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Barriers to domestic retrofit quality: Are failures in retrofit standards a failure of retrofit standards?

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Abstract

Thermal retrofits of homes are central to the UK's fuel poverty and net zero carbon policies but there are concerns about poor quality installation and so new standards are to be introduced (PAS2035). We have explored retrofit installers' perceptions of the barriers to installing internal wall insulation (IWI) and of current regulations and standards for retrofits. We conducted four focus groups with retrofit installers. Thematic analysis identified three themes. (1) IWI is viewed as impractical in situations other than new builds, extensions and conversions as it is too time-consuming and expensive. (2) Installing IWI is perceived as an unskilled job with no need for training or referring to standards during installation. (3) Because standards lack credibility, installers can be sceptical of potential problems caused by on-site installation adaptations, for example thermal bridging. Our results show that retrofit standards have not improved retrofit quality. Awareness and credibility of standards is low, and new standards (PAS2035) will introduce additional costs which may reduce the pool of installers willing to engage in the retrofit market. Policies need to address installer training, professional identity and social practices, and reduce barriers to change in order to increase success.

Keywords

Domestic retrofit quality, Internal wall insulation, Regulations, Standards, Performance, Qualitative

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Introduction

The 2015 Paris agreement showed that Governments have committed to reducing carbon emissions, although the latest United Nations convention on Climate Change (COP25) highlighted that more action is needed to achieve targets (UNEP2020).[1] The UK government has unilaterally committed to net zero by 2050[2] and is aiming to improve the energy efficiency of all fuel poor homes to an Energy Performance Certificate (EPC) of C by 2035.[3] Much progress towards these goals has been undertaken in recent years: by 2018 the UK had achieved a 43% reduction on 1990 levels of carbon emissions.[4] However, the domestic sector still consumes 26% of UK primary energy[5] and is responsible for 15% of national Greenhouse Gas (GHG) emissions[4] with space heating specifically being responsible for around 10%,[6] while only 40% of homes have an EPC rating of C or above in England and Wales.[7]

Reducing the emissions associated with space heating can be addressed via a combination of (1) decarbonising heat (e.g. renewables or low carbon electric heating) and (2) reducing space heating demand in homes. Both solutions have significant strategic infrastructural challenges.

First, in regard to low carbon heating, gas central heating is currently used in 86% of UK homes[8] and gas

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and oil combustion makes up 68% and 13% of national domestic space heating energy use, respectively, while electric and renewable heating constitute just 19% and 1%, respectively.[9] The gap between peak electricity demand and capacity[10] means that transitioning from gas to low carbon electric heat would require a substantial reduction in peak heat demand.[11] Transition to renewable heat is also challenging: currently renewables supply less than 3% of UK total heat demand (domestic and non-domestic) and over 40% of this is provided by wood combustion in homes,[4] which has implications for air pollution.[12] Converting methane to hydrogen could provide a substantial reduction in emissions arising from domestic heating[13] but to reassure the public about the increased production costs of hydrogen[14] homes need to become more energy efficient. Thus, there is a long way to go to decarbonise heat, and this approach appears to be dependent on also increasing the energy efficiency of homes.

Second, while reducing space heating demand in homes reduces carbon emissions and fuel bills for householders, and has been linked to reductions in fuel poverty[15] and improvements in occupants' health,[16–18] progress against policy targets is slow. Improvements may be achieved relatively simply in new homes through addressing heat loss standards via Building Regulations. However, relatively few new homes are being built, meaning that 85% of the 2050 UK housing stock will be made up of homes that already exist.[19] Therefore, the greater challenge is to retrofit the existing housing stock. Current retrofit rates are low, equivalent to around 600 per day[20] and these are reliant on government policy, most prominently, the Energy Company Obligation (ECO).[21] This is a problem since estimates suggest that over 2000 homes will need retrofitting daily to achieve net zero carbon targets, predominantly funded by the market through access to green finance, although ECO and other policy mechanisms are still likely to be major contributors to achieving domestic retrofit targets.[16,22]

Beyond the low numbers of homes being retrofitted, there is also concern around the quality and standards of retrofits installed via ECO,[23–25] and Government data suggest 10% of homes fail technical monitoring.[26] These concerns prompted the Each Homes Counts (EHC) industry review of retrofit standards,[27] which resulted in upgrades in the technical specifications in PAS230[28] as well as the introduction of new standards to be implemented fully in 2021 on quality processes for retrofits – PAS2035.[29]

While PAS2030 already identified a need for design surveys, competency schemes for installers, and commissioning and handover to be incorporated in all retrofit projects,[30] it was observed that some of these stages were being missed,[27] resulting in substandard retrofits. PAS2035 therefore maps out new quality process requirements for retrofits, more clearly defining these for low-, medium- and high-risk projects. Adding more regulations may add additional cost to the retrofit process, though it is not clear how much this may be and if it will affect the rate of retrofits being installed. One additional major change in PAS2035 is the requirement for a qualified Retrofit Coordinator to oversee retrofit projects, which will ensure compliance is checked throughout the project by the project team itself rather than relying on technical monitoring. This aims to ensure compliance rates and quality are improved.

Technical monitoring and requirements for certifying the performance of thermal retrofits is covered by another standard, PAS 2031.[31] Currently, only 5% of retrofits on average are checked via technical monitoring.[32] However, while PAS2031 has been updated to be in line with PAS2035, it has not fundamentally altered the way technical monitoring is delivered.

Beyond input from industry leaders into the EHC process, it is not clear that alternative approaches to improve compliance with standards were considered, or that on-the-ground installers were consulted. Studies undertaken in other areas of construction regulation to improve compliance with standards have taken this approach. Addressing personal factors for workers, rather than company or management factors, was shown to be an important step in ensuring compliance with safety standards in the construction industry.[33] The authors recommend that experiences from peers be included as part of training packages to highlight examples of failure to comply with standards leads to accidents. The same study also identified that 'family responsibility' is more likely to result in compliance with standards,[33] which counters the approach taken in PAS2035, where the Retrofit Coordinator, rather than individual workers, is responsible for compliance.

Another project, also aimed at improving compliance with construction site safety requirements, identified peer-to-peer communication as a successful way to improve compliance with standards,[34] and while the retrofit coordinator under PAS2035 will provide guidance to retrofit installers on how and why to comply with the standards, they may not necessarily be regarded as 'peers' by the rest of the team; they may not even be part of the same organisation.

Finally, a study into compliance with waste reduction requirements on construction sites found that the most effective approach combines 'reactive actions', such as making more site inspections and providing more direct feedback including penalties and rewards,

'preventative actions' such as increasing the amount of training and communication and 'prioritisation' such as investment and management level buy-in.[35] PAS2035 changes to retrofit standards, however, have relied on improving and enhancing 'preventative actions' rather than 'reactive actions', i.e. technical monitoring.

Making changes to standards without considering evidence on effective ways of changing installer behaviour may result in missed opportunities. This paper investigates barriers to compliance with retrofit standards of internal wall insulation (IWI) installers, one of the most technically demanding retrofits. Previous research has focused on policy, technical performance and the perspective of occupants but has neglected the perspective of retrofit professionals and it is essential that their voices are heard.[36]

Research method

Retrofit installer sampling

Our 22 participants were all male, and they ranged in age from 23 to 58. All lived and worked in the North of England. Most were self-employed builders or employed by SMEs, and all installed retrofit IWI, one of the most technically demanding retrofits.[24,37,38] Three no longer worked solely on site and instead worked in a contract or supervisory capacity. They were recruited via a specialist fieldwork agency. All groups took place in West Yorkshire and participants were provided with industry-standard incentives. The findings may be relevant to the rest of England and Wales, which operate under the same policy frameworks (ECO); however, the ability to extrapolate to the rest of the UK or EU is less certain. Findings linked to technical issues related to retrofitting solid walls may well be more widely applicable, for instance in Scotland[39] and other EU countries where solid wall homes are prevalent in a similar climate.

Data collection

We used a qualitative approach to the research, which provides more depth understanding about behaviour than would be possible using quantitative methods, such as surveys. There were two stages to data collection. The first stage involved in-depth interviews with two participants with extensive experience of installing different types of IWI, and this preliminary stage identified the areas to explore during focus groups, which formed the main part of the study. Focus groups provide an opportunity for participants to share, compare and discuss their thoughts, feelings, expectations and experiences, and therefore generate data that provide in-depth insights into behaviours and motivations.

Our focus group discussions covered the following:

- Experiences of installing IWI.
- Challenges typically experienced when retrofitting IWI.
- Training to install IWI.
- Situations when the design specification is not followed.
- Ways of making installation instructions more user-friendly.

We conducted four focus groups, each with five builders who retrofit IWI in domestic settings. Each focus group lasted one hour and, with permission from participants, was audio 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.

Data analysis

Transcripts were analysed thematically[40] by coding the data using the research question: What are the barriers to effectively retrofitting IWI? 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. The criteria for a theme were that it is internally homogeneous, i.e. the sub-themes it contained all shared a certain perspective, and that it is externally heterogeneous, i.e. that the themes were fundamentally different from one another. This stage was iterative, with sub-themes merging and moving between themes until a grouping was identified that provided the most parsimonious data structure while capturing the full set of codes. One researcher (FF) coded the transcripts and undertook first-stage sorting. The second author (DG) reviewed the thematic structure alongside the transcripts. Both the authors then finalised the themes and sub-themes. Quotes from the focus groups were selected on the basis that they best illustrated each sub-theme. The number of the focus group (FG1–4) is indicated in brackets after each quote.

Results

We identified three themes in the data. (1) IWI is often viewed as impractical to use in a retrofit capacity, which means that it is not always suggested as an option; (2) participants do not perceive PAS2030 as relevant: most are unfamiliar with it and have not

received formal training in installing IWI; (3) adaptations that participants apply when the specified insulation design needs to be amended on site. These three themes are described in more detail here.

Impractical

Participants identified many difficulties associated with installing IWI that would deter them from selecting it as an insulation product or suggesting it to customers. This includes 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. This makes it time-consuming and they believe that the additional cost is prohibitive and clients would not be prepared to pay. One described installing IWI as part of a heat pump insulation, because the additional cost of insulation was viewed as more proportionate. Participants were also concerned that the amount of time to complete an IWI retrofit is unpredictable, since when they remove these items they may reveal previously unknown problems that need addressing, which makes it difficult to quote for a job.

> 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 you're losing internal space as well. (FG3)

Participants also highlighted that IWI takes up too much room in small properties. For these reasons, they did not think that IWI currently offers a practical retrofit insulation solution.

However, participants would use IWI in a loft conversion or an extension, which offers a 'blank canvas' and as such it is easier to use. Some also talked about being asked to use it on floors. 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. Better sound insulation is an immediate and tangible improvement and installers were more aware of this benefit, while less tangible or abstract benefits, such as lower fuel bills, were not seen as salient. This may indicate the importance of co-benefits of insulation in retrofit demand.

Participants also talked about how insulation products need to be simple to install and simple to maintain and repair. Participants discussed how they are unwilling to install technically complex products because they anticipate them being 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. If you're putting it on a building, the simplest way of doing it is Kingspan then render. If it's damaged it's very simple to repair and 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)

In addition to the technical difficulties of installing and repairing IWI, participants talked about how they do not like working with IWI products as it often involves working in confined spaces which can overheat, and some participants were concerned about future health problems caused by dust from these products.

> It's a horrible job. 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)

> it's just the dust, isn't it? You can see it. When you've got a torch in a loft you can just see it, just floating around all over, but I suppose, if you have a mask and glasses. But you'll put a mask on, and then you'll put your glasses on, and then your glasses are steamed up. So, you either take your mask off and get a load of dust, or take your glasses off and get a load in your eyes. (FG 4)

Irrelevant

Very few participants were aware of PAS2030 accreditation, and none believed it relevant to them or their business. A few had previous experience of ECO-funded projects, and most talked about onerous application and payment processes and additional checks on their work. Generally, they found such checks restrictive rather than constructive, as they often believed that these inspectors did not have their depth of experience and did not understand the need to adapt plans to individual situations on site.

> 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. Sometimes you've got to adapt plans 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 IWI or verification of their skills. They had all learned by watching others or simply developing skills on-site as they used the products. They discussed that pairing more experienced workers with less experienced ones is the best form of training. 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 IWI can be time-consuming to install, it is not technically challenging, and they assume that any experienced builder can install it effectively.

> It's not really rocket science. It's not that difficult. (FG4)

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

Despite being sceptical of the need for training, a few participants talked about how they had observed poor installation of IWI, 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 to help, of varying skills levels. However, many participants judged the quality of installation on cosmetic appearance.

Some, but not all, participants were aware of the potential consequences of poor installation. They 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)

On-site adaptations

Generally, participants were 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 adapting to on-site challenges, rather than deliberately taking shortcuts.

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 often ask to see photographs of the build. Adaptations, in contrast, are well 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, adaptations 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.

> 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)

Discussion

Increasing the energy efficiency of homes is an essential step in achieving net zero ambitions. In this study, we have explored retrofit installers' perceptions of the barriers to installing IWI and their perceptions of the regulations and standards for retrofits. Some barriers have relevance to a wider range of retrofit types and we identify this in this discussion. The implications for retrofit policy targets and how they may relate to new standards being introduced are discussed.

The first barrier to achieving high quality IWI identified by builders working in small businesses is that it is perceived as impractical in situations other than new builds, extensions and conversions. It is believed to be too time-consuming and therefore expensive, and so technically challenging or novel products can be rejected in favour of products that are simple to install

and to repair. Our participants typically chose not to suggest IWI because they assumed that clients would be unwilling to pay. While this assumption may not always be true, our participants talked about the need to minimise costs when quoting for work, which mitigates against suggesting additional energy efficiency options. Reluctance to suggest retrofit insulation because of perceptions that customers are not willing to pay have been identified previously.[36] Installers did not discuss the benefits of IWI of comfort, health and well-being with customers.[41] A fundamental problem is that installers themselves did not think that IWI provides good value for money in retrofits. Similar concerns have been found previously, with building professionals being reluctant to recommend technologies that may not be cost effective.[42] The main example of suggesting insulation in our data was when to accompany a heat pump, which requires well insulated homes to operate effectively, and as the pumps are relatively expensive, the additional cost of insulation was viewed as being more proportionate. Installer confidence appears to be a success criterion for retrofit products; this may have implications for products other than IWI.

There were some elements of the product itself that our participants disliked, for example they were concerned that the amount of dust it produces could have long-term health implications. This barrier would require changes to the product design. Rigid foam board insulation used for IWI is also commonly used in rooms with sloping ceiling and suspended timber floor insulation, and so this may also be a problem for these retrofits.

Preferences of installers to avoid particular retrofit types could be a concern since the whole-house approach promoted in PAS2035 necessarily means that all retrofit options should be considered and selected to best suit the house, not the installer preference. These conflicting motivations in retrofit decision making could undermine the standard of retrofits delivered in ECO, meaning there is a risk that PAS2035 may force installers to use a system they dislike, or not engage in policy schemes, reducing supply chains and meaning that homes which could benefit from IWI are not insulated at all. When a whole-house retrofit is being undertaken, this barrier may be less significant since the client may be more accepting of disruption and have a larger budget, although this currently forms only a small fraction of retrofits. The experience of the installers, however, was primarily to install single-measure retrofits for a specific budget. None discussed experiences of being able to upsell their work to whole-house retrofits; any scope creep was considered a problem rather than an opportunity.

The second barrier is that our participants did not view installing IWI as a particularly skilled job and so did not see the point of training or referring to standards. This illustrates a failure in retrofit standards to articulate the problems that can manifest when IWI is not installed correctly, which in turn appears to be contributing to standards not being well respected. A lack of confidence in standards that has been described previously,[36] taken with our findings, highlights the need to engage more effectively with SMEs and micro-businesses if retrofit standards are to be improved. Greater two-way communication in a whole-systems approach has been identified as a means of improving total building performance.[43] Further evidence of this was found in that PAS2030 regulations are not well known, and the bureaucracy associated with ECO-funded projects deters small businesses from pursuing these projects. This suggests that the additional process requirements proposed under PAS2035 may also be ignored and it may further discourage SMEs from entering the retrofit market or engaging with standards. This may be a problem for a wide range of retrofits delivered under PAS2035, not just IWI.

In addition, the people who inspect sites are not always seen as credible. This could mean that the decisions made by the new professional roles proposed in PAS2035 such as the Retrofit Coordinator may not carry authority if their roles are not embraced by installers, i.e. no sense of 'family responsibility'[33] manifests. Moreover, PAS2030 regulations are perceived by some installers as irrelevant. PAS2035 is designed to explain more clearly the purpose of the PAS2030 technical standards, and how to achieve them. To ensure this is achieved, consideration needs to be given to dissemination strategies designed to change installer culture of noncompliance with the standards, so that the same failings of PAS2030 are not repeated with PAS2035. There is also a need to develop a better technical understanding of low-energy construction, alongside problem-solving and communication skills and a professional identity aligned with sustainability.[44] This has been termed 'competence' and has been argued as being essential in order to address the performance gap and meet emission targets.[45] Our results show that all three of these elements – knowledge, skill and professional identity – need to be addressed.

The final barrier to achieving high-quality IWI retrofits identified by installers 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. This leads to some perceptions that the standards are deliberately unachievable for particular details or circumstances, so that the manufacturers can avoid liability, and therefore, standards are not flexible enough to be useful. Sometimes

installers are aware of how the adaptations they make reduce the effectiveness of insulation but believe that there is nothing they can do. Sometimes they are unaware of the consequences and sometimes they are sceptical of potential problems. It is important to note that even similar house types can have unique features, and previous research has identified that onsite adaptations are necessary for all types of retrofit products[46] so it is likely that this barrier to standards is common for all retrofits.

PAS2030 identifies that in these situations installers should consult designers rather than use adaptations. PAS2035 similarly requires installers to consult designers in these situations, though it provides additional processes to encourage this to happen. However, it is not yet known if, for example, the addition of a Retrofit Coordinator will be enough to ensure that there is a change in culture and practice, especially since this study suggests professionals in these roles may be treated with scepticism by some installers. It is also unclear how much the additional processes may cost and how this will affect retrofit rates undertaken via policy or the number of privately funded retrofits that take place outside of the regulatory framework.

Our results suggest that the approach to the implementation of retrofit standards have contributed to failures in the standards of retrofits and that future policy should attempt overcome two key issues. First, awareness and credibility of regulations is low in subcontractors, who form the bulk of the UK construction workforce. Many do not know what the regulations are, and others do not believe the negative consequences of breaking them. It is not yet clear if this problem will be overcome by the new PAS2035 regulations which add additional layers of process and guidance but do not increase the amount of technical monitoring of standards. Revising PAS2031, for example increasing the number of inspections that need to take place by third party monitoring agents, would be an alternative approach to tackling underperformance. It is also important to address the problems we identified with the credibility of regulations. Therefore, changes in construction training and licensing may be required, alongside broader interventions to change installer behaviour.

Second, installers always encounter the need for onsite adaptations. They do not believe that third party inspectors have the experience to recommend how to achieve these adaptations. For retrofits taking place via Government policy, it is possible that PAS2035, in which a qualified Retrofit Coordinator oversees the retrofit, will address this, though this may only occur where the processes are already being followed, and will rely on the acceptance of Retrofit Coordinators by installers. PAS2035 increased process and procedural requirements for installers, and since the burden of compliance was one cause of non-compliance, it is not yet known if these additional processes will add to or relieve this burden. Many practitioners in the building industry consider sustainability certification as an extra layer of unnecessary documentation and costs,[47] so PAS2035 may perversely increase non-compliance rates or perhaps reduce the pool of installers willing to engage in the regulated retrofit market. Support may therefore be needed to promote the role of the Retrofit Coordinator and explain the benefits of the additional process steps that installers need to take to ensure compliance. These are the issues that have implications for all retrofit types, not just IWI.

Conclusions

Our results identified three major barriers to achieving standards in IWI, which to some degree can be translated to other retrofit products. First, installers' enthusiasm does not match the national ambition for retrofits. Understanding how to incentivise installers and householders to engage in the retrofit market, for example better knowledge around co-benefits and fostering a professional identity that includes sustainability, may be critical to overcoming this barrier. Second, installers do not perceive the standards to be credible; more understanding on the extent of this in other retrofit products is needed. Finally, the research found that standards are not flexible enough for real-world retrofit scenarios and so they were viewed as unachievable. Adding additional processes and a Retrofit Coordinator in PAS2035 is a move to address this but it may increase the distance between the installer and the principles that underpin the standards. Research is needed to understand how an alternative route to raising standards could be achieved through installers becoming more empowered to take more responsibility over retrofit quality and training being expanded to go beyond skills to address all the three elements of competence: knowledge, skills and professional identity.

The research identifies that on-the-ground installers can feel that current retrofit standards make their job more difficult and this may be pushing some out of the retrofit market. Additionally, new standards and processes may add cost into retrofits that installers feel are already unaffordable, potentially reducing the number of retrofits that can take place. There is therefore a contradiction in that more retrofits are needed to support net zero carbon targets, and retrofit standards need improving, yet raising standards may reduce the number of retrofits taking place. This challenge therefore goes beyond just standards: new policy supporting a national retrofit strategy may be needed. Previous policies may not have considered barriers to change

in the target audience, nor how interventions accompanying policies and regulations could make use of theoretical models of behaviour change and behavioural insights in order to increase their chance of success. This is an area that needs more research in the context of domestic retrofits.

Authors contribution

All authors contributed equally in the preparation of this manuscript.

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