Thin Internal Wall Insulation (TIWI)

Measuring Energy Performance Improvements in Dwellings Using Thin Internal Wall Insulation

Annex A; Introduction to TIWI

Literature, Household & Industry Reviews

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Contents

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Executive summary

The Leeds Sustainability Institute at Leeds Beckett University were tasked by BEIS to quantify the benefits and risks of installing internal wall insulation (IWI) and thin internal wall insulation (TIWI) retrofits into solid wall homes. In order to deliver this, a holistic approach was adopted, and the project was split into 4 main sections:

1) Technical evaluation of retrofit case studies undertaken in test houses
2) Modelling of IWI and TIWI retrofits in a range of house archetypes
3) Laboratory tests to determine how weathering affects condensation risk and moisture accumulation in solid walls pre and post insulation
4) A review of literature and sociotechnical barriers to IWI and TIWI, which are covered in this Annex, and involved:
    - Defining the need for IWI and TIWI to improve the thermal performance of solid wall homes.
    - Undertaking a literature review to investigate existing opportunities and concerns with IWI.
    - Evaluating existing understanding around fire risk associated with IWI and TIWI.
    - Survey historical retrofits of IWI to identify evidence of problems manifested over time.
    - Undertake 100 surveys of solid wall homes to identify technical barriers to IWI and TIWI.
    - Conduct a questionnaire to gauge perceptions of retrofits and explore social barriers to IWI.
    - Compiling lessons learned from installers to create a communication strategy to improve standards.

The literature review identified that adding IWI can achieve greenhouse gas (GHG) emissions reductions by around 5% to 10% in homes. However, it may also introduce some moisture accumulation and condensation risks. No substantial increase in fire risk was reported.

Five surveys were undertaken in homes that had previously had an IWI retrofit. It was observed that surface condensation risk was not common, although there was evidence of thermal bridging around complicated detailing and where alterations were made to the walls. There was also often air movement behind IWI. While no major problems were found, the surveys suggested that the retrofits had not adopted a whole house approach as infiltration rates in some homes were particularly high, undermining the potential benefit of the insulation.

A survey of 100 solid wall homes revealed several technical barriers to installing IWI. It was found that there are often many obstacles on walls that would need to be removed and replaced, adding cost and delays to IWI retrofits. Additionally, boilers, telephone sockets and utility meters were common which need specialist licenced contractors to remove. Furthermore, walls were often not straight which complicates the installation of IWI and TIWI based on rigid boards. Many of the surveyed walls were already plaster boarded, adding a substantial cost if removal was required. TIWI products that are <10mm deep could avoid some of the major barriers such that items fixed to walls may be left *in situ* or the same fixings can be reused.

Additionally, damp was observed in 9 out of 10 homes, a quarter of walls required repair, and 1 in 10 homes had no ventilation. All of these issues need to be remedied prior to retrofit, regardless of the insulation being installed.

A questionnaire gathered 180 responses from individuals and suggested that the most important motivators for having retrofits were to reduce energy bills, that it was good value for money and would make their homes warmer. Improvements to house prices and appearance were not considered important. The better-known measures were the most popular (i.e. PV, double glazing and new boilers) and since IWI was the least-well-known it was also the least popular retrofit. According to a conjoint analysis, the most important factor driving respondent's preference for IWI was the cost of installation, followed by the perceived energy savings, and lastly the hassle factor.

A guide to compiling a communication strategy was developed following feedback from installers. One of the main findings was that installers believed manufactures' specifications to be deliberately unachievable so that underperformance can be blamed on installation practices. Furthermore, four focus groups, each consisting of 5 installers, identified that installers did not like using IWI, and specially, did not want to be involved in ECO delivery due of the administrative burden and because they did not value the additional quality assurance. Most installers only install IWI when households were undertaking other work. Furthermore, they considered PAS 2030 to be irrelevant and impractical although most had not received training. There was relatively little understanding and some scepticism of thermal bridging, yet installing IWI was viewed as a simple task not requiring training. Despite this, installers were expected to design solutions to complicated design problems on the spot, for which guidance is not provided. They suggest training for installers should be bitesize, free, practical and have some additional advantage for the installer such as a qualification. It was the opinion of the installers that peer experience currently drives knowledge transfer and will continue to do so, and that building control officers do not have the knowledge to support installers to improve retrofit quality.

1 Annex A; Introduction to TIWI

1.1 Research Project Overview

Thin internal wall insulation (TIWI) could play a role in UK energy policy, though the extent to which it can contribute to emissions targets, increase retrofit rates of solid wall homes, reduce fuel poverty, improve thermal comfort and mitigate unintended consequences is not fully understood.

On behalf of the Department for Business, Energy and Industrial Strategy (BEIS), Leeds Beckett University have investigated the potential of TIWI to achieve warmer homes and lower fuel bills with fewer unintended consequences than conventional internal wall insulation (IWI).

Five output reports describe the research and results from this project, these are:

1. Summary Report
2. Annex A, Introduction to TIWI: Literature, Household & Industry Reviews
3. Annex B, TIWI Field Trials: Building Performance Evaluation (BPE)
4. Annex C, Predicting TIWI Impact: Energy & Hygrothermal Simulations
5. Annex D, Moisture Risks of TIWI: Laboratory Investigations

1.2 TIWI Annex A Overview

This report presents the qualitative and quantitative supporting research that was undertaken to investigate the current landscape among the retrofit industry and householders as well as identify any other non-technical obstacles in homes that may be limiting uptake of IWI.

This report is structured as follows:

- Section 2, The Rationale for TIWI
- Section 3, Reviewing Existing Understanding of IWI
- Section 4, Evaluating Fire Risk for IWI
- Section 5, Historical Surveys of IWI Retrofits
- Section 6, Identifying Barriers to IWI and the Hassle Factor via Building Surveys
- Section 7, Investigating Householder Acceptance of TIWI via Questionnaires
- Section 8, Understanding Installer Perceptions around TIWI via Interviews and Focus Groups

2 The Rationale for TIWI

2.1 The need for retrofit

The energy efficiency of the UK housing stock impacts many areas of Government policy: carbon budgets, where homes are responsible for 40% of total UK CO_2 emissions (CCC, 2016a) while heating homes accounts for 15% (BEIS, 2017a); fuel poverty targets, as currently 11% of households are defined as fuel poor (DECC, 2016); innovation and the industrial strategy, considering that domestic retrofit accounts for 40% of the insulation market*; healthcare, given that around 9,000 deaths every winter are directly attributable to cold homes (NEA, 2016); and fire management, as exposed by tragic events at Grenfell Tower.

2.2 IWI in retrofit policy

Recent targets for the Energy Company Obligation (ECO) are to thermally improve 1 million homes by 2020 and the Government has mandated that a proportion of these (21,000) must be solid wall insulation (SWI) retrofits, including internal wall insulation (IWI). SWI retrofits however remain relatively rare. Conversely cavity wall insulation retrofits, which are simpler to install and more cost effective have been more widespread and now there are more uninsulated solid walls left (around 6 to 8 million homes) than uninsulated cavity walls, as shown in Figure 2-1.

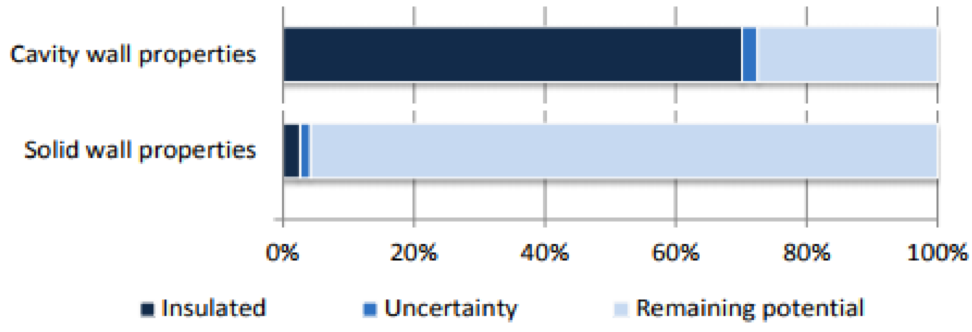

Figure 2-1, Remaining potential for retrofit (DECC, 2013)

2.3 Low IWI installation rates

The IWI market in the UK is small; of 2 million ECO retrofits, only 145,000 were SWI, and of these 95% were external wall insulation (EWI). This means that IWI represented fewer than half a percent of all installed measures (BEIS, 2017c). EWI is more common than IWI, which is often only favoured in areas, such as conservation zones, where EWI has planning restrictions.

2.4 Thin internal wall insulation (TIWI) potential

In this project, TIWI is defined as any IWI with a thickness that is less than 25 mm. As such it may have characteristics that allow it to achieve market penetration where conventional IWI has not. TIWI was funded under previous schemes such as the Community Energy Savings Program (CESP). However, it is seldom considered as an option in ECO since it yields lower U-values than conventionally thicker IWI.

* www.amaresearch.co.uk/products/building-insulation-products-2015

This means that those homes that may not have been suitable for conventional IWI, may have had no retrofit at all, even if TIWI was possible. The motivation for this project, therefore, is the idea that TIWI could save many homes a small amount of energy which cumulatively has the potential to provide a greater benefit to society than conventional IWI saving fewer homes larger amounts of energy. This project will provide evidence on the potential for TIWI to contribute to carbon budgets, achieving SWI ECO quotas, insulating 1 million homes, stimulating innovation and opening new markets with owner occupiers, like loft insulation and cavity wall insulation (CWI) in previous decades. The success of TIWI may relate to its ability to overcome challenges faced by conventional IWI.

2.5 Challenges facing IWI

Problems with IWI are well documented (Hansford, 2015, Bonfield, 2016). In summary IWI:

1. is expensive and labour intensive, requires decoration after installation, involves complicated detailing around features and often requires services to be relocated, increasing install durations.
2. is disruptive, has access issues, and requires householder cooperation.
3. has unintended consequences in dwellings and for neighbours increasing risks of cold bridging and moisture problems.
4. reduces room floor areas.
5. has few qualified installers and is not yet achieving economies of scale.
6. has less certain returns on investments since evidence is only on a case study level.

2.6 IWI is an expensive option

The Retrofit for the Future programme suggests installation costs vary between £4,920 and £14,720 for a home with 40m^2 of external wall area (SWEET, 2014). In practice, this means that for every home fitted with IWI, between 16 and 50 homes could be installed with CWI. Costs vary hugely for IWI installations in part due to differences in material costs, though mainly due to a lack of understanding of enabling works or unforeseen costs such as relocating services, making good decoration or providing additional strengthening or repairing building fabric prior to IWI installation. This project will investigate if TIWI reduces labour costs (e.g. installation time, simpler redecoration, fewer skilled trades to relocate services) and has less product wastage, which may make its cost per $kgCO_2$ savings more competitive compared to IWI, as well as compare the relative TIWI options themselves.

2.7 Installing IWI is complex and causes householder disruption

A report by the Leeds Sustainability Institute (LSI) previously identified that installers and registered social landlords (RSL) preferred EWI since it provides less disruption for tenants and complexity for the installers (Gorse et al., 2017). This report identified that IWI was only seen as a viable retrofit option when required by planning, or when the property had become void: in one instance the RSL paid for the householders to go on holiday while work was completed. The inconvenience of IWI installations is a barrier to uptake as well as a major contributor to its potential cost. This project will investigate if TIWI installation protocols and requirements differ to IWI and monitor complexity of the installer and disruption levels to the occupants.

2.8 IWI can have unintended consequences

Junctions and discontinuities in insulation layers (e.g. at window reveals or around services) create regions of comparatively higher heat loss; these areas are referred to as thermal bridges. These are a concern where substantial amounts of insulation are applied to surrounding areas. They are therefore an issue for IWI since installers tend to aim for theoretical U-value targets of 0.3 W/m²K, the limiting U-value for new dwellings in UK Building Regulations (NBS, 2014), as this provides higher modelled carbon savings per installation. While the thermal bridging in new-build dwellings is reduced by specifying accredited details and by thermal modelling, it may not be appropriate in retrofits where detailing is often ad-hoc.

Figure 2-2, WUFI model of moisture build up following solid wall IWI retrofit

This means retrofitting IWI can elevate condensation risks due to reductions in interstitial surface temperatures and build-up of moisture content in the wall, as well as reductions in adjacent room surface temperatures and increasing heat flow through thermal bridges. Moisture modelling undertaken in the Leeds Core Cities research project is shown in Figure 2-2 and thermal bridging modelling in Figure 2-3 which have previously identified these phenomena (Gorse et al., 2017).

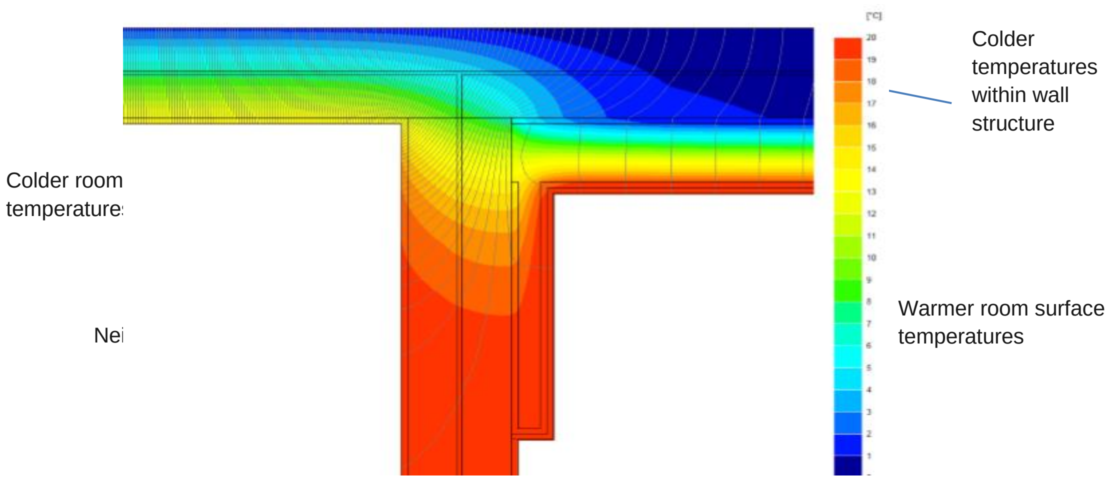

Figure 2-3, Physibel TRISCO model of Impact on wall temperatures of retrofitting IWI in adjacent rooms

This effect is greatest at low wall U-values; this project will discover the optimal trade-off of sacrificing fabric thermal performance for lower moisture risk using TIWI. Where cold bridging is not a problem TIWI may be able to increase wall surface temperatures so that they stay above the critical temperature factor (f_{Rsi}) of 0.75. The surface temperatures will be measured in this project using surface thermocouples and thermography, and temperature factors are calculated before and after TIWI is installed using the following equation:

Equation 1

$$f_{Rsi} = \frac{T_{surface} - T_{Ext}}{T_{Int} - T_{Ext}}$$

Where:

f_{Rsi} is the critical temperature factor

$T_{surface}$ is the surface temperature

T_{Ext} is the external temperature

T_{Int} is the internal temperature

2.9 Immature IWI retrofit supply chain and lack of DIY potential

Whilst the supply chain for IWI is small, by contrast, loft insulation (LI) is the most successful home energy efficiency measure, partly due to ease of installation and DIY market. IWI requires specialist installation especially with regards to installation around features like staircases, openings or wall mounted items like radiators. This project will investigate the extent to which some TIWI could penetrate the DIY market. Some solutions will be more appropriate than others, depending on their application process. However, the implications of DIY on quality of installation, carbon savings, the number of homes receiving retrofits and cost effectiveness is not well understood.

2.10 IWI can reduce floor areas

The floor area that may be lost to IWI is a concern for customers; Table 2-1 shows that, using English Housing Survey (EHS) data, IWI can take up to almost 7% of a dwelling's floor area, while TIWI may only take up 1% and therefore could stimulate new demand, especially in smaller dwellings.

Table 2-1 Estimated loss of dwelling floor area†

	Average floor area m^2			
	Mid terrace	End Terrace	Semi	Detached
IWI thickness	87	89	97	151
15 mm	0.39 (0.4 %)	0.60 (0.7 %)	0.63 (0.6 %)	1.04 (0.7 %)
25 mm	0.66 (0.8 %)	1.00 (1.1 %)	1.04 (1.1 %)	1.74 (1.2 %)
100 mm	2.62 (3.0 %)	4.00 (4.5 %)	4.18 (4.3 %)	6.95 (4.6 %)
150 mm	3.94 (4.5 %)	6.00 (6.7 %)	6.26 (6.5 %)	10.43 (6.9 %)

† Assuming homes are square and have 1 internal partition wall

2.11 Uncertainty around IWI energy savings

Numerous tests on IWI have reported a wide range in energy reductions though uncertainty is compounded by the fact that tests often use different materials, product thicknesses and installation methods, not to mention tests being conducted in various dwelling archetypes over different time periods and test conditions, all of which makes comparisons difficult. This project will provide more inter-comparability since test homes will be exposed to fewer variables and have common test procedures, so differences in performance may be attributed to relative characteristics of each TIWI.

2.12 Wider considerations of IWI

2.12.1 Thermal comfort

Thermal comfort is significantly affected by radiant temperatures. IWI offers potential for greater thermal comfort by raising internal surface temperatures, thus reducing radiant heat exchange with the occupant. It is unknown whether this comfort improvement is identical for both IWI and TIWI. If people feel more comfortable, they may turn heating off or down, and in doing so, reduce carbon emissions and fuel bills.

This project investigates thermal comfort changes related to TIWI through increasing surface temperatures, and how this may relate to setpoint temperatures and models the impact of this on carbon emissions and fuel bills. Beyond this, there are concerns that IWI may adversely impact summertime overheating in dwellings, which may be especially problematic for vulnerable households. This project will therefore use calibrated dynamic simulation modelling to predict the impact of this as well as look at how the risk may increase under future climate warming scenarios.

2.12.2 Dwelling heat up and cool down times

The way we use homes is changing and transient occupancy is becoming more widespread with, for example, commuters living in single occupancy flats spending much of their time away from their homes. Heating homes to support transient occupancy profiles is challenging where homes have large areas of externally exposed thermal mass since the heating system will be slow to elevate air temperatures while some heat is used to charge (or warm) the fabric of the dwelling. Furthermore, heat pumps which provide low temperature heat are slower to respond to calls for heat where there are large areas of exposed mass. Where TIWI is installed less heat will be lost to charging exposed walls, which will benefit transient occupancy as this will shorten the time taken for the heating system to warm the room. This project will measure heat up and cool down times before and after TIWI is installed.

2.13 Summary of rationale for TIWI

Insulating solid walls is a national priority, yet current solid wall retrofit options have not been installed at scale and there are concerns around the risks they may introduce into homes. TIWI may be able to address both of these problems, however, there is limited research available which compares the benefits and risks associated with IWI and TIWI.

3 Reviewing Existing Understanding of IWI

3.1 Review methodology

There is a wealth of literature on the benefits of reducing energy use and condensation risk in homes. To ensure the literature review is manageable, a structured approach was taken, specifically using the key term "*internal wall insulation*" (IWI) and focussing only on peer reviewed scientific articles. Additional literature is also referred to where the authors are aware of research that was not captured by the structured review to ensure the critique is complete. Particular features of IWI are also discussed in relevant chapters of this report where it aids the interpretation of the results. Following this, an overview of TIWI on the UK market is presented, which will inform the selection of TIWI for investigation in this paper.

The initial search for "Internal Wall Insulation" when entered into Science Direct literature database yields 95 scientific papers, these are summarised in Figure 3-1 and as can be seen almost all of these were published in the last decade. This was deemed to be an appropriate sample and no further refining was required.

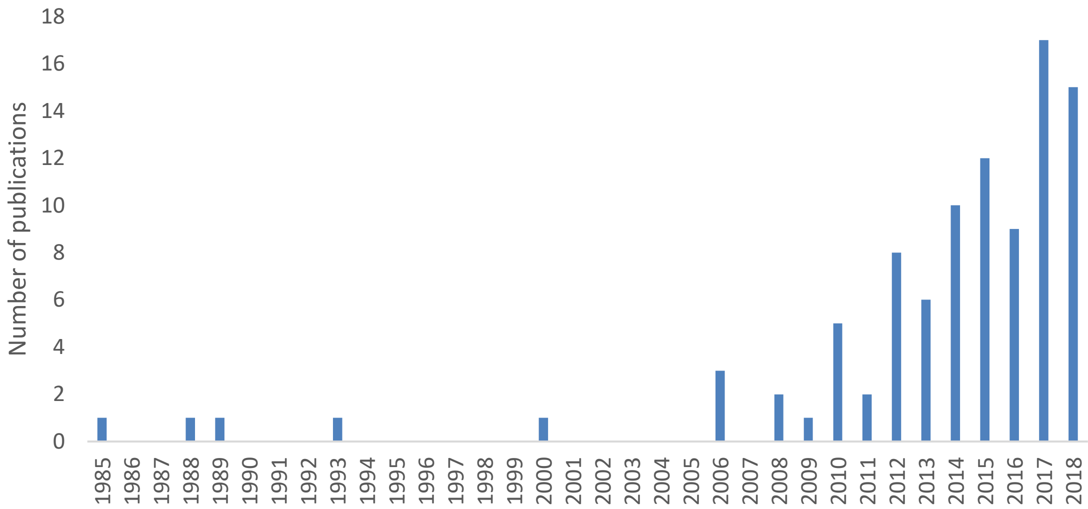

Figure 3-1, Publications on Internal Wall Insulation

Of these publications, 76 were research articles and 7 were review articles, while the remaining 12 were book chapters or other publication types. The UK appears as the major hub of research into IWI, as shown in Figure 3-2, which may be unsurprising as the literature review was undertaken in the English language. It may also perhaps be due to the UK's unique building archetypes, abundance of solid wall buildings, planning and heritage laws as well as having an active buildings-based research community and colder, moist climate where IWI may be more abundant.

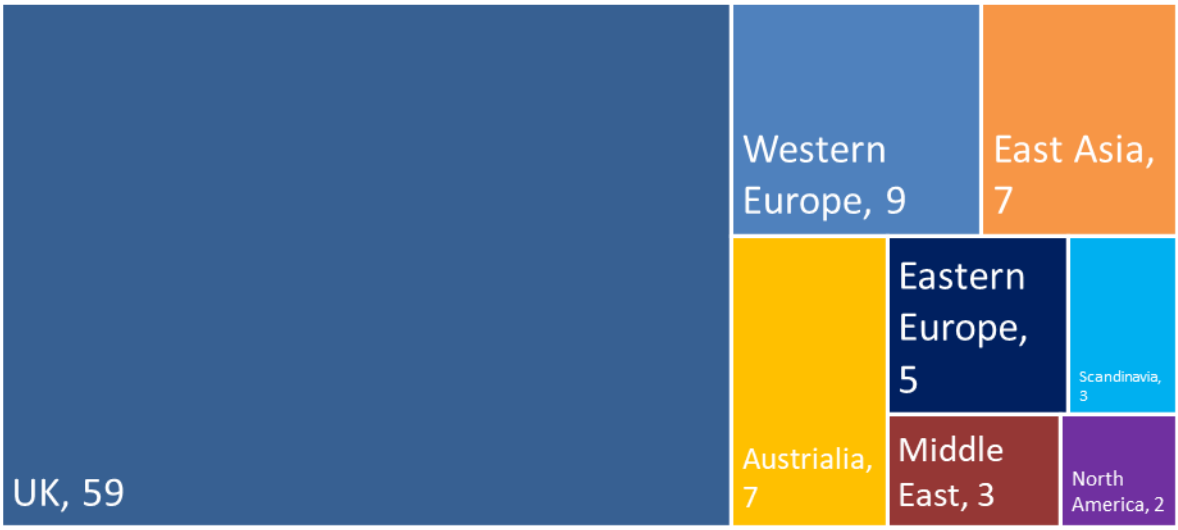

Figure 3-2 Tree map showing country of origin of IWI research papers

The stated keywords from the title and abstracts of the papers themselves were compared, identifying that each paper could be categorised into 5 major areas:

1) Policy, Energy & Carbon,
2) Hygrothermal Behaviour & Mould,
3) Comfort, Overheating, Air quality, & Climate adaptation,
4) Measurement, Performance & Modelling, and
5) Heritage, Materials & Life Cycle Assessment (LCA).

Only one of the papers was found to be specifically on a potential TIWI product and this was for a non-domestic application, all others dealt with IWI generally, usually as part of a wider retrofit narrative. Some papers covered more than one area, and each area was relatively well represented. However, as shown in Figure 3-3 the majority, perhaps unsurprisingly, focus on the energy efficiency improvements that IWI can achieve.

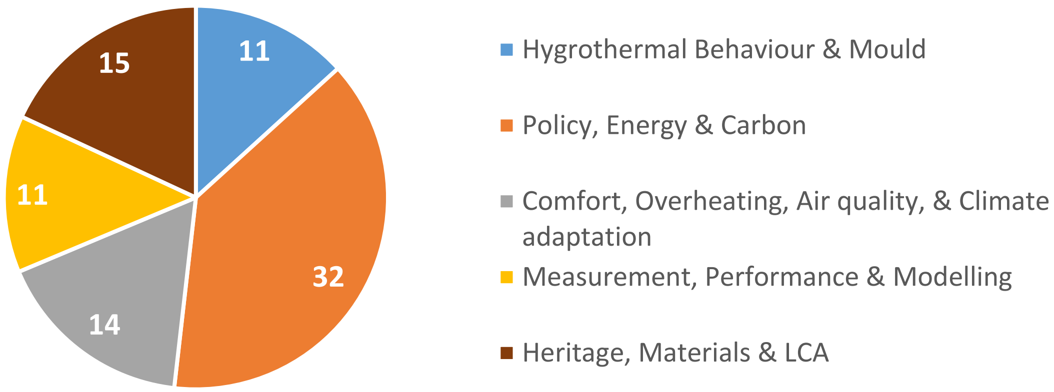

Figure 3-3 IWI literature topics

It was also clear that there was substantial concern surrounding the impact that IWI may have on the heritage value of the buildings and the embodied energy associated with the materials. Many papers took a meta-approach to evaluating the impact of IWI on national GHG policy and while this is useful, this research is more specifically concerned with the impact at a building level, i.e. improvements to internal living conditions, the way that moisture is affected and the potential for reducing household GHG emissions. The following sections therefore present the main discussion points from the following areas: Hygrothermal Behaviour & Mould; Measurement, Performance & Modelling; and Comfort Overheating, Air Quality & Climate Adaptation. As mentioned, where appropriate, non-peer-reviewed publications outside the structured review, such as Government or project reports, have also been included for completeness.

3.2 Hygrothermal risk of IWI

Eleven papers were found to report that SWI (IWI and EWI) may reduce heat loss, but not always by as much as anticipated, and that it can often increase moisture risk via three routes: 1) warmer internal temperatures, meaning increased moisture in the air, 2) thermal bridging causing localised cooling spots, and 3) potential for reduced infiltration rates, trapping moisture in buildings. This supports previous research (Farmer et al., 2017, Johnston et al., 2016, Peat, 2013, May and Griffiths, 2015, May, 2013, Gorse et al., 2017) and suggests moisture issues may manifest as condensation, leading to damp and then possibly mould or rot over time. The next 2 sections provide detail on thermal bridging, which is the most commonly discussed contributor to moisture problems, and summarises other moisture considerations that were presented.

3.2.1 Heat loss and thermal bridging

Although heat loss will be reduced following the installation of IWI it is difficult to properly insulate some junctions and architectural details, leading to greater heat loss in these areas, i.e. thermal bridging. This can reduce the effectiveness of IWI but also result in cold spots relative to the rest of the fabric (Marincioni et al., 2016). Indeed, it is likely that the default values used to represent bridging's effect on heat loss in current UK models is too conservative (Marincioni et al., 2015, Sierra et al., 2017). Cold bridges following IWI retrofits may not be properly accounted for in energy saving models or retrofit risk assessments. This is a concern, as following IWI retrofit there in an expectation of warmer internal temperatures and therefore higher humidity levels, which may further increase risk of condensation at these colder spots. Several papers focussed on this concern and are described in the next section.

3.2.2 Other moisture considerations

It is generally considered that installing IWI and EWI can increase the sensitivity of dwellings to moisture problems (Zhou et al., 2018). Thus, any building fabric faults that may previously not have caused problems in a dwelling for years may come to light if not addressed following a retrofit. Campbell et al. (2017) revisited homes that were retrofitted with IWI after several years and confirmed high moisture levels were found in the now insulated walls. Additionally, since IWI can increases moisture risks within walls, models have also identified that they can accelerate the impact of freeze-thaw weathering (Zhou et al., 2017), where repeated expansion and contraction of bricks in response to changes in temperatures can cause cracks.

It is viewed, however, that where IWI is fitted according to specifications and where ventilation is appropriate, moisture risks do not always increase (Hall et al., 2013) though little evidence of real world long term investigations exist to explore if this takes place in reality. It is possible to undertake sensitivity analysis to identify moisture risks to inform designs (Marincioni et al., 2018) though this has cost and time implications and it is not mandatory. Marincioni and Altamirano-Medina (2017) identified that moisture risk can even exist when using breathable insulating materials such as wood fibre. They found that the assumptions used in predictions, for example the number of hours a junction is exposed to moist air conditions, are very influential in properly evaluating risks. In addition, there has been some modelling to show that coupling IWI with external rendering that had low capillary action could also reduce the risk of moisture build up (Zhou et al., 2018).

3.3 GHG reductions from IWI

The potential for IWI to contribute to policy targets on GHG reduction was a common feature in the literature, though often IWI was not the sole product being investigated within each retrofit. Importantly, when considering the success of retrofits, it was moreover suggested that, regardless of what retrofit takes place, the occupant behaviour can overshadow attempts to reduce energy consumption via retrofits (Chen et al., 2013, Dineen and Ó Gallachóir, 2017, Elsharkawy and Rutherford, 2015, Elsharkawy and Rutherford, 2018, Galvin and Sunikka-Blank, 2014, Milne and Boardman, 2000).

In the papers reviewed here, IWI was often only one part of a wider retrofit and it was not usually possible to identify the specific impact of the IWI in isolation; indeed stated savings varied from 49% to 93% reductions in household GHG emissions when IWI was part of a whole house retrofit (Gupta and Gregg, 2016, Jones et al., 2017, Moran et al., 2014, Rodrigues et al., 2018, Wang and Holmberg, 2015, Yang et al., 2017). Generally, energy modelling software were used to determine predicted savings achieved by the IWI. However, when BPE tests or monitored *in situ* data were used to corroborate the predictions, it was found that the simulations had over predicted the savings. Some projects were observed to miss their targeted reductions by more than 30% (Mantesi et al., 2018, Elsharkawy and Rutherford, 2018). This was also borne out by Gupta and Gregg (2016) who showed that despite 80% GHG emission reductions being predicted for a Victorian and modern house having a retrofit in the UK, only 75% and 57% were achieved in practice respectively, though this is still a substantial improvement. Reasons for the performance gap included inability to accurately calibrate the models to replicate how the occupants use the house or reflect actual heat loss via infiltration. In addition, simulations cannot account for any number of inconsistencies in the quality of the retrofit performed, which research has shown to be particularly poor under Government schemes (Glew et al., 2017).

The majority of retrofits that take place via Government schemes are single measure installations (BEIS, 2017b), yet data on the performance of IWI as an individual measure is scarce. One project based on in use monitored data from three single measure retrofits of EWI observed a much more conservative 11% reduction in heat loss (Hardy et al., 2018). Since space and water heating energy is normally considered to account for around 40% of domestic GHG emissions (CCC, 2016b) this relates to around only 4% to 5% of household GHG savings. This is significantly lower than the predictions being suggested via models of whole house retrofits that include IWI. Determining actual improvements in heat loss from in use data, however, is notoriously difficult and there are many confounding variables that can affect the certainty of the results.

A publication describing a retrofit taking place inside a controlled environmental chamber (Salford Energy House) measured a 45% reduction in heat transfer coefficient of an end terrace house when an IWI and EWI hybrid retrofit was installed (Swan et al., 2017), which would only represent around 18% in overall dwelling GHG emissions when hot water and electricity are accounted for.

Only one research project was found which has been undertaken to measure the impact of IWI retrofits on two houses in Leeds; in this project coheating tests were undertaken before and after IWI was installed. The first retrofit was measured to achieve a 56% saving in heat transfer coefficient (HTC), though a whole house approach was undertaken in this instance. The second house achieved only 25% savings in HTC and in this instance, fewer additional improvements we made, meaning it is perhaps more indicative of what the IWI in isolation achieved (Gorse et al., 2017). Again, if heating alone represents around 40% of domestic GHG emissions then these results would indicate IWI could achieve between 10% and 22% GHG emission reductions. This is again substantially lower than models tend to predict. However, it is also worth stating that these homes were back to back houses, which means they only had 1 external wall to insulate due to having neighbours to either side and the rear. The impact of IWI on terraced, semi-detached or fully detached homes with 2, 3 and 4 external walls respectively, will differ and has not been explored in the literature.

Variables influencing energy use in homes, such as heat exchanges with neighbours, can often be too great to determine exactly the nature of the savings achieved by IWI retrofits to a high degree of certainty if they are not properly considered in the experimental design and analysis. Issues to consider when interpreting the usefulness of projects where savings are predicted or measured resulting from any retrofit include: the external wall area available, the existing energy efficiency of the property, complimentary retrofits taking place, how occupant's behaviour influences energy use, and finally the thermal properties of the insulation itself.

It is worth noting that the majority of SWI retrofits are designed to achieve a U-value of 0.3 W/m^2K and generally assume the starting wall had a U-value of around 2.1 W/m^2K, which was the Government's RdSAP modelling default for solid walls (BRE, 2012). However, it is difficult to make direct like-for-like comparisons of the SWI being tested in the papers identified here, since different systems and products are used. One exception is a piece of modelling research that was commissioned by BEIS, which investigated the effect of installing a thin IWI onto a solid wall property, i.e. without the aim of achieving a U-value of 0.3 W/m^2K. In this project, 2 scenarios of 10mm and 20mm latex roll achieved U-values of 1.28 W/m^2K and 1.03 W/m^2K respectively and were found to reduce heat loss by up to 9% or 12% respectively depending on the thickness installed and the occupant behaviour (AECOM, 2016). This equates to 4% or 5% of domestic GHG emissions assuming 40% of emissions are related to heating. However, this may be an underestimate since the study assumed a starting wall with slightly better thermal properties than is identified in RdSAP, i.e. a starting U-value of 1.7 W/m^2K. In addition, the model used a semi-detached house (i.e. with 3 external walls) to make this prediction and so the savings on other house types may again vary.

In summary, the GHG reductions that IWI could achieve are relatively uncertain; with reports ranging from 4% to 93% depending on the occupant behaviour, the starting thermal efficiency of the house, the type and amount of insulation installed, the complimentary measures also installed, the interaction with neighbours, the heating fuel type, the accuracy of the models and finally, the performance gap.

Wall insulation is most effective when there are large areas of external wall. However, most solid wall homes have fewer than 3 external walls, which impacts the scale of savings that could be achieved on a national scale. Similarly, occupant behaviour will impact on realised savings; fuel poor households tend to under heat homes and are more likely to live in solid walled homes than other household groups. Thus, IWI retrofits in these homes may not achieve large measured fuel bill savings, especially where comfort taking take place, i.e. as a result of the retrofit occupants using their heating for longer durations or selecting higher set-point temperatures.

Two projects were found that used measured data to investigate retrofits where solid wall insulation (SWI) was the only measure installed. The first included a before and after coheating test for an IWI retrofit, which indicated that the household GHG emissions may be reduced by 10% (Gorse et al., 2017). The other was based on in use data collected before and after an EWI retrofit, which showed a 5% reduction is more likely (Hardy et al., 2018). BEIS's own statistical assessment based on fuel bill savings via the NEED database suggests SWI could achieve 14% reductions in heating energy. Thus, taking the assumption that heating accounts for 40% of domestic GHG emissions, this means BEIS data suggests solid wall insulation, including IWI, could result in a reduction of around 6% in household GHG emissions. This is in line with the order of savings found by these two research case studies. Historically, government backed schemes tend to only install single measures at a time; however, IWI can contribute greatly to meeting GHG targets where IWI and TIWI may play some part in a more holistic retrofit that adheres to the guidance in the Each Homes Counts report (Bonfield, 2016).

3.4 Health impacts of IWI

Most of the literature found which commented on IWI's impact of on health, focussed on overheating strategies in hot climates, which included adding insulation to reduce peak temperatures. Mitigating overheating risk is not the main focus of this project though one overheating study in the UK was found which highlighted that, while there may be increased summertime temperatures, this should not discourage IWI from being installed to provide benefits in the heating season (Tink et al., 2018). There was one other paper from a cold climate (Nepal) that predicted a benefit of installing IWI of increasing internal temperatures by around 2°C in winter, as part of a whole house approach, though this was based only on simulated retrofits and the building typology differs from UK archetypes (Fuller et al., 2009). The project which modelled the impact of a TIWI also confirmed an uplift in internal average temperatures may be achieved in the UK, however, this was thought to be less than 1°C (AECOM, 2016).

3.5 Literature Review Summary

There are some field studies on IWI and some understanding of the benefits and risks associated to IWI retrofits. Installing IWI may reduce household greenhouse gas emissions (GHG) by around 5% to 10% and may improve comfort in homes, however thermal bridging, condensation risk and overheating are concerns.

4 Evaluating Fire Risk of IWI

This section reviews the properties of IWI with regards to fire safety published in the literature. There is limited information on the fire performance of insulation materials when used internally, therefore information on the insulation product performance in isolation, and when used in other situations within buildings, has been considered.

4.1 Fire performance of IWI

Between 2015 and 2016, 76% of fire-related fatalities (229) and 75% of casualties (5,761) occurred in dwellings (Smalldridge, 2017). Trade literature and published laboratory tests on the fire safety of IWI is not abundant, and often reports are non-scientific reports meaning information on performance is unclear which may be a concern as IWI retrofits are often undertaken by small contractors with limited capability to source reliable information (Gorse and Sturges, 2017).

In general, it is known that solid wall retrofits have increased the volume of combustible materials in buildings (Holland, 2016a). Urethane and other insulation products add to the fuel load in buildings (Gorse and Sturges, 2017, Backus et al., 1965, Boult, 1972, Jiao et al., 2013, McKenna and Hull, 2016, Holland, 2016a). Gaps in construction present a passage for oxygen, fire and smoke thereby increasing the risk of a fire developing and moving to other parts of the building (Littlewood and Smallwood, 2016) where air gaps are introduced. This may be particularly pertinent to rigid board insulation, which is often not installed perfectly flush with existing surfaces (Glew et al., 2017). Additionally, it is not known if blown, injected, trowelled or painted insulation will fill all the voids and air gaps, which are commonly observed in walls.

The spread of fire may be limited by compartmentation and firestopping; however, for retrofits with complicated detailing firestopping may be difficult to achieve (Smith, 2017). Additionally, while a new building may be designed to limit fire spread across external surfaces, the situation for retrofit is less clear (Holland, 2016b).

Based on the temperature curves experienced in modern buildings, buildings with high fuel loads reach temperatures more than 800^{o}C within 30 minutes; at such temperatures, urethanes, even with fire retardants combust and behave unpredictably (Backus et al., 1965). Thus while fire resisting urethanes will prevent initial fire spread and limit early combustion they will combust at high temperatures and degrade (Backus et al., 1965, Boult, 1972, Jiao et al., 2013, McKenna and Hull, 2016).

4.2 Building Regulations and IWI fire risk

Where the installation of Internal Wall Insulation constitutes a change affecting the thermal elements, or alters its energy status or energy performance of a building, then this constitutes 'building work' and the Building Regulations apply (MHCLG, 2019)

The requirements of the Building Regulations B2 Internal Fire Spread (linings) will be met if the spread of flame over the internal linings of the building is restricted by making provision for linings to have low rates of surface spread of flame and, in some cases, to have a low rate of heat release or a low rate of fire growth (MHCLG, 2019). The European fire tests requirement of B2 will be met if the heat released from the internal lining is restricted by making provision for the linings to have a resistance to ignition and a rate of fire growth that is reasonable. This is particularly important for circulation spaces where linings may offer the main means by which fire spreads and where rapid spread is most likely to prevent occupants from escaping.

If the introduction of thermal wall linings results in a cavity behind the lining, then (under Requirement B3: Internal spread of fire (structure)) in such cases, the building shall be designed and constructed so that the unseen spread of fire and smoke within the concealed spaces in its structure and fabric is inhibited. InB2 there is guidance on the use of thermoplastic materials, which relates to items such as light diffuses and fitting, but there are no specific comments on thermosets such as PIR or PUR which also combust and add to the fuel load. Both thermoplastics and thermosets add to the fuel load and must be considered in relation to spread, rate and growth of fire.

The regulations on wall and ceiling linings do not specifically address products fixed to the internal face of the construction which are then covered, (MHCLG, 2019)regulatory requirement restricting the spread of flame and heat release still needs to be met (MHCLG, 2019) Furthermore, the introduction of thermal elements, which change energy performance, as described above, constitutes 'building work' meaning that Building Regulations apply.

Under the Scottish Building Regulations for domestic buildings, protected zones should have wall and ceiling surfaces which are low risk or non-combustible and additionally, where a factory-made sandwich panel is used for internal walls or linings it should have a non-combustible classification (DCLG, 2017).

4.3 Generic fire risk properties of insulation materials

Information on whole system fire risk performance is not available, though comparisons of individual product performance can be made. Thermoplastics, synthetic foams and fabrics with high calorific values increase the speed of fire growth, heat release and fire severity in buildings (Ariyanayagam and Mahendran, 2013, Ariyanayagam and Mahendran, 2014). IWI materials contribute to the fire load within the building and need protection if they are not to be considered a fire risk.

Stec and Hull (2011) tested insulation products typically used in wall construction for combustion, reactions and production of hazardous gases; glass and stone wool were the most stable and resistant to combustion, while extruded polystyrene XPS and expanded polystyrene ESP burn readily. PIR, PUR and Phenolic PhF offered resistance at lower temperatures, though they combust and produce toxic gas at higher temperatures. This confirms previous research findings on urethanes (Backus et al., 1965). Table 4-1 provides information on the Euroclass range of different IWI in relation to fire safety.

Table 4-1 Generic table describing insulation type, properties and reaction to fire (Stec and Hull, 2011)

Insulation	Density range (Kg/m^{-3})	Thermal Conductivity range‡ ($Wm^{-1}K^{-1}$)	Euroclass fire reaction range
Glass Wool (GW)	10 - 100	0.030-0.045	A1-A2
Stone wool	22 - 180	0.033 – 0.045	A1-A2
Extruded polystyrene (XPS)	20 – 80	0.025 – 0.035	E – F
Expanded polystyrene (EPS)	30 – 40	0.025 – 0.041	E – F
Phenolic (PhF)	30- 40	0.029 - 0.041	B – C
Polyurethane (PUR)	30 – 80	0.029 - 0.041	D – E
Polyisocyanurate (PIR)	30 - 80	0.023 - 0.041	C – D

Generally, when considering the combustion of urethanes, there are two main processes affecting PU and PIR boards:

1) Oxidation – Combustion, reacting with O_2 resulting in flaming combustion
2) Pyrolysis – Thermal decomposition in an inert (no O_2) atmosphere

Flame retardants and additives are designed to limit the effect of oxidation, but little can be done to stop pyrolysis. Pyrolysis, including thermal decomposition and degradation, occurs at two stages:

i) 250-350°C, a reversal of the polymerisation process occurs and some irritant/asphyxiant gases released.
ii) At 400-600°C, carbon chains forming the insulation products break down completely to release volatile organic compounds (aldehydes, ketones, alkenes, esters, aromatic compounds) and basic smaller molecules (HCN, CO, CH_4, CO_2).

At higher temperatures the pyrolysis products can react together exothermically to perpetuate these processes. This means some of the volatile organic compounds can act as reducing agents at higher temperatures, limiting any effects that occur when O_2 is reintroduced (Backus et al., 1965, Boult, 1972, Jiao et al., 2013, McKenna and Hull, 2016). Figure 4-1 provides an indication of the toxicity of building insulation materials in well ventilated fires though at high temperatures these materials may break down without oxygen.

‡ Lambda values presented are different to those offered by product manufactures

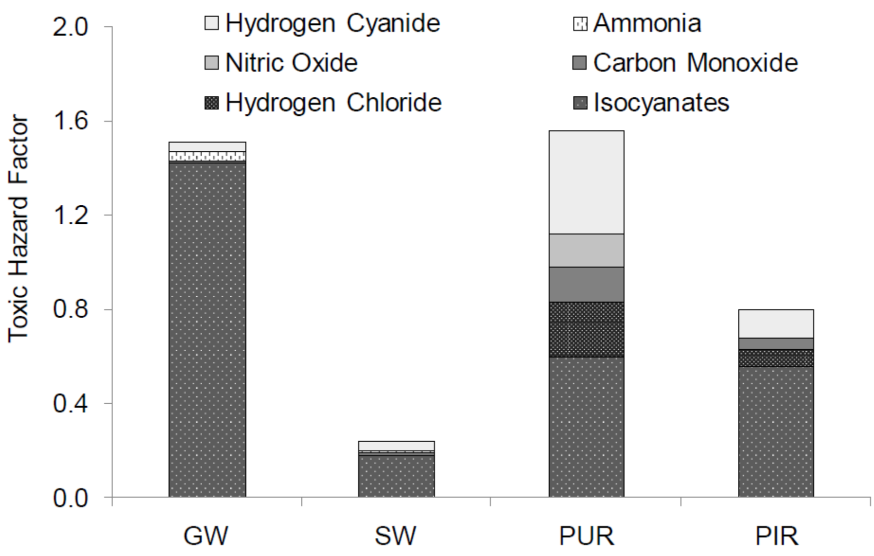

Figure 4-1 Assessment of the fire toxicity of building insulation materials (Stec and Hull, 2011)

4.4 Overview of specific fire risk for chosen TIWI

Table 4-2 provides a review of the IWI and TIWI products used in this research summarising the product and trade literature. Manufactures' information claims to limit surface spread of flame, thus, the main risk presented is the potential to contribute to the fire load and toxic fumes.

Table 4-2 Fire performance properties based on trade literature and product data

TIWI	Characteristic behaviour in fire
PUR plasterboard laminate 70mm	• The laminated plasterboard will limit fire spread and development. • Mechanical fixing helps to maintain integrity of the system. • BS 476: Part 7: 1997 Surface spread of flame tests for materials. Class 1. • BS EN 13501-1: 2007 + A1: 2009 B-s1, d0 • Very limited contribution to fire growth. • Generic observation of PUR products • Limited fire spread and limited fire development under initial flame exposure. Breakdown and combustion occur at higher temperatures. Adds to the fuel load.
EPS plasterboard laminate 22mm	• The plasterboard will limit fire spread and development. • Hazardous combustion products from EPS may include carbon monoxide, carbon dioxide, and styrene monomer. Hydrogen bromide may also be released from fire retardant grades. • Generic observation of EPS products • Will combust. Adds to the fuel load. Fire retardant will limit initial combustion, but a poor performing material in fire. Normally considered class F, does not meet the criteria of any class of fire performance.
PIR plasterboard laminate 27.5mm	• Fire Rating (Reaction to Fire): Euroclass B-s1, d0 B • Surface spread is based on gypsum board performance, making it resistant to surface spread and initial combustion. • Generic observation of PIR products • Limited fire spread and limited fire development under initial flame exposure. Breakdown and combustion occur at higher temperatures. Adds to the fuel load but generally not as combustible as PUR.
Cork lime render 20mm	• The insulating plaster system has high fire resistance, is classed non-combustible and does not emit smoke (Euro class A1). No contribution to a fire. • Generic observation of Cork products

TIWI	Characteristic behaviour in fire
	• Limited fire spread and limited fire development under initial flame exposure. Char develops during early exposure to flame protecting the core. Cork will combust at higher temperatures. Cork granules and dust will combust more readily. • General properties: Cork dust is flammable due to the cell structure being broken down. Cork oaks maybe more fire resistant than other trees. • Cork render (corksol) Euro-class B rating. Very limited contribution to fire growth. • Internal and external Fire Reaction Euroclass A2-s1, d0 – UNI EN 13-501-1 • No significant combustion to fire growth, limited smoke and droplets • Varies from not combustible to no significant contribution to fire.
Latex foam with coated woven fibreglass face 10mm	• SME Centre de Recherche du Bouchet – Fire Rating Class M1 (France) – non / low combustion
Aerogel Magnesium board laminate 14mm	• Aerogel (Class C-s1, d0) (limited combustion to flash over, no smoke) Magnesium Oxide Board (Class A1) No combustion
Thermo-reflective paint 1mm	• Fire rating (EN 13501-1): A2 – s1, d0 • No significant contribution to fire growth, limited smoke and droplets • Heat resistance after application: -40°C to +150°C • Composition: hollow glass microspheres, Aerogel, Binder

4.5 Summary of IWI fire risk

Based on the manufacturers' literature, the surface spread of flame is expected to be limited in all of the IWI reviewed. However, fire test data on technical sheets are not always easy to find or interpret. Some products do not appear to have been tested under conditions suitable to assess their properties when used as a lining or composite lining material.

The first area of potential concern is the fuel load that some materials may present. All the hydrocarbon products add to the fuel load of a building and in the event of a fire developing, the increase in fuel load will increase the risks associated with dwelling fires. Secondly, in the event of a fire, polyurethane insulation products present a potential fire toxicity hazard.

While the regulations address the need to limit fire development and heat release, it is considered that the use of insulation materials as part of a retrofit would benefit from a specific review of products installed *in situ* to evaluate performance when part of a whole house system.

However, while additional fuel load may be added to the homes, the surface spread of flames may be limited by the IWI reviewed, though as with all insulation products, should have an independent accreditation for their fire safety.

5 Surveys of Historical IWI Retrofits

To investigate if problems with TIWI manifest over several years, LSI researchers visited five homes in Leeds five or more years after IWI retrofits took place to observe if any unintended consequences or signs of performance gaps could be observed. Five dwellings provided by Leeds City Council were surveyed. Possible issues to be investigated during the surveys included thermal bridging, missing insulation, incorrect installation, excessive infiltration, occupant management and evidence of condensation.

5.1 Airtightness Test Method

Blower door tests were used to establish the dwelling airtightness; however, Building Regulations Approved Document L1B (for existing dwellings) does not specify an airtightness test methodology only stating that "reasonable provision should be made to reduce unwanted air leakage through new envelope parts" (NBS, 2010b, NBS, 2010c, NBS, 2010a). The tests were therefore undertaken in compliance with the procedure for new-build dwellings provided by the Airtightness Testing and Measurement Association, Technical Standard L1A, Measuring Air Permeability of Building Envelopes (Dwellings) (ATTMA, 2010). Tests were conducted using an Energy Conservatory Minneapolis Series 3 blower door system and the results reported (unless stated otherwise) are the mean value of both pressurisation and depressurisation tests.

5.2 Thermographic Survey Method and Quantification of Moisture Risk

Thermal images were captured following the airtightness testing to identify the location and extremity of thermal bridging and infiltration paths. The houses were maintained where possible under depressurisation at 50Pa to allow infiltration paths to become observable. Although not always possible, a 10°C ΔT was sought as this is considered necessary for using thermography to determine the severity of thermal anomalies.

Using surface temperature readings, temperature factor (f_{Rsi}) analysis could also be undertaken, where possible, following equation 1 which is presented in full in section 2.8. For steady-state models if $f_{Rsi} < 0.75$ there is considered to be a high risk of surface condensation. This can easily be misinterpreted though due to surface properties, thermal mass effects, moisture, reflection and the system not being at a steady state. Although not at steady-state, this method can still provide useful indications of where potential issues may occur.

5.3 Findings from the surveys of historic retrofits

A summary of the findings is presented in Table 5-1. The sample includes a range of dwelling ages from the 1900s to the 1970s and retrofits were between 6 to 18 years old. Interestingly, two of the dwellings were found to have cavity walls. Whilst this was unexpected, dwellings from the 1970s can have smaller cavities and so even after retro-filling with Cavity Wall Insulation (CWI) it may be deemed that the thermal performance still requires improvement and so IWI is subsequently retrofitted. This is an interesting area for future study that may result in an uplift in the number of homes remaining as targets in the IWI market, especially as hard to treat cavity walls are more expensive to retrofit than standard CWI (EST, 2019). The retrofits in this sample included hybrids of EWI and IWI, and CWI and IWI, as well as whole house retrofits.

The thickness of the IWI was observed to differ, even within the same home. Thus, this small sample illustrates the complexity and diversity of retrofit products installed in homes over previous decades and such diversity makes it difficult to predict the benefits and risk of IWI.

Table 5-1 Surveyed Dwellings with Historic IWI Retrofits

No.	Dwelling type	Wall type	Age of dwelling	Airtightness (m^3/ ($h.m^2$) @ 50Pa)	Δ T during thermographic survey (K)	Insulation	Target wall U-value (Wm^2/K)	Date of retrofit	Condensation risk observed (f_{Rsi} < 0.75)	Notes
1	Mid Terrace	9-inch Solid brick	1900s	4.85	6.8	IWI 90mm Gyproc (front) IWI 100mm GypLiner (rear)	0.3	2012	No	Single whole house retrofit
2	End Terrace	9-inch Solid brick	1918	11.15	10.3	IWI	n/a	2000	No	Multiple retrofits over time
3	Ground floor flat	Cavity brick	1976	n/a	7.8	CWI and IWI	n/a	2005	No	Multiple retrofits over time
4	Mid Terrace	Concrete System	1965	n/a	8.4	EWI 60mm (front) IWI (rear)	n/a	2001	Yes	Multiple retrofits over time
5	Ground floor flat	Cavity brick	1976	n/a	6.1	CWI and IWI	n/a	2005	Yes	Multiple retrofits over time

The main observations from the surveys included:

- No instances of moisture risk were identified where a whole house retrofit was undertaken. This indicates that if properly installed, IWI retrofits may not necessarily increase condensation risk.
- Services including the gas meter cupboards and service risers were left uninsulated, even during whole house retrofits. Thermal bridges were observed and could be at risk of condensation.
- In most instances IWI boards were not perfectly butted together and joints were visible in the thermographic survey. Although these do not tend to pose any condensation risk, they become more pronounced under depressurisation indicating there could be air movement behind the boards which would indicate some underperformance.
- Where boards had to be cut to fit corners or edges, partial boards were often fixed using nails as opposed to adhesive which may result in some localised bridging around mechanical fixings. This shows that IWI retrofits often require on-the-job fixes and designer or manufacturer instructions may not always be available, appropriate or followed. This has implications for the impact PAS 2035 has, meaning improvements in compliance must be implemented along with improvements in standards.

- Substantial infiltration was observed around cellar doors and suspended timber floors which could be undermining IWI retrofits and introducing cold, moist air into dwellings. Thus, it is evident that installers were not addressing whole house issues during IWI retrofits and permitted insulation to be installed without addressing excessive infiltration rates.
- One instance of missing insulation was observed where it appears a penetration in the external wall was infilled and the resulting hole was simply boarded over, potentially years after the retrofit. This indicates that an understanding of how IWI influences the ongoing maintenance of dwellings is essential, otherwise unintended consequences could be introduced years after the initial retrofit.
- Infiltration at the intermediate floor and external wall junction was observed sometimes, but not always. Where this was observed it could indicate there could be air movement behind the IWI.
- Pre-war homes can have solid stone door thresholds that cannot be insulated and so introduce a thermal bridge. This represents an opportunity for innovation to provide a solution to this detail which may be currently overlooked in existing IWI retrofits.
- The temperature factor (not conducted under steady-state conditions) was only observed to be below the critical level (i.e. condensation was considered a risk) at the eave junctions on a wall with EWI. No walls with IWI were deemed to be at risk, which indicates that IWI may reduce surface condensation risk. It was not possible to evaluate interstitial condensation risk as this would have required destructive survey techniques.
- Generally, the ground floor and external wall junction showed the coldest surface temperatures because of difficulties in continuing IWI below the ground floor level. This may be an area where innovation is required to reduce condensation risk in homes receiving IWI retrofits, especially where bathrooms are located on the ground floor as these areas experience high humidity levels.
- Mould was only observed on one external wall at the junction with the uninsulated party wall (it is unknown if the adjacent dwelling had IWI which may have reduced heat gain from the neighbouring dwelling), and where air circulation had been limited due to furniture (baby's cot). All other walls were free of mould indicating IWI retrofits may reduce risk of surface mould growth.

5.4 Summary of surveys of historic retrofits

Five historic IWI retrofits installed between 6 and 18 years ago were surveyed to observe if underperformance or unintended consequences had manifest. Surface condensation risk was not present on insulated walls, though some air movement behind IWI was observed. At complicated details (gas meters, fenestrations, corners) and when subsequent changes to the wall were made (openings later bricked up), thermal bridges, air movement and discontinuities (missing insulation or poorly fitted insulation) were observed. Excessive infiltration rates were found in the dwellings (generally around ground floors and doors) indicating IWI retrofits did not have a whole house approach that incorporated tackling infiltration. Other common problems include bridging at stone door thresholds and junctions between walls and ground floors. The surveys were not able to inspect interstitial condensation risk because this would have required destructive survey methods (e.g. removing sections of insulation). To understand the risk on a national scale, more homes of different ages and construction types need to be surveyed, possibly incorporating destructive survey techniques.

6 Identifying Barriers to IWI and the Hassle Factor via Building Surveys

100 surveys of solid wall homes were undertaken to investigate common obstructions or other extenuating factors in homes that could limit the application of TIWI or IWI. The surveys took place in West Yorkshire and London and were part of the Green Doctor scheme run by Groundworks, which offers fuel poor households energy saving advice. The homes in the sample are examples of those retrofitted under ECO; however, the limited nature of the sample should be considered when interpreting findings.

6.1 Wall features and furniture as a barrier to installing IWI

Often the cost of IWI is exacerbated by the extent of enabling works that are needed to prepare the wall in advance of the retrofit or works afterwards to redecorate. The building surveys identified several items which may increase the costs of the retrofit.

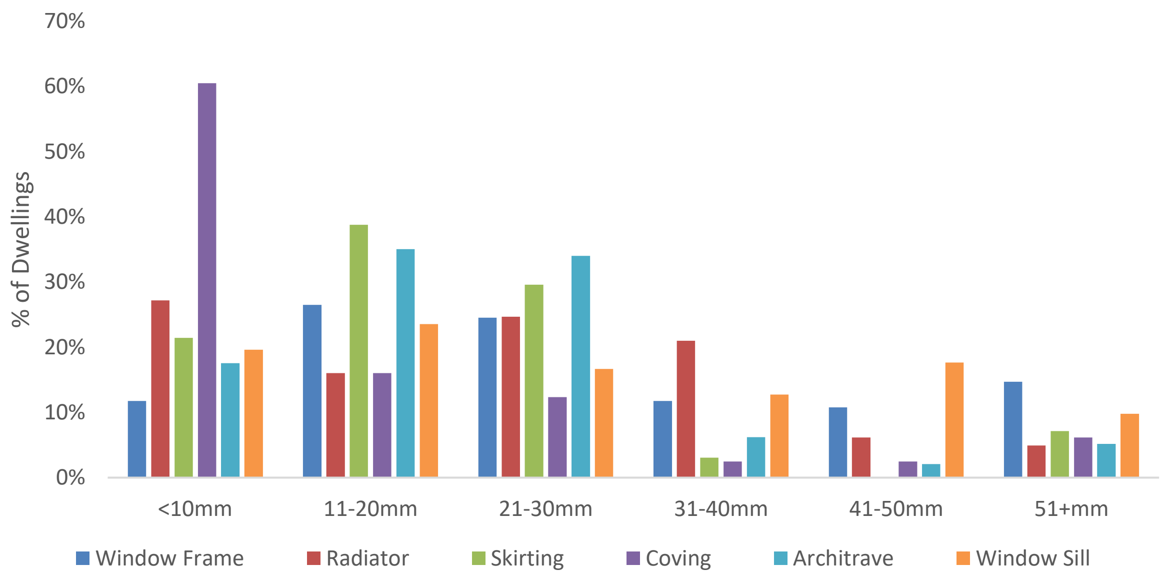

Figure 6-1 Extent of obstructions to IWI

These are grouped according to how deep the obstacles are in order to identify which could be installed without the need to relocate or remove the items. As can be seen in Figure 6-1, in the majority of homes, coving is often thinner (<10mm) than TIWI (<25mm) and there are also a large number of skirting boards, architraves, window frames and windowsills that may also be less deep than some TIWI products. This means even in some TIWI retrofits detailing issues may add cost and time to the retrofit. However, this is not always the case; a substantial number of properties had window frames, windowsills, skirting boards, door architraves, and radiator clearances >25mm. Of 561 items that were observed, 137 were >30mm, which could, where appropriate, allow a TIWI of <25mm with a layer of finishing plaster to be installed without the need to replace or relocate these building features. Thus, TIWI <30mm avoid enabling works in around one quarter of homes.

6.2 Window edges obstructing IWI

Adding insulation to window reveals is possible where there is sufficient window frame, though this can limit the amount by which casement windows are able to open. It is therefore common practice to install TIWI as a reveal board even in conventional IWI retrofits. This survey found that just under a third of homes were likely to have insufficient space to accommodate a reveal board of 25 mm without affecting the ability of casement windows to open. Having even thinner TIWI that could be installed in these reveals <10 mm may alleviate this problem. Where it is not possible to insulate reveals at all, a conventional IWI retrofit would introduce excessive thermal bridging at these locations. In these instances, a TIWI retrofit would reduce thermal bridging and the risk of condensation, though reveals should always be insulated if possible.

6.3 Interior wall finish

If a home has been dry lined it must be removed before IWI is installed, representing an additional cost. Some TIWI which is installed as a plaster, paint or wallpaper may be installed directly on to drylining. Figure 6-2 identifies that over half of homes surveyed already had some drylining and in only 43% of cases IWI or TIWI could be installed directly onto the wall. This highlights the importance of bespoke pre-installation surveys to identify the condition of the existing walls. This also indicates that TIWI may be a more cost-effective option when it can be incorporated into existing wall finishes in homes, though it is not known if this would result in other unintended consequences emerging.

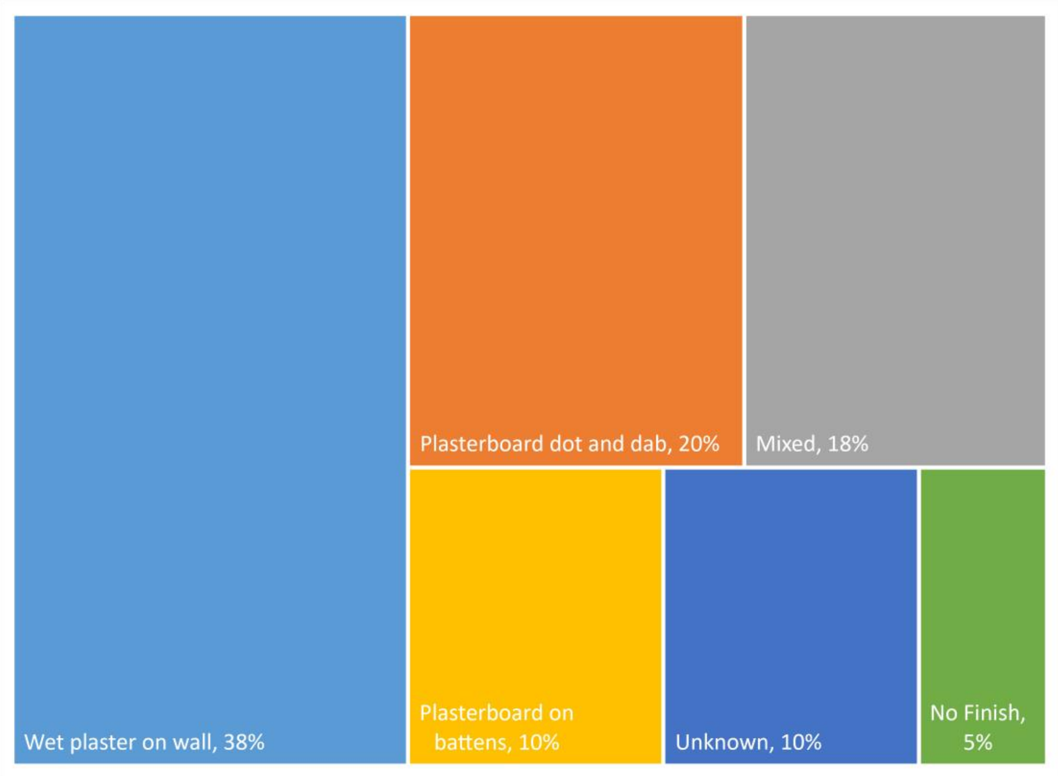

Figure 6-2 Internal wall finish

6.4 Condition of wall

Retrofits of any kind should not be installed on walls where there is pre-existing damage. Figure 6-3 shows that from the surveys undertaken, in approximately a quarter of instances the walls may already have some form of damage adding cost to the process of any retrofit which would affect both IWI and TIWI retrofits.

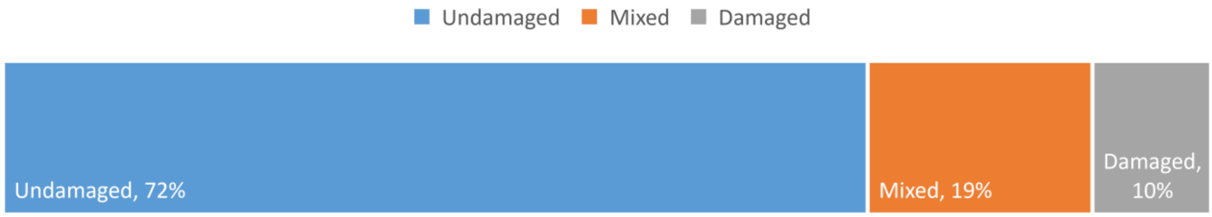

Figure 6-3 Condition of wall

6.5 Pre-existing damp

In addition to damaged walls, retrofits should not take place where walls show signs of damp, however this survey found evidence of damp in almost 9 out of 10 properties as shown in Figure 6-4. This may be one of the greatest challenges for the IWI and TIWI markets since remediating damp in walls can be costly. It is recommended that more research into the benefits and risks of breathable IWI products on damp prone walls is undertaken.

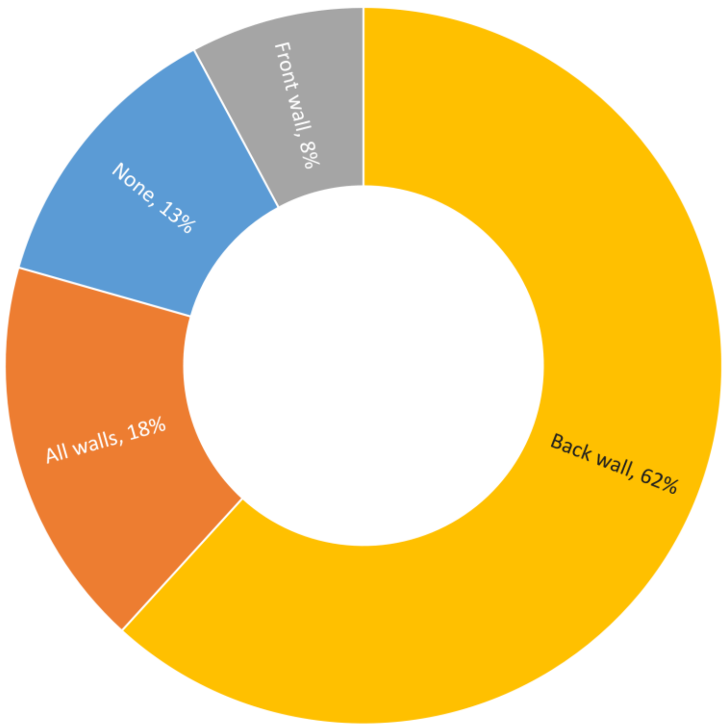

Figure 6-4 Presence of damp

6.6 Ventilation

Moisture issues are inextricably linked to ventilation and in the houses surveyed, over 10% of homes had no ventilation present at all and almost one fifth had only one type of ventilator, as shown in Figure 6-5. This shows there will be a minority of solid walled homes where ventilation may need increasing. This is important to remedy prior to and IWI and TIWI retrofits since warmer air after the retrofit can hold more moisture and if there is insufficient air changes the risk of damp and mould may increase, especially if the retrofit introduces thermal bridges, which is more of a concern for IWI than TIWI.

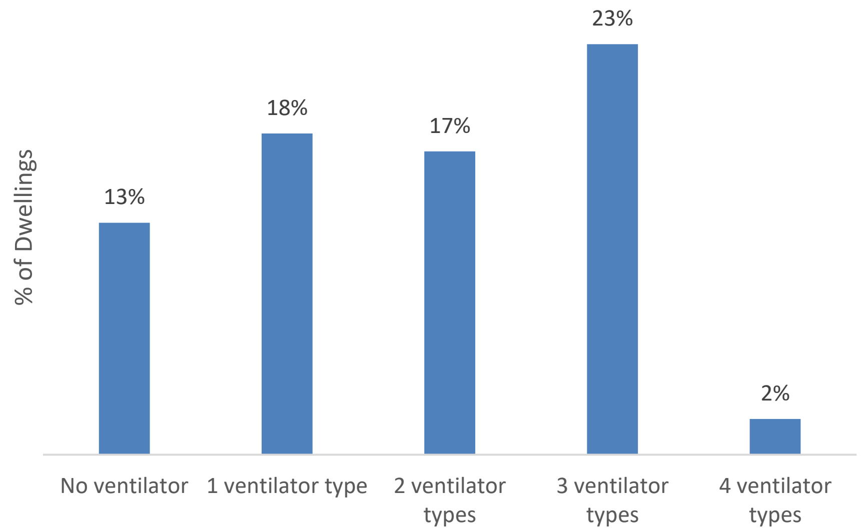

Figure 6-5 Number of ventilator types present

Of the ventilators that were observed, Figure 6-6 shows that most houses had air bricks, extractors or trickle vents. Air bricks are at risk of being covered by inappropriately installed IWI and will often need extending after IWI is fitted. In addition, extensions to extractors would be needed for conventional IWI which would be an additional requirement and cost when retrofitting. Being able to fit TIWI around the existing ventilators or using existing fittings would be advantageous.

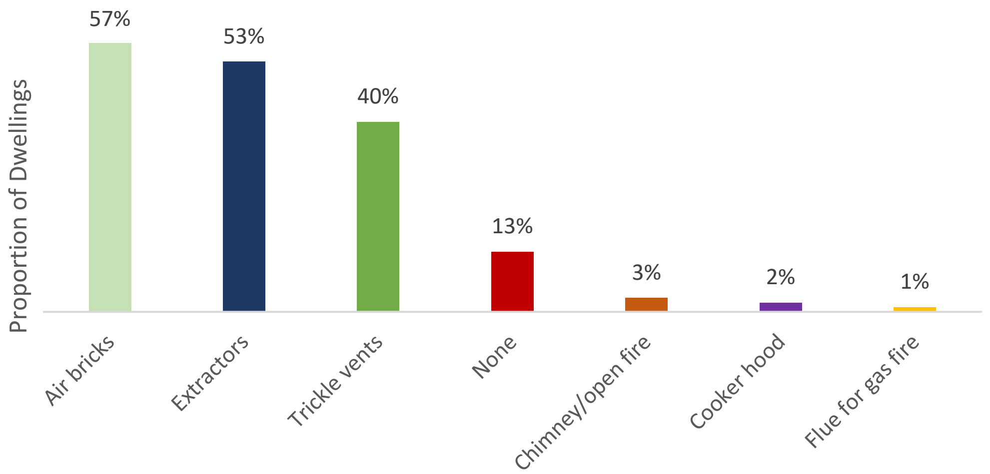

Figure 6-6 Type of ventilators

6.7 Other obstructions

Figure 6-7 shows the frequency with which each of the most common wall obstructions were observed. Having to relocate shelving, coving and dado rails could be a common occurrence which would add a time and cost to a retrofit project. Furthermore, power or telephony socket, boiler, radiator or utility meter etc. also appear to be obstructions in a large proportion of homes which is doubly a concern since these can only be moved by a licensed contractor. If a TIWI product can be installed around these items or using existing fittings, without creating a thermal bridge, the cost of the retrofit could be substantially cheaper.

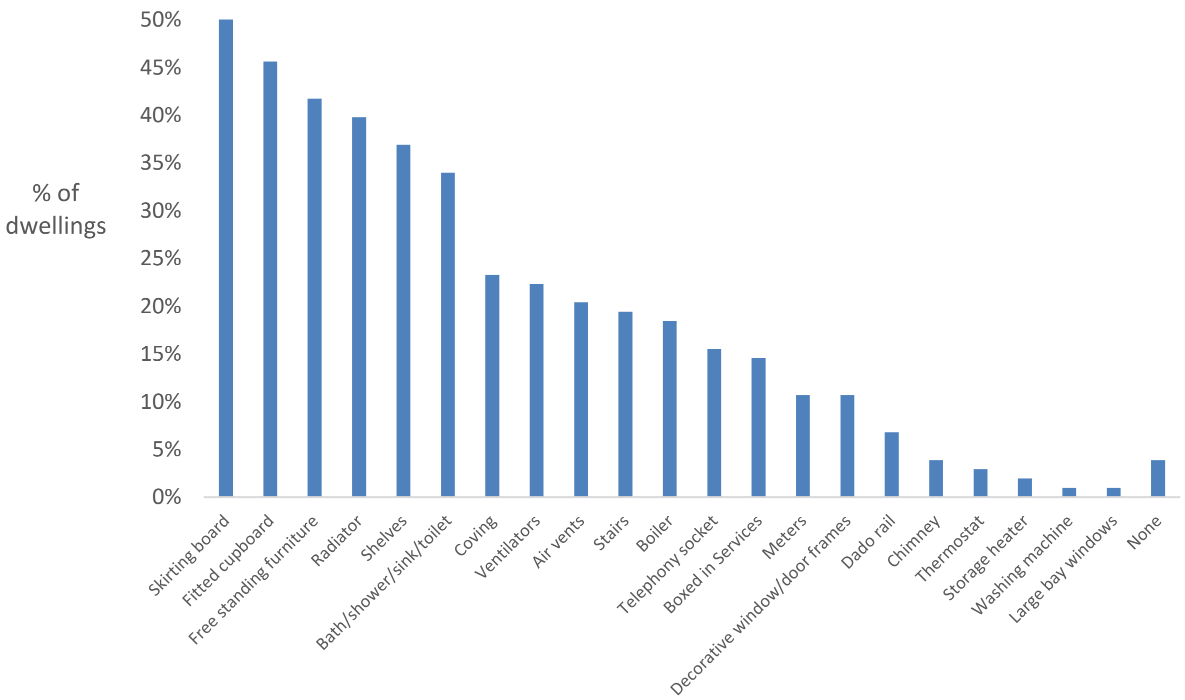

Figure 6-7 Obstructions observed on external walls

As can be seen, kitchen cupboards and fitted bathrooms were an obstacle in many homes and removing and refitting these will add additional cost and delay to IWI retrofits. This explains why housing associations and councils often only install IWI in their homes on a room by room basis, tackling these rooms only when the bathroom or kitchen suit are due for renewal, often meaning they remain uninsulated for years or decades. Understanding the impact of this room-by-room approach to retrofit may therefore be important and innovation in the bathroom and kitchen industries could consider incorporating IWI or making it easier to undertaken IWI retrofits once installed.

Stairs on external walls were observed in 15% of instances and since these are structural elements, they would not be removed prior to a IWI or TIWI retrofit. This means a thermal bridge may be present where stairs adjoin externals walls, exacerbated by the complicated detailing created around and under the stairs. TIWI that is more simply installed around complicated details could be cheaper to install in homes with stairs on external walls.

6.8 Wall flatness

Another feature that was recorded in these home surveys was the flatness of external walls, since IWI that is based on laminate boards requires a flat surface on which to be fixed. These surveys identified that in about 13% of dwellings, the walls surveyed were found to not be flat or (often termed “flush” or “plumb”) when a meter rule was held against them. This will cause problems for any IWI and TIWI products that use rigid boards since applying these will require additional time to fix the products and may result in imperfect installations.

6.9 Summary of building survey implications for TIWI

These surveys have confirmed that the building characteristics and features themselves may be limiting the opportunity for IWI and in many cases can increase the costs of the installations. In summary, 100 solid wall homes were surveyed to identify potential barriers that may prohibit or increase the cost of IWI retrofits. In 95% of cases at least one wall mounted obstruction would require removal.

The work has also been useful in identifying the features of TIWI that may make it more successful in overcoming some of these barriers, specifically TIWI that:

- Can be applied direct to either the wall or onto exiting plasterboard.
- Can be installed at depths less than 10mm.
- Are not based on boards.
- Are easy to install around complex details.

Only a TIWI applied as a plaster would fit these criteria so it is likely that most TIWI will experience some of the same barriers to installation as IWI. It is also important to understand that the surveys reflect only the building features observed in a small number of dwellings so cannot be extrapolated to be nationally representative figures. They are however indicative of the types of buildings that are targeted for IWI retrofits in Government schemes and no other large-scale survey of the appropriateness for IWI retrofits has been undertaken.

More general observations were that remedial works should be expected in almost all retrofits as damp was observed in almost 9 out of 10 homes, a quarter of walls were already damaged, and one in ten homes had no ventilation, all of which are issues that require remediation regardless of which insulation is used. In addition to physical obstructions to IWI and TIWI, there are more general barriers to the uptake of IWI related to perceptions and motivations of householders and these are discussed in the following section.

7 Investigating Householder Acceptance of TIWI via Questionnaires

To complement the research into the physical and technical barriers to the uptake of IWI, a questionnaire was designed to investigate householders' motivators for, and barriers to, IWI retrofits.

7.1 Questionnaire Sample

A questionnaire was distributed to staff within Leeds City Council and Leeds Beckett University. In total 180 responses were received. While this covers a range of demographics it does not reflect a nationally representative sample. The sample is large enough, however, to test the statistical significance of the conjoint analysis posed and moreover, the survey provides a useful indication of salient issues and trends that may be further explored in future nationwide surveys into retrofits and IWI.

7.2 Questionnaire Design

In addition to collecting general information about the householder and their understanding of retrofits and specifically IWI, the questionnaire poses a conjoint analysis of the following three factors: 1) cost, 2) hassle factor and 3) effectiveness at reducing fuel bills. The following sections present the findings from the questionnaire ending with the conjoint analysis.

7.3 Motivators for IWI

Respondents were asked what would motivate them to have internal wall insulation. They rated each characteristic as: not at all important; fairly important; very important; and extremely important. This was converted into a scale from 1 to 4 in which higher numbers indicate greater importance. Mean responses are shown in Figure 7-1. The characteristics found to be the most important are suitability for the home; reduction of energy bills; making the home warmer; and good value for money. The characteristics found to be least important are that it increases the value of their home and that it improves the appearance of their home. This appears to challenge the idea that cost of retrofits may be recovered via proportional increases in house prices.

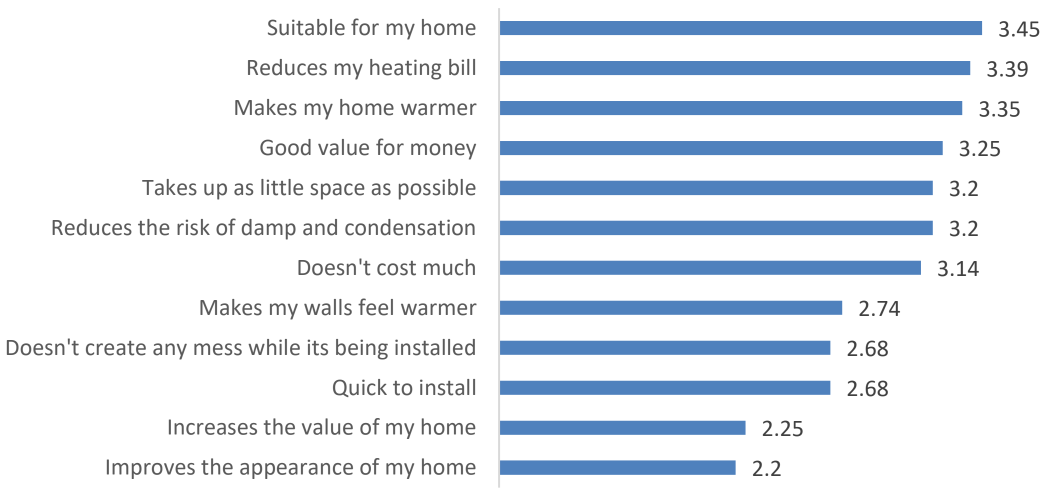

Figure 7-1 Motivations for undertaking an IWI retrofit

7.4 Duration of IWI retrofits

One possible deterrent to IWI retrofits is the length of time taken to complete, which is one component of the hassle factor. To explore this, respondents were asked to propose the maximum amount of time they would be willing for an IWI retrofit to take. Their options ranged from 1 to 14 days. To avoid anchoring bias no 'normal' or 'standard' installation times were identified. Most respondents selected 2 or 3 days which indicates that most consumers are willing to accept a few days of disruption and a smaller number were willing to accept up to a week. However, as shown in Figure 7-2, very few would accept IWI retrofits of longer than this. These results indicate that there could be a larger market for IWI that can be installed in 2 to 3 days and suggest TIWI that are quicker to install could have a competitive advantage.

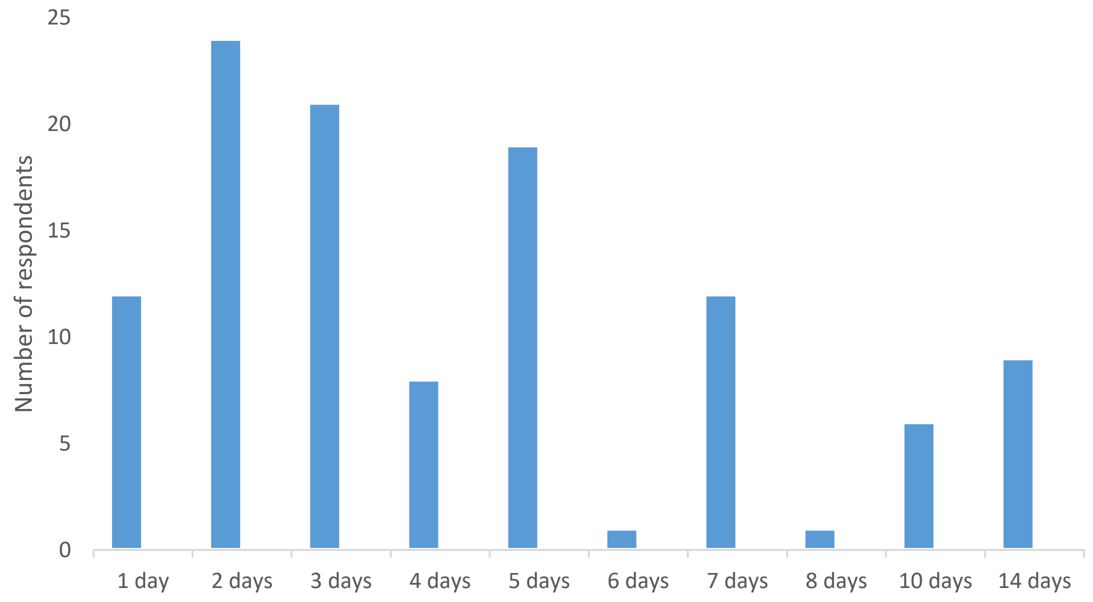

Figure 7-2 Expected maximum duration of IWI retrofit

7.5 Preferred retrofit types

In order to understand the motivations behind demand for different retrofits, respondents were asked to rate on a scale from 1 to 4 on how effective they believed a range of different improvements would be in making their home more energy efficient. They could choose between not at all effective, fairly effective, very effective, and extremely effective. They could also select that they don't know or that the improvement is not applicable. Responses were converted to a numeric scale in which higher numbers indicate greater effectiveness. The mean ratings for each of the improvements are shown in Figure 7-3 which shows that IWI is not among the preferred options. However, respondents who had previously heard of internal wall insulation had statistically significantly higher ratings of its effectiveness (M=2.88) compared to those who hadn't (M=2.24) (t = 3.46, p = 0.001). This suggests that a lack of awareness of what IWI is may be responsible for low demand for IWI retrofits.

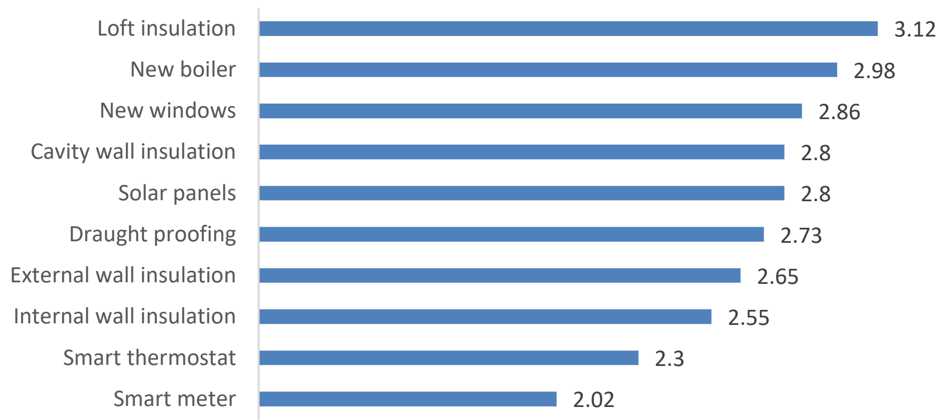

Figure 7-3 : Mean ratings of effectiveness for each retrofit

The percentage of respondents who did not know the effectiveness of the different improvements and those who said that the improvements were not relevant to them are shown in Figure 7-4.

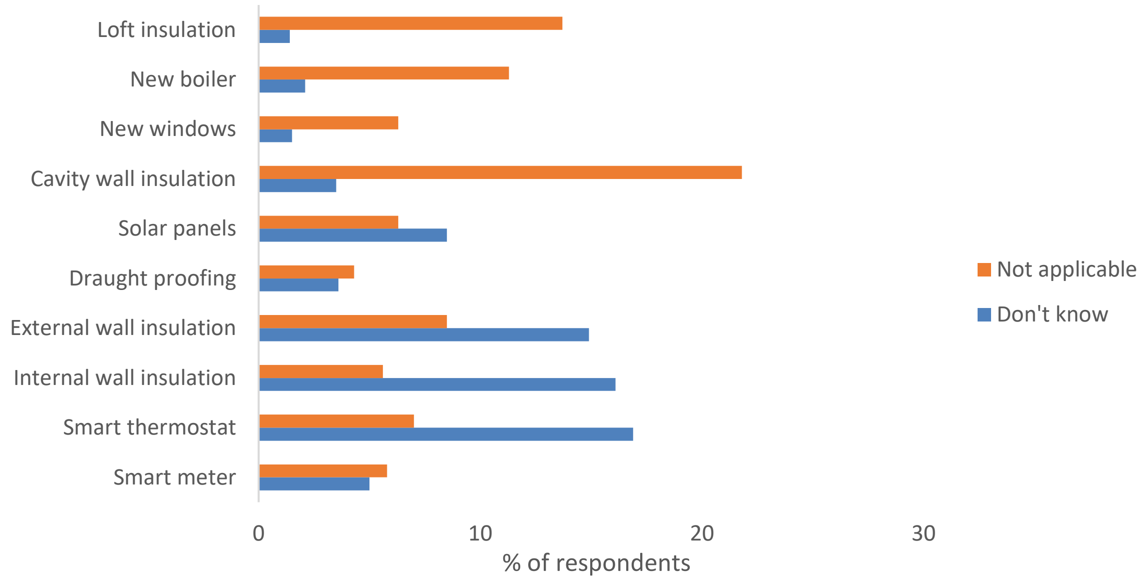

Figure 7-4 Percentage of respondents who reported they did not know how effective the improvements would be and the percentage who reported the improvements are not applicable to their home

Respondents were asked to rate on a scale from 1 to 4 their interest in having these improvements in their own homes. Mean values were calculated excluding those who did not know or who reported that this option was not applicable and is shown in Figure 7-5, preference is not necessarily linked to performance, for example, draft proofing, which respondents understood to not be the most effective retrofit measure was among the most popular, indicating that people may perceive themselves to be in thermal discomfort when drafts are present. Other retrofits that performed well were double glazing and solar panels, which had higher awareness scores than other retrofits.

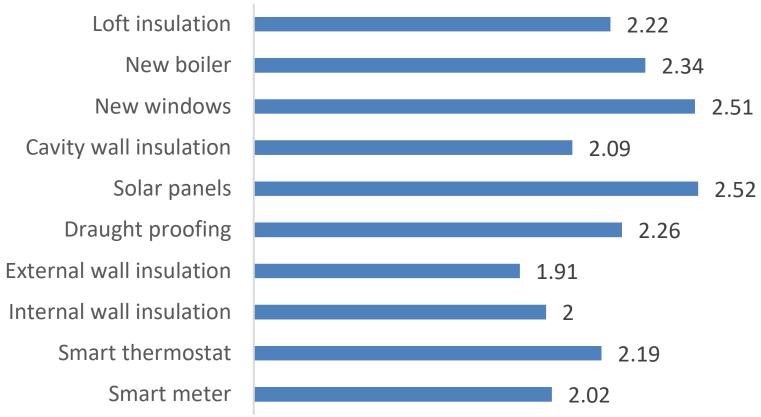

Figure 7-5 Mean ratings of respondents' interest in having each of the improvements (excluding respondents who were not aware of the measures or who judged it to be unsuitable for their home)

Respondents were asked which of these improvements they would be *most* interested in and were only able to select one option. The results shown in Figure 7-6 identify the most popular improvements as solar panels (26%), new windows (20%) and a new boiler (20%). It is not known why these were the most popular but may be due to familiarity with boilers, the potential income generation from PV or the aesthetic benefits of new windows. The responses identified that only 3% reported they would prefer internal wall insulation and 5% EWI insulation, indicating that the current market for SWI has extremely low demand. Interestingly loft insulation had the lowest score, however as this option was consistently popular in other questions, this is may indicate that most respondents already had loft insulation.

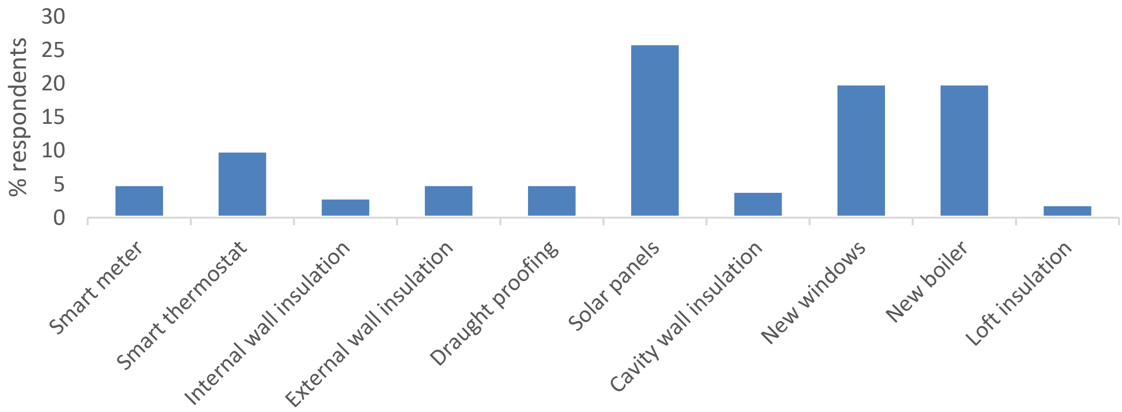

Figure 7-6 Preference for retrofits

The reasons why respondents preferred their particular retrofit are summarised in Figure 7-7. Alongside these are presented the reasons why some individuals chose IWI as their preferred option, to identify similarities in the preferences for IWI and other measures.

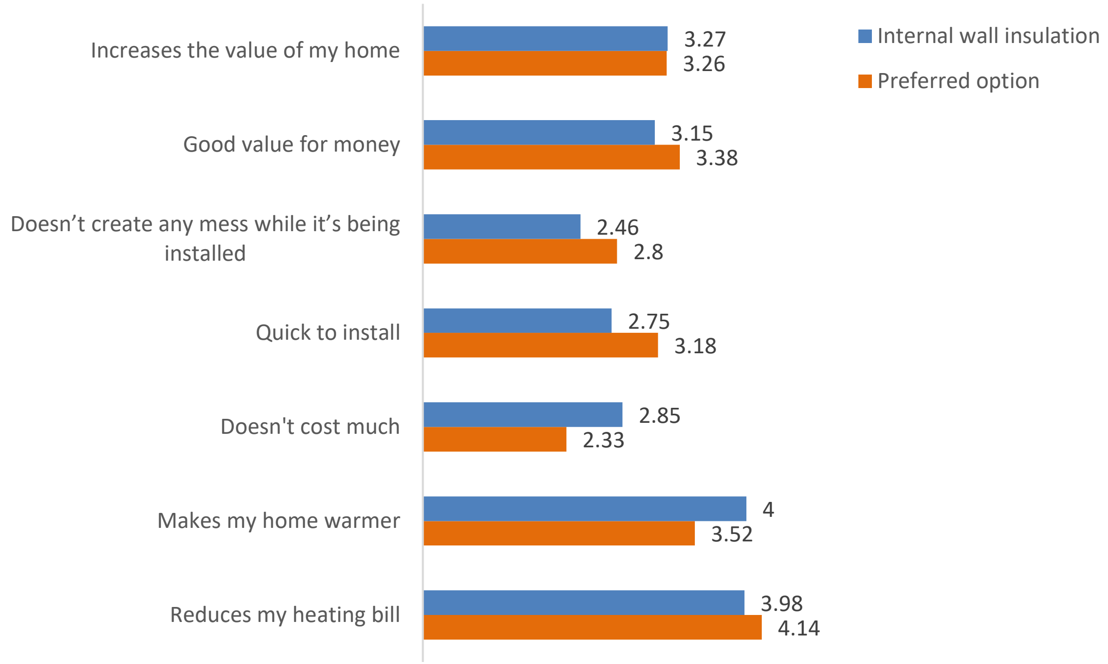

Figure 7-7 Mean ratings for why respondents preferred their chosen retrofit and why in some instance IWI was preferred

Those who preferred IWI did so as it was perceived to reduce fuel bills and result in a warmer home. There was little difference in assumptions around how the respondents’ preferred retrofit, or IWI, would affect the value of a home. However, there may be a belief that IWI is more likely to make a home feel warmer compared to other retrofits. This may not be surprising since the other retrofit options included measures that did not affect heat demand. For all other motivations, IWI was outscored by the other retrofits, reflecting the stronger preference for other retrofits rather than IWI. Those people who preferred other retrofit types mostly did so on the grounds of value for money, it being quicker and less messy to install and because it would be reducing their heating bills and make the home feel warmer. The following section explores these motivations and how they relate to IWI retrofits.

7.6 Cost, hassle and fuel bill reductions; a conjoint analysis

A conjoint study was undertaken in which participants were shown a series of options for IWI and asked to rate how likely they would be to choose that option. The options varied on:

- Time to install (Hassle factor) (1, 2 or 10 days)
- Install cost of retrofit (£1,000, £3,000 or £10,000)
- Percentage saving on annual fuel bills (5%, 10%, or 30%)

If this analysis were to be run again, based on the responses to the previous questions it would be interesting to evaluate the relative importance of “it makes my house warmer”, which yielded the strongest score in motivations for preference for IWI retrofits.

Respondents were asked to use a scale from 1 to 10 where 1 is that they definitely wouldn't choose that option and 10 is that they definitely would.

An orthogonal design plan was generated using SPSS which reduced the number of combinations from 27 (3x3x3) to 9 and a conjoint analysis was run on the dataset. All three variables were specified as discrete rather than linear because, for the installation time, we did not know whether shorter installation times would be preferred to longer times. In addition, while we anticipated that greater savings and lower cost would be preferred, we did not know whether the relationship would be linear. The data were screened to remove cases with incomplete datasets, or those in which the same rating was given to every option. This left 31 complete cases. The results are shown in the three charts in Figure 7-8 which show the utilities (preference scores) for time, cost and savings. Within each attribute, utilities sum to zero, so these figures illustrate the relative value of the different options when all other aspects are equal. A negative utility value indicates the option is less preferable, though may still be acceptable.

7.6.1 Time to install (Hassle)

Regarding the hassle factor, of the three options, a 2-day installation time is preferred whilst a 1-day or 10-day installation were the least-preferred options. Whilst it may be expected that a 10-day installation would be least preferred, perhaps it is surprising that 1-day was not favoured the most; this may be because respondents assumed that a quicker installation time may not be able to yield significant results or quality workmanship. Both the TIWI and IWI tested in this research project mostly took between 2 and 5 days to install.

7.6.2 Cost

Respondents had a particularly high preference for the lowest cost option of £1,000 and as may be expected a particularly strong negative utility on the highest cost option of £10,000. The TIWI and IWI tested in this research were costed at around or slightly over £3,000 per dwelling.

7.6.3 Energy bills

Respondents did not place a high value on a saving of 5% and also had a negative utility for 10% savings indicating savings of 30% were considered more acceptable. This is particularly important since the estimated GHG savings of IWI (which may be taken as a proxy to fuel bills) is around 5% to 10%.

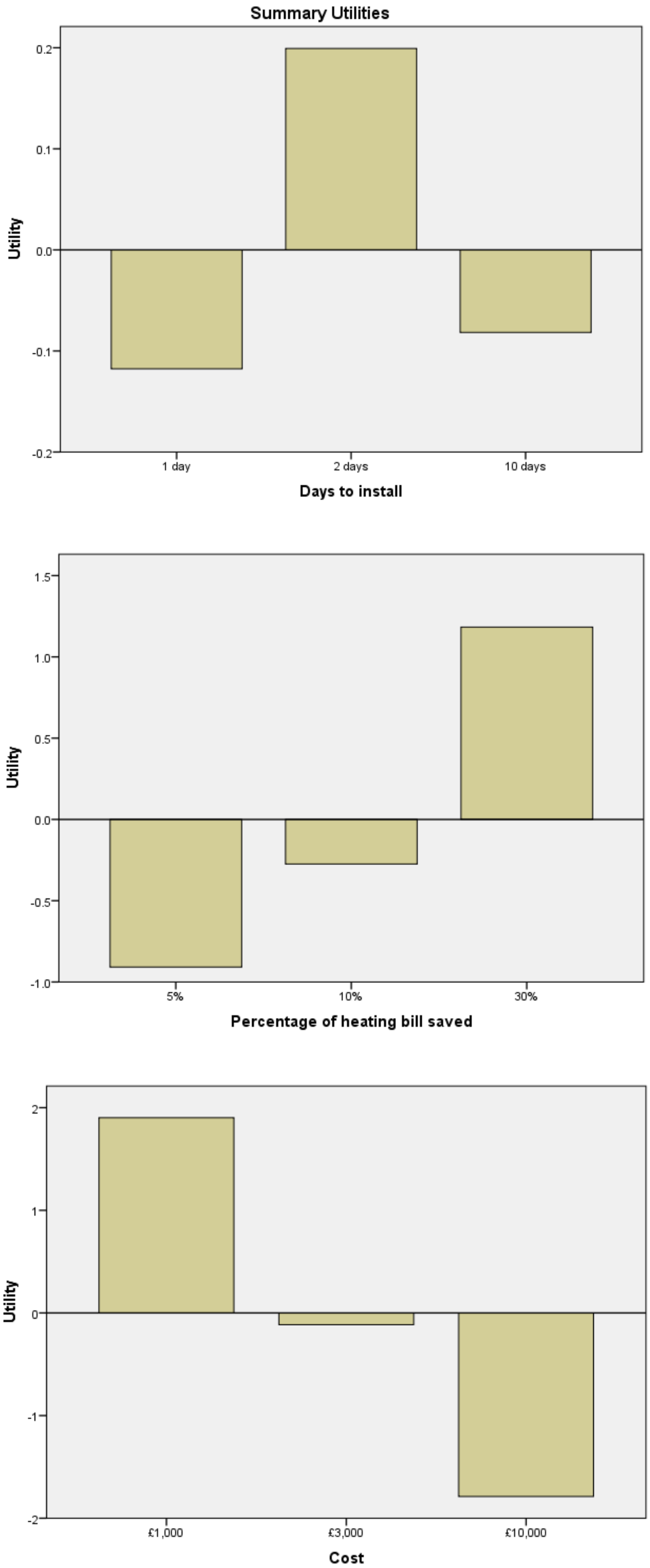

Figure 7-8 Utility values for installation time, energy bill savings and cost

Figure 7-9 shows the relative importance of the three different variables with cost of installation measured as the most important factor. The next most important was energy bill saving, and the installation time was least important. This is useful in guiding innovations in IWI and TIWI markets. Furthermore, this project has found TIWI is usually less expensive than IWI suggesting TIWI may have a larger potential market than IWI, even though it may take as long to install and provide marginally lower fuel bill savings.

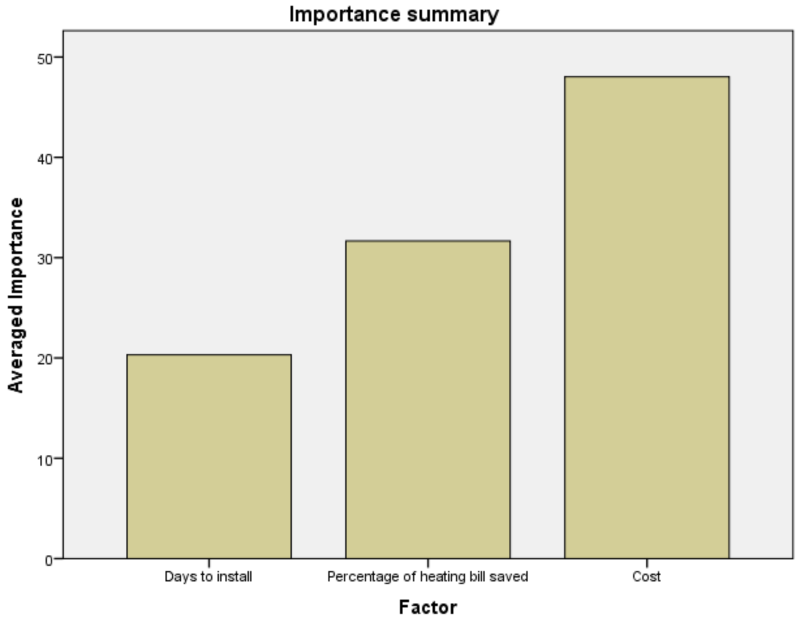

Figure 7-9 Relative importance of installation time, energy bill savings, and installation cost

The sample is large enough to yield significant results, however a larger more representative sample would be required to investigate if this trend was representative for the UK. It would also be useful to introduce condensation risk in a future questionnaire, since this may be a particularly sensitive issue and is one area, in addition to installation costs, where TIWI outperforms IWI.

7.7 Questionnaire Summary

180 questionnaire responses investigated general perceptions around retrofits indicating that suitability, effectiveness and low costs were the most important motivators for undertaking retrofits while the impact on house prices and appearance is the least important. Solar panels, new windows and boilers were the most popular, perhaps because it was found that better well-known retrofits were favoured more; IWI was least well known and least popular. A conjoint analysis ranked installation cost as the most important factor for perceptions around IWI retrofits, ahead of energy saving potential and finally the hassle factor. This may be significant for TIWI as they are often cheaper than IWI.

8 Understanding Installer Perceptions around TIWI via Interviews and Focus Groups

This section outlines investigations undertaken to explore the attitudes of installers in the retrofit industry around ECO and specifically of IWI retrofits. The LSI was tasked by BEIS to produce guidance on how best to communicate and engage with the industry to facilitate their attempts to improve standards. The contents of this report therefore describe the opinions of retrofit installers, not the LSI researchers or BEIS.

8.1 Installer Interviews

The installers who delivered the IWI and TIWI retrofits outlined in Annex B were interviewed as a pilot study to provide an insight into installer practices and attitudes to IWI. IWI installers are generally plasterers accustomed to installing dry lining and render in homes. This may have adversely affected the latex roll retrofit which required wallpapering skills, however, experts were brought in to train the installers and ensure quality was achieved. Throughout the 6-month installation period, the installers discussed their views on the IWI market, how their customers view the products, and how policy impacts their work. At the end of the project a social scientist interviewed the installers to capture their feedback on the project specifically as well as the industry and policy environment generally.

8.2 Installer Interview Findings

Interviews were conducted with the contractors who carried out the insulation installations, including the director of the business and the installer. The main findings from the analysis of the interviews is presented here:

- Installers cited difficulty in signing up to government retrofit schemes since grants vary over time and they cannot keep up nor adequately explain the requirements to householders.
- Installers believe that manufacturers deliberately make it difficult to meet their installation standards. Participants speculated on whether this was so that, if the evaluation showed their product as performing poorly, they could highlight that the products were not installed according to the technical specifications.
- One of the participants highlighted that a manufacturer claimed that the specification was not met because the installer used their own trowel rather than the proprietary version. As the trowel used was of the same type, but simply not the version supplied by the manufacturer, this was perceived as an entirely unjustified requirement.
- Participants discussed how the manufacturers make installation requirements "nearly unachievable" and explained that installing a product in a lived-in property is very different to installing it in a "wide square box with no holes [windows etc] in it" as might be the case when a product is tested in a laboratory by the manufacturer. They talked about how it is not feasible to, for example, take a plug socket out and insulate behind it, or move the plumbing, as required on the technical specification. They highlighted that customers would not be prepared to pay for the additional cost required to meet the technical specification.
- Participants talked about how an installation rarely goes to plan and on site they need to work around the challenges that they encounter, and these challenges mean that meeting the installers specifications is rarely practical.

> *"The manufacturers will always say that you can meet their specification. But there will always be something on site that means that you will never, ever reach what they say you will reach…. We always provide a quality finish, there's never a corner cut but you can never meet that install spec."*

- Participants talked about how there is a lot of small print on the guarantees supplied with insulation products and this suggests that the manufacturers lack confidence in their product. It can make it difficult to talk with customers about how the product will perform when the manufacturers make claims that the installers know will not be achieved.
- Participants talked about how they usually suggest insulation products to their customers. They discussed how most customers are interested in insulating their homes at the same time as having other work done. Insulation products are suggested at the same time as other improvements, such as adding electrical sockets, and are generally welcomed.
- Participants noted that they need to have confidence in the quality of the products in order to recommend it to customers. They had various levels of confidence in the products involved in the research both in terms of how easy they are to install and how likely they are to be damaged during normal family use of the home. They also discussed how they assume that the thicker the product the more effective it will be. They would therefore need to see evidence of thinner products being as effective as thicker ones if they are to recommend them.
- Participants discussed how products that are easy to install and hardwearing, such as insulation boards, are likely to be more popular with installers.
- The installers believed that manufacturers' specifications are made to be "nearly unachievable" to avoid liability for future problems and they wilfully omit providing guidance for common details experienced in real homes.
- Installers believed that the grants available are too low, meaning that specifications "can never be met" especially as additional work is usually needed.
- Installers found it easier to sell IWI to customers when other home improvements are taking place rather than installing IWI by itself.
- Installers discussed preferences for rely on hardwearing products that they trust.

These insights provide a useful indication of the attitudes of "on the ground" installers in the retrofit industry delivering Government supported retrofits under ECO. These initial investigations informed a broader investigation into the attitudes of the industry, data for which were collected via a series of focus groups, presented in the following section.

8.3 Industry Focus Group Method

The two interviews with the installers involved in the Test House retrofits for this project were used to develop a focus group topic guide to be used with builders who install internal wall insulation. Discussions followed a semi-structured format and covered:

- Experiences of installing internal wall insulation.
- Challenges typically experienced when retrofitting internal wall insulation.
- Training to install internal wall insulation.
- Situations when the design specification is not followed.
- Making installation instructions more user-friendly.

Four focus groups were conducted, each with five builders who retrofit internal wall insulation in domestic settings. All were male, and they ranged in age from 23 to 58. Most participants were self-employed builders or employed by SMEs. Two no longer worked solely on site and instead worked in a contract or supervisory capacity. All groups took place in West Yorkshire and participants were provided with industry-standard incentives. The first two focus groups (FG1 and FG2) took place in April 2019, and the remaining two (FG3 and FG4) took place in May 2019. Observers from BEIS attended FG3 and FG4. After these two groups, participants were invited to try out augmented reality training demonstrations.

Each focus group lasted an hour and, with permission from participants, audio was recorded and transcribed verbatim. All participants were given a full explanation of the nature of the study, what taking part would involve, and how to withdraw from the research. Written informed consent was obtained.

Transcripts were analysed thematically using the methods of Braun and Clarke (2006). Transcripts were coded using the research question: What are the barriers to effectively retrofitting internal wall insulation? An inductive approach was taken in which the codes arose from the data rather than by applying a pre-determined framework. Codes were grouped together with others of similar meaning and sorted into a thematic structure that best described the data. Quotes from the focus groups were selected to illustrate each theme. The number of the focus group (FG1-4) is indicated in brackets after each quote.

8.4 Industry Focus Group Findings

Three themes were identified in the data. The first is that internal wall insulation is often viewed as impractical to use in a retrofit capacity, which means that it is not always suggested as an option. The second is that participants do not perceive PAS 2030 as relevant: most are unfamiliar with it and have not received formal training in installing internal wall insulation. The third theme is the workarounds that participants apply when the specified insulation design needs to be adapted on site. These three themes are described below, illustrated with quotes from the focus groups.

8.4.1 It's impractical

Participants identified many difficulties associated with installing internal wall insulation that would deter them from selecting it as an insulation product or suggesting it to customers. These include the need to remove skirting boards, pipes and radiators, problems with decorative coving, and the need to remove kitchen units to install insulation behind them. They believe that the additional cost is prohibitive, and clients would not be prepared to pay. Also, they believed that internal wall insulation takes up too much room in small properties. In addition, participants talked about how cutting insulation causes a lot of dust and that the product itself is itchy and some were concerned about future health problems caused by working with these products. For these reasons, they did not think that internal wall insulation currently offers a practical retrofit insulation solution.

> *"Imagine if you said [to the customer] well we have to rip all your kitchen out to put it back in, there's another 20 grand on top. It's impossible for a customer to sort of say: I can justify that cost."* FG3

"You've radiators to contend with so you've got all the radiators to take off the walls. And then you've got all your pipes removed because the pipe centres are all different so it's just more difficult really without destroying the coving, the skirting. And to fit it properly, so if you were fitting it in a kitchen you're only fitting in areas where the kitchen units aren't. So, it's either a case of you take all the kitchen out and do it. And you're losing internal space as well." FG3

However, participants would use internal wall insulation in a loft conversion or an extension which offers a "blank canvas". They also talked about being more likely to use it for sound insulation purposes than for energy efficiency, for example when installing a partition in a room. Some also talked about being asked to use it on floors. Even in loft conversions, internal wall insulation is viewed by the participants as an unpleasant product to use because installers are often working in a confined space in high temperatures.

"*It just takes time. It's a time-consuming thing. And to be honest with you, we all don't like doing it, so we try and pawn it off on each other."* FG2

Participants also talked about how insulation products need to be simple to install and simple to maintain and repair. Participants discussed how they are often approached by manufacturers or sales staff who make claims for different products. They talked about how the claims are usually exaggerated, and they are unwilling to install technically complex products because they anticipate it will be difficult to install and repair. For this reason, most participants preferred simple insulation products such as an insulation board that is then rendered.

"*The more technical material you put on, the more difficult it is or the less cost effective. So, we get loads of people coming to us with all these wonderful products that will do X, Y and Z claiming that they can do it at a particular price, which they can't do. And the material is so complex or so difficult, that okay it's good when you put it on, but in reality, if you're putting it on a building, the simplest way of doing it, for example, we just done a load of wall insulations, literally it's Kingspan then render. And the reason we've done it is if it's damaged it's very simple to repair. It doesn't need technical skills to do it. Any competent tradesman can repair a bit of insulation. It's the simplicity of it*." FG1

8.4.2 PAS 2030 is perceived as irrelevant

Very few participants were aware of PAS 2030 accreditation and none believed it relevant to them or their business. A few had previous experience of ECO-funded projects, and most talked about how they would not participate in these schemes because the paperwork is too onerous - both the application and payment processes. Those participants who had worked on ECO-funded projects (most as subcontractors) talked about the additional checks that were made on their work. Generally, they found this a restrictive rather than constructive step, as they often believed that the inspectors did not have their depth of experience and did not understand the need to adapt plans to individual situations on site. Even when they recognised a plan needed to be adapted the inspectors did not have the experience to suggest alternatives. This suggests opportunities to improve quality might be missed because building control officers and technical monitoring officers are either unwilling or unable to provide recommendations.

> "*You've always got somebody fresh out of the university who's basically telling you by the book what to do and they tend to ignore your years of experience. I find nowadays, for some reason you get these people who come on a job and they've read it off a sheet, they've looked at the drawing. But it doesn't always work in practice, sometimes you've got to adapt to it. And they don't have the experience to say, well you can do it like this, which would make life easier on site*." FG1

None of the participants had received any training in installing internal wall insulation or verification of their skills. They had all learned by watching others or just developing skills on-site as they used the products. Most believed pairing more experienced workers with those less experienced is the best form of training.

> "*It's passed down through generations isn't it? You'll get on a job and there'll be one guy there that's about 107 and he'll have seen it all and done it all and he'll teach everybody*." FG3

> "*Partnering up with someone who's got experience and then handing that experience down. There's too little of that, with apprenticeships and stuff like that. There's not enough of that going on*." FG2

Some were puzzled at the suggestion that there might be training to install insulation as they believed it to be a very simple process. They talked about how, while internal wall insulation can be time consuming to install, it is not technically challenging, and they assume that any experienced builder can install it effectively. This suggests that installers did not associate training with an opportunity to learn how to adapt designs or "workarounds".

> "*It's not really rocket science. It's not that difficult*." FG4

> "*There's an assumption that you've got skilled tradesmen who can turn their hand to new products that come out*." FG2

> "*It's very difficult, in my opinion, to justify sending anyone on a training course to do what is basically insulation behind plaster*." FG1

> "*Fitting the internal wall insulation though, it's very similar to just fitting a plasterboard, it's like, yes, that's all it is, just like fitting, doing a plasterboard in really. So, it's pretty standard stuff.*" FG3

Despite being sceptical of the need for training, a few participants talked about how they had observed poor installation of internal wall insulation, which could arise from not taking sufficient care or not being aware of certain required steps, such as taping over seals. They highlighted how a main contractor could appoint several different subcontractors to work on a single project, each of which could bring in additional people of varying skills levels to help. The quality of the insulation installation will vary with individual workers, which is difficult for the main contractor to control.

Participants talked about the main requirement of an insulation job being that it "*does the job*", i.e. provides effective insulation. However, some participants judged the quality of their internal wall insulation on its cosmetic appearance. Some were more aware of the potential problems caused by poor installation and talked about how condensation or mould could emerge some years later if there is insufficient ventilation. A few talked about cold bridges, but some had not heard of this term, and others did not believe that leaving some areas uninsulated could cause cold bridges.

Several participants talked about not always understanding the reasoning behind regulations, although they did mostly follow these regulations even when sceptical of their effect.

> "*Well the new specification from building control is that you put an insulation back board over the joist to stop the cold bridging through the joist. Now, a piece of timber that's nine inches wide and two inches thick, how is that a cold spot?"* FG1

8.4.3 You need workarounds

Generally, participants are provided with designs or specifications for retrofits by architects or engineers and so did not decide on the thickness, and sometimes the make, of insulation. However, participants talked about situations in which they intentionally deviate from the specification. They framed this as creating workarounds to challenges, rather than deliberately taking short cuts.

While they acknowledged that in the past, unscrupulous builders might deliberately install inferior products, they talked about how this practice is now rare as clients and building inspectors will often ask to see photographs of the build. Workarounds, in contrast, are good-intentioned deviations from the plan believed to be necessary given specific site circumstances. They highlighted that there may be situations in which people deviate from the specification to keep a job within budget, and often in consultation with the client. Participants recognised that in some situations, workarounds decrease the thermal performance of the insulation, for example when there is a need to trim an insulation board to slide it into place. However, they talked about how it is in their own interests to work to high standards as many jobs carry a guarantee, and if their installation has been faulty, they need to re-install at their own expense. This also carries a reputational risk.

> "*Sometimes you have to trim the back out of it to get it over the surfaces, so you're reducing its insulation value*." FG1

"*There will be circumstances where people don't follow the specification, but it will come down to, if you've got a budget of £10,000 and you want a way to meet the budget, you cut slight corners and if it's a private job, that's how it works. It might even be with the agreement of the client. You know, we can't do this, it's going to cost you £12,000, okay how do I make it fit £10,000 for you? We can do X, Y and Z."* FG1

> "*It only takes one job to go wrong for your name to be ruined. That's the risk if it's not installed correctly, so it's going to come back and bite eventually*." FG2

8.5 Preferences for training

During the focus groups participants were asked about how they should be trained to install internal wall insulation and their preferences for the format that training might take. There was generally little interest in learning about the details of internal wall insulation: it's a job that people had been doing for a long time with a product that they don't believe has fundamentally changed, and so they don't see the benefit of being told to do things differently.

“*It’s just a non-starter because you’ve not got time to do it anyway. And other times it’s boring because you’ve been doing it for 20 years or something. You know, and then they’ve got this piece of paper saying well you should have done it 5mil more off the wall and stuff. I’ve done it for 20 years, so I’ve had no problems, what’s the difference!”* FG3

However, a few talked about how they would be more interested in training if it helped them to work faster or more efficiently.

“*If it was a free course, if it’s going to improve my knowledge of it, and maybe speed up how fast I can do the job, for instance, then you would do it.”* FG4

A project manager who worked for a larger building company talked about how he would contact the manufacturer if there were any queries about how to install a particular product. He talked about how, in his experience, manufacturers are happy to visit the company to provide information and guidance about using their product. However, none of the other participants had experienced this, and none had seen a demonstration about fitting insulation.

“*If it was something that you hadn’t used before, you would go to the company that’s supplying it, the manufacturer, and usually they’re happy to come out. Basically, they’ll give us a demonstration for the first install, and then we get the guys watching that and carry that on into their day-to-day work.*” FG2

Because few participants thought there wouldn’t be any benefit in training on installing internal wall insulation, the discussions were widened to talk about training more generally. Most participants had completed training for other elements of their work, although framed it as a “*nice to have*” rather than essential unless it is a requirement for a qualification or accreditation to work with a particular product. Many were sceptical that they themselves or their colleagues would voluntarily take any training. Most participants believed that the best form of training is unofficial on-site learning from colleagues.

“*Builders are builders they don’t give a [expletive] they just want to get on and get the job done and that and finish it.”* FG3

“*There’s no learning like learning off somebody on site*.” FG1

Participants were asked about their preferences for formal training. Most talked about how getting a certificate, accreditation or qualification is important as it could set them apart from competitors. There were mixed preferences for the format of training. While many highlighted that e-learning is least disruptive, they anticipated they would become distracted when they tried to complete it at home and so wouldn’t actually learn very much. Few were interested in app-based learning because they did not think they would have the opportunity to complete it on site, and they were not sufficiently interested or motivated in training (especially on internal wall insulation) to complete it at home. Very few were deterred from e-learning or app-based learning because they lacked the technical skills: the problem was lack of motivation rather than lack of IT skills. The most common suggestions were on-site demonstrations, demonstrations in builders’ merchants, and a series of short small-group training sessions with free refreshments available. Many talked about how classroom training would not engage people.

> "*I'm old school, I don't have a frigging clue*." FG4

> "*I have the attention span of a nut, and so after 15 minutes in the classroom it's shut down. You're in there just going through the motions*." FG2

Participants talked about the cost of formal training being a barrier and how free training or subsidised places encourage them to attend. Participants also discussed how, as self-employed builders, they need to factor in the cost of lost day's work. Some participants were sceptical about the quality of training and how applicable the techniques would be. They highlighted how it is often impossible to work "*by the book*" on site, and so training provided by somebody with little or no site experience wouldn't be useful. Instead, a few suggested that training in dealing with on-site challenges, such as how to install internal wall insulation without removing all the kitchen units, would be useful. However, many assumed that training would be involve installing the insulation on a blank wall, and therefore it would be useless.

> "*Who gives the training? And where have they learnt? Have they learnt from a book? If it's a person straight out of university telling somebody who's been doing it for 30-odd years how to do it, it breeds resentment*." FG1

They suggested the best way of communicating with them about training is through builders' merchants or professional builder magazines. Some suggested that the most effective way of increasing training uptake is to make it compulsory in order to be able to install those products, but in which case the training should be free. However, they discussed whether a single training course would be sufficient to cover installation of all the different manufacturers' products, or whether each manufacturer would expect builders to attend their own training to install their own products. They would be more interested if the training includes a session on new developments and gives them a preview of forthcoming products.

> "*It's nice to be in the know for stuff that's going to be coming out. Then you can offer it to your customers or your clients*." FG1

8.6 Installation instructions

Participants were also asked about their ideas for how instructions on installing internal wall insulation could be made more user-friendly. Few participants had read any installation instructions for the products they use. They thought it would be possible to find them online, if they were minded to look. A few thought that there might be some instructions that come with the packaging, although nobody had seen any. However, one participant pointed out that many small businesses will only buy insulation boards for one job at a time, and this is unlikely to be a whole pack, so they won't receive the instructions. Instead, the participant suggested that three or four basic installation instructions could be printed on the boards themselves.

> "*There's manufacturers guides' online for absolutely everything nowadays. If you were that interested in finding out*." FG1

> “*Manufacturers might put instructions in a full pack, but it’s only large contractors that buy a full pack of boards. A lot of housing projects and smaller stuff, somebody goes into the builders’ merchants to get half a dozen sheets. You don’t get half a dozen sheets and a leaflet*.” FG4

Several participants talked about manufacturers providing training videos on YouTube or apps that they could consult. However, they did not think that builders would look at such videos on site, as phone use is generally discouraged on site. Also, they suspected that if builders were told they could use their phones to check installation instructions, they would actually use their phones for social purposes. They also talked about how it is not the building site culture to check instructions: if you need to ask, you would ask a colleague, or simply guess.

> “*Most suppliers will have YouTube videos, and stuff, on how to install their products. Or, ask the suppliers, and say, what’s the best way to fix this? What should we do with that? Have a look on their website.”* FG4

> “*You see too many guys on their phones, and they’re not doing research for the work that they’re doing. They’re doing it for something else that evening or something*.” FG2

Participants were asked whether it would be useful for instructions to include an explanation of why it’s important to follow certain procedures, for example the increased risk of condensation if windows and reveals aren’t insulated. Most thought it unlikely that these instructions would ever be read, but in one focus group participants talked about how they might glance at an information sheet and notice that the recommended method was different from their own, so an explanation of why this is the recommended method would be useful for them to understand why they should follow the instructions.

> “*I’m not saying you’d look at it but sometimes on your dinner break you’re sitting there with your butty and that you might start looking, oh, that’s different to what we’ve been doing*.” FG3

However, participants discussed how these decisions are made by the architect or system designer, and if it’s on their job specification they would do it, regardless of any information on instructions.

8.7 Focus Group Conclusions

We have explored the main barriers for builders working in small businesses to effectively retrofit internal wall insulation.

First, it is viewed as impractical in situations other than new builds, extensions and conversions. It is too time-consuming and therefore expensive to remove pipes, skirting boards, etc, and to replace window ledges etc when insulating around windows. It’s not a job that people enjoy, given it can be fiddly to use and the product itself can be itchy and dusty. More technically challenging or novel products can be rejected as our builders wanted a product that is simple to install and to repair.

The second barrier is that our participants did not view installing internal wall insulation as a particularly skilled job and so did not see the point of training. PAS 2030 regulations are not well known, and the bureaucracy associated with ECO-funded projects deters small businesses from pursuing these projects.

The regulations themselves, and the people who inspect sites are not always seen as credible. Therefore, PAS 2030 regulations are perceived as irrelevant.

The final barrier is that even when builders are following a well-designed specification, they encounter situations on site that means they need to deviate from the specification. Sometimes they can be aware of how such deviations reduce the effectiveness of insulation but there is nothing they can do. Sometimes they are unaware of the consequences of the adaptations they make, and sometimes they have heard of potential problems but are sceptical of them.

There was very little interest in training for installing internal wall insulation as it is not seen as a technically challenging task despite the comments received about the complexity of onsite situations and the need for workarounds. Learning usually takes place on site from more experienced colleagues. There would need to be some benefit to people if they are to attend external training, for example a certificate or accreditation that could provide a competitive advantage, or that the training enables people to install the insulation more effectively, faster or cheaper. Apps were not viewed as an ideal source of information, as smartphone use is discouraged on site. Information sheets inside products are unlikely to be read, although printing a few key points on the products themselves may be more effective.

8.8 Communication strategy to engage with IWI retrofit installers

Leeds Beckett University were asked by BEIS to develop a strategic approach to future communications with installers regarding the implementation of standards, based on interpretations of the feedback given by installers that is described in this section. The following guiding principles are therefore recommended in any future communications campaign that targets installers.

1. Be clear about the benefits of training: what will they be able to do faster, better, cheaper etc. if they complete the training? Will there be a certificate or accreditation that they can use to gain a competitive advantage?
2. Make the training sound relevant to life on-site: builders will assume training content will be dull and irrelevant to life in the "*real world*". A problem-solving approach will help this, for example case studies dealing with common challenges that they are likely to encounter on site.
3. Make the training format interesting. Builders will assume that training will be boring, delivered in classrooms by people from University with little site experience. E-based or app-based learning will need to be very engaging for people to complete it. Latest developments in virtual or augmented reality will help, as will gamification techniques.
4. Develop a "*hook*" for the training that means that builders believe they will be ahead of the game if they attend, e.g. telling them about a new technology that is simple to use, affordable, and they will be able to offer to their clients.
5. Minimise the commitment required for training and the disruption to the working day. A series of brief, free breakfast sessions (with breakfast included) that build towards an accreditation or certificate could be viable.
6. Builders are more likely to consult training materials the first time they use a product. A short simple message pointing new users to a quick and easy information source that will make

installation easier may be used. Training resources could be introduced alongside the release of new products.

7. Linking the training to new regulations on carbon emissions will help builders to recognise that practice needs to be tightened up and installing internal wall insulation is not the same as installing plasterboards. They need to understand how to deal with on-site challenges in a way that doesn't compromise U-values. Developing a snappy title, such as: "*U need to know*" or "*U got it*" could help with this.
8. A campaign could highlight that every site or business needs to have one person who knows about U-values and can pass their knowledge on, e.g. "*I can tell U*"
9. A few key pieces of information about a product, printed on that product are more likely to be read than information sheets. "*Three things to know about me*" could be displayed in large print or symbols could illustrate the most important things to be considered for effective installation.

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