Wall Detail 1:10



Party Wall Detail

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Client Riverside

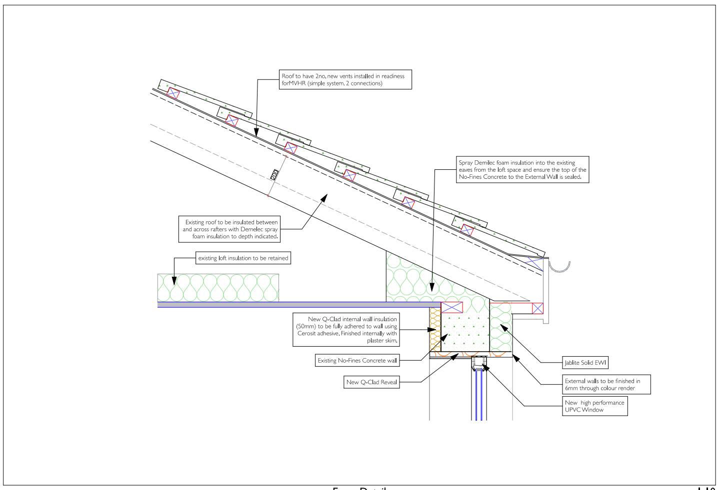
Project NEA Halton 02 The Glen

Layout Party Wall Details

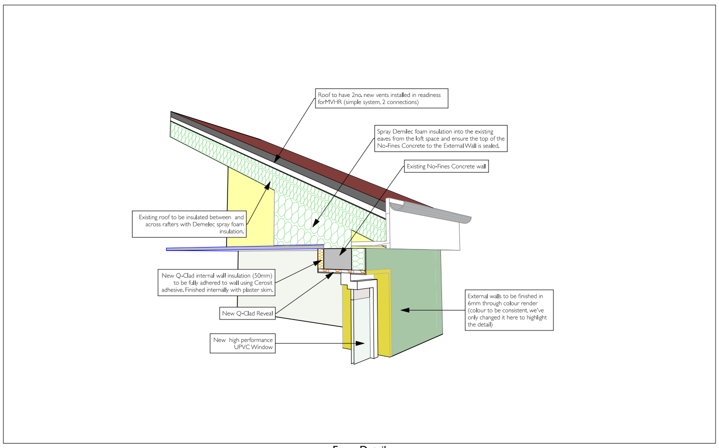
Drawings Party Wall / Roof Detail, Party Wall Detail, Party Wall, Party Wall / Roof, Party Wall / Ceiling

Drawing Number: 654 CTS 002 ZZ DR A 4703

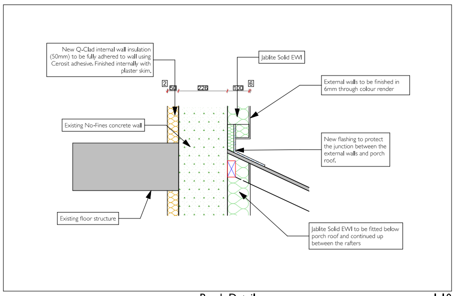
Revision: 01



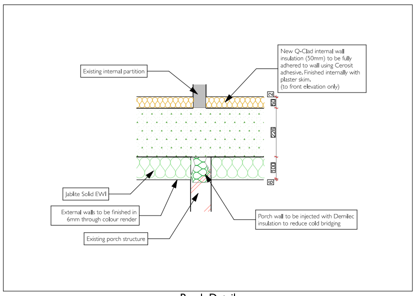
Eaves Detail 1:10



Eaves Detail



Porch Detail 1:10



Porch Detail

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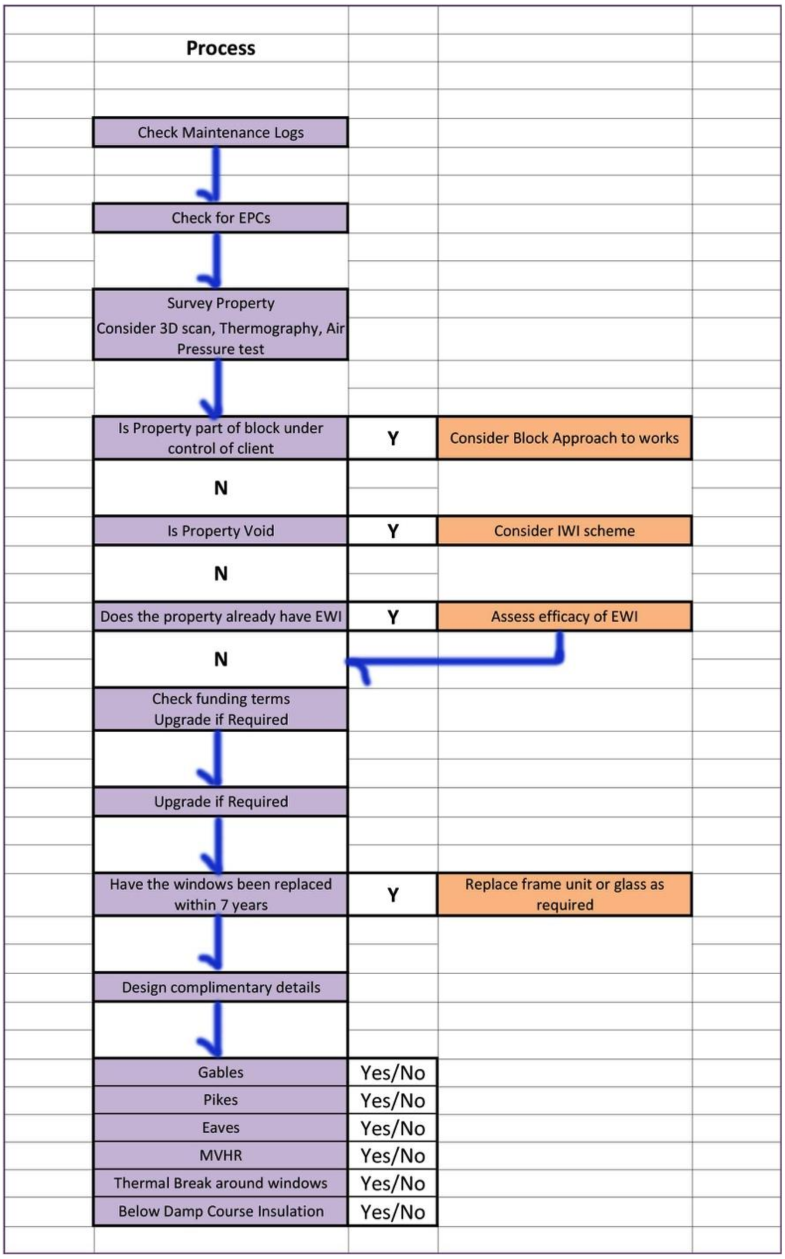
Client	Riverside
Project	NEA Halton 02 The Glen
Layout	Roof Details
Drawings	Porch Detail, Eaves Detail

Drawing Number: 654 | CTS | 002 | ZZ | DR | A | 4704
Revision: 01

Appendix 4: Matrix of Measures for Larger Stock Roll-out

A matrix tool for large stock roll-out has been developed by the architect for no-fines terraced houses. The principal is to enable a design-led approach to retrofit that takes account of the current building condition, together with available funding streams in order to specify the most pragmatic, efficient and best-fit solution for differing properties within a scheme.

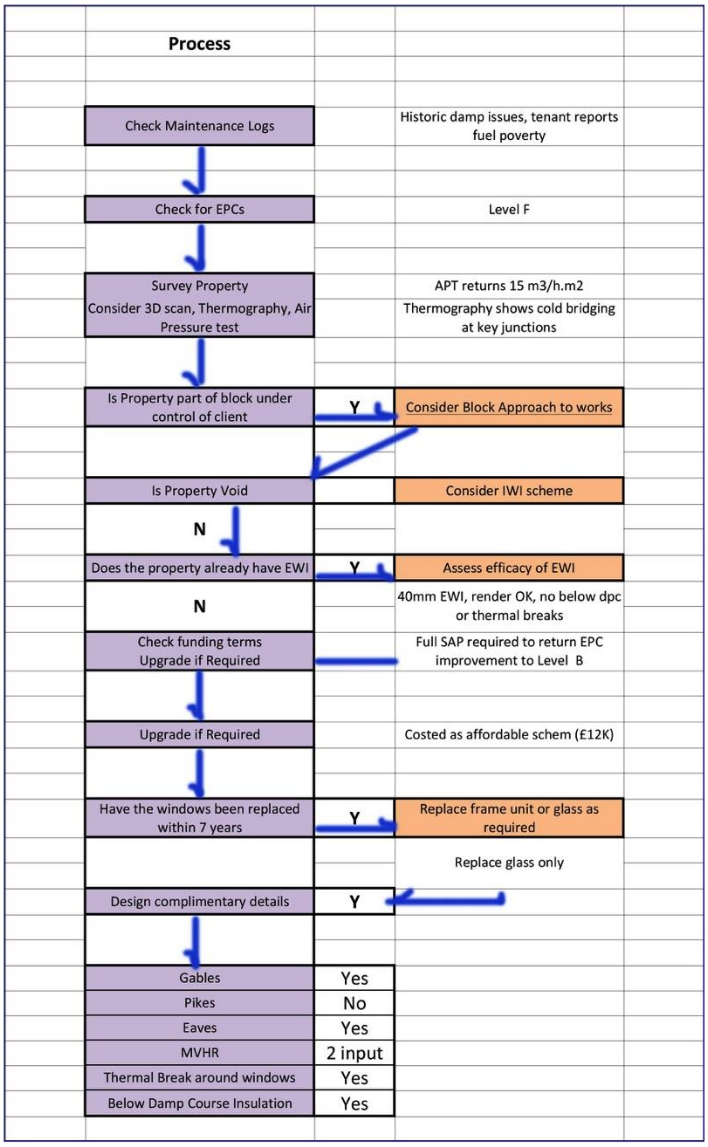
The process begins with an appraisal of available funding and grant schemes, then assesses the property types using a variety of scanning, surveying and testing tools. By comparing the survey results with historic Energy Performance Certificates (EPCs) and maintenance records, it is possible to use the matrix to derive a costed schedule of works. The process flowchart is outlined below.



Appendix 5: Example of the application to Larger Stock Roll-out with decision based flow chart to aid identification of measures

The specification matrix was applied to a case study in Netherley, Liverpool. The architects assessed a selection from 200 properties with three typologies. 3D scanning, energy modelling and thermography air pressure testing were used. The process highlighted incidences of damp and fuel poverty that are inherent in no-fines properties despite the houses already having external wall insulation (EWI). The existing EWI is approximately 10 years old and offers limited improvement in thermal performance. Without applied intervention to the design, specification and installation process, it would be likely that the existing EWI would be removed and a new system would be installed, without the inclusion of details to reduce air-permeability. This would offer moderate thermal performance improvements at a cost of circa £20K.

Running through the specification process, it was possible to arrive at a solution which utilised the existing EWI, with a cost of between £8K and £12K per property to reach a SAP rating of B/C and an improvement of air-tightness to a leakage rate of <$8m^3/hm^2$


Process
Check Maintenance Logs
Historic damp issues, tenant reports fuel poverty
Check for EPCs
Level F
Survey Property
Consider 3D scan, Thermography, Air Pressure test
APT returns 15 m3/h.m2
Thermography shows cold bridging at key junctions
Is Property part of block under control of client
Y
Consider Block Approach to works
Is Property Void
Consider IWI scheme
N
Does the property already have EWI
Y
Assess efficacy of EWI
40mm EWI, render OK, no below dpc or thermal breaks
N
Check funding terms Upgrade if Required
Full SAP required to return EPC improvement to Level B
Upgrade if Required
Costed as affordable schem (£12K)
Have the windows been replaced within 7 years
Y
Replace frame unit or glass as required
Replace glass only
Design complimentary details
Y
Gables
Yes
Pikes
No
Eaves
Yes
MVHR
2 input
Thermal Break around windows
Yes
Below Damp Course Insulation
Yes

Appendix 6: Health and Innovation Programme 2015 – 2017

The Health and Innovation Programme (HIP) was a £26.2 million programme to bring affordable warmth to fuel poor and vulnerable households in England, Scotland and Wales.
The programme launched in April 2015 and was designed and administered by fuel poverty charity National Energy Action as part of an agreement with Ofgem and energy companies to make redress for non-compliance of licence conditions/obligations. To date, it remains the biggest GB-wide programme implemented by a charity which puts fuel poverty alleviation at its heart.

The programme comprised 3 funds

- **Warm and Healthy Homes Fund (WHHF):** to provide heating, insulation and energy efficiency measures for households most at risk of fuel poverty or cold-related illness through health and housing partnerships and home improvement agencies

- **Technical Innovation Fund (TIF)**: to fund and investigate the impact on fuel poverty of a range of new technologies

- **Warm Zones Fund (WZF):** to install heating and insulation and provide an income maximisation service to households in or at risk of fuel poverty, delivered cost-effectively through partnership arrangements managed by NEA's not-for-profit subsidiary Warm Zones Community Interest Company

What it involved

- **Grant programmes** to facilitate the delivery of a range of heating and insulation measures and associated support. Grant recipients were encouraged to source match and/or gap funding to increase the number of households assisted and to enhance the support provided to them
- **Free training** to equip frontline workers with the skills needed to support clients in fuel poverty
- **Outreach work and community engagement** to provide direct advice to householders on how to manage their energy use and keep warm in their homes

In addition we undertook substantial **monitoring and evaluation** work, to assess the effectiveness and measure the performance of the technologies, and to understand the social impacts of the programme. Our **communications programme** helped partners to promote their schemes locally as well as share best practice with others. The programme generated a considerable amount of **knowledge and insight** which will be made freely available to help support future policy and delivery.

Proper investment of advanced payments allowed us to generate interest which, along with efficiency savings, was reinvested back into the programme in the form of additional grants and support which helped us further exceed our targets.

For more information see www.nea.org.uk/hip

NEA Technical
September 2018

NEA Action for Warm Homes