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Title: **Outside influence – some effects of retrofit installers and advisors on energy behaviours in households**

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Abstract

We analyse qualitative data from home energy retrofit projects in England, looking beyond the boundaries of the building and its design for human behavioural influences on home energy use. We recognise that energy use is not solely determined by the decisions of building users or designers, but that intermediaries involved in energy retrofit may also be influential. Our focus is on retrofit which encompasses a range of changes to existing buildings to alter energy use. Decisions to incorporate new energy technologies into the home (both energy efficiency and renewable energy technologies), and how these technologies are then used, are shaped by the advice and action of energy efficiency advisers and energy

technology installers (intermediaries). Understanding the nature of this influence, and how it might be directed to increase energy efficient behaviours, is an overlooked opportunity. We found that influence was greatest at the pre-installation stage, and that influence which could be exercised post-installation was not realised. We conclude that by recognising how the role and influence of intermediaries varies at each stage of the retrofit process, policy and action can be identified to enhance the contribution intermediaries can make to changing behaviours and reducing domestic energy use.

[197 words]

Keywords

Retrofit, advisors, installers, energy efficiency, microgeneration

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Introduction

Energy use in the home is not determined solely by the decisions of building users or designers. When householders contemplate changing their homes in ways which may influence energy use, their decisions to incorporate new energy technologies and how they then use the newly installed technologies, are influenced by the action of intermediaries, including energy efficiency advisers and energy technology installers. Understanding the nature of this influence, and how it might be directed to increase energy efficiency, is an overlooked opportunity, particularly in the context of the number of intermediaries. A UK trade association representing small and medium sized building firms recently reported that the market value of refurbishment and renovation of existing homes was up to £6 billion per annum [1]. Each refurbishment project offers an opportunity for energy use reduction.

We explore why retrofit activity is important for building energy use, review how the role of specific intermediaries has been identified and described to date and suggest the stages at which intermediaries' influence on the energy behaviours of people in their homes can be identified. Drawing on empirical data from case studies of retrofitting energy technologies into homes in England, we then illustrate the kinds of influence that intermediaries exert at these stages, and what constrains or enables the effects of that influence. We use these examples to suggest ways in which the potential of intermediaries in reducing residential energy demand might be realised.

Background - Retrofit

Retrofit is used here to encompass a range of activities in repairing, improving and maintaining buildings, incorporating innovations that shape energy use directly or that influence user behaviour to reduce energy use. A focus on retrofitting buildings is justified, indeed necessary, as a large proportion of the housing stock which needs to be near zero carbon emissions by 2050 already exists [2]. This imperative is also recognised beyond the UK, and retrofit of existing buildings is identified as a priority at EU level not least through the Article 4 of the Energy Efficiency Directive 2012/27/EU [3].

The range of retrofit measures address energy conservation, energy efficiency and microgeneration of electricity or heat. Energy conservation and efficiency measures can be readily understood to influence energy use directly by reducing demand, although expected reductions may not be realised due to an effect called “rebound” [4]. However, the link between renewable microgeneration of heat or electricity, and reductions in household energy demand, and therefore household carbon emissions, is less direct. In the UK, microgeneration of electricity typically feeds the electricity distribution grid, with the home generating the electricity having ‘first call’ on the electricity as it is generated (i.e. before export to the grid). Electricity used in this way will displace energy generation in the wider grid, and so also reduce distribution losses associated with the grid. Homeowners’ behaviours may also change when they have microgeneration installed as they become more aware of energy generation and use [5] although such effects may be temporary if new habits are not

formed after installation. Table 1 offers an illustrative range of technologies which can be retrofitted and which were represented in this exploratory analysis.

Technology type	**Example technology**
Energy conservation (constrains energy demand directly)	Thermostatic radiator controls
Energy efficiency (reduces energy demand through increasing efficiency of energy use)	Draft proofing Boiler replacement Low energy lighting Cavity wall insulation Loft, flat roof, ceiling and floor insulation Solid wall insulation Window replacement and refurbishment
Microgeneration – heat	Air source heat pumps Ground source heat pumps Solar thermal systems Biomass boilers
Microgeneration - electricity	PV cells Micro-wind turbines Micro-hydro

Table 1: Retrofit energy technologies

Activity after technology installation influences energy use in a home, thus there is a need to influence how these technologies are used. For example, a heating engineer installing thermostatic valves on radiators can also set them to different comfort temperatures in different rooms rather than leaving the householder to do so. However, this process of influencing technology use is not unidirectional. The design of the technology will encourage, allow or constrain particular forms of use [6]. And the design itself will have been formed by the knowledge, understanding and framing of the design team [7].

Role of intermediaries in retrofit

The influence of householders and householder behaviour on effective energy retrofit has been widely studied [e.g. 8-10] with extensive research on inhabitant behaviours that change energy consumption, exploring the effects of individual values [e.g.11, 12], the household's social practices and habits [13, 14], and lifestyle stages and choices [15]. This work is neatly summarised as "buildings don't use energy, people do" [16]. However, this paper starts to look beyond the household, to explore the role of specific intermediaries who influence household members. A wide range of intermediaries, performing different roles, has been identified in the study of infrastructure transition and, more narrowly, renewable energy [17, 18]. We focus on the function of the intermediary rather than the type of organisation that they belong to. This paper focusses on two specific functions of the intermediary: advising on technologies that householders can consider for adoption, and installing those technologies. These functions would typically be carried out through a range of activities including:

- advising a household on energy efficiency measures or energy technologies that could be incorporated in a retrofit project;
- designing or specifying those measures;
- procuring technology or materials;
- costing different retrofit options;
- explaining to clients the measures undertaken;
- advising and explaining to other trades why measures are undertaken;
- commissioning; and,
- maintaining retrofit works.

Intermediaries may have a purely advisory role, for example the energy efficiency adviser who assesses the need for insulation or a change to heating systems, or advice may be integrated with implementation, with a building contractor or heating engineer specifying a retrofit job and implementing the measures specified. The technical standard PAS2030 which sets the clear requirements for Green Deal (the UK's flagship pay-as-you-save retrofit scheme) and other retrofit work does include reference to commissioning activities, but with a purely technical focus, requiring installers to ensure that equipment is installed and commissioned in strict accordance with the manufacturer's specification [19].

Architects and engineers are also very visible agents in determining the effect of retrofit activities, and the design principles, technologies and innovations they employ clearly affect energy use. Their role in interpreting, applying and influencing low carbon building regulation in the UK has been recognised [20]. We note, however, that for much domestic retrofit activity, this design and professional expertise is rarely drawn upon and although an architectural technician may draw up plans to fulfil local permitting requirements, much of the design detail often emerges through the construction and installation process.

Conceptualising sociotechnical systems (STS) has enabled researchers to analyse building retrofit beyond the fabric and technology of a retrofit project, with people and technologies influencing each other within a broader landscape of change. While there is no single STS approach, using a socio-technical perspective allows a range of other actors and influences to be considered when seeking a major change or innovation [21]. The comprehensive reduction of energy consumption in housing is

an example of shifting from a focus on a particular sector (energy technology) to the wider socio-technical system encompassing a range of technologies and people, with influence between all aspects of the system. The potential for microgeneration as a niche technology was described in a sociotechnical exploration of how we might move towards low carbon systems, and the importance of installers in developing those niches was identified [22]. An STS approach also revealed the difficulties of implementing the (economically rational) condensing boiler in the UK around the turn of the century. Heating engineers, the key intermediaries in installing this technology, lacked the experience and motivation to support the innovation [23].

In developing the sociotechnical approach, new ways to think about the structure of the retrofit system are being proposed, such as a “middle out” approach considering the role of intermediaries, rather than top down (regulatory) or bottom up (individual behaviour) approaches [24]. It is suggested that this approach might help overcome some of the evident divides between drivers, values and action [25]. In the “middle-out” analysis, intermediaries who have a professional role in retrofit projects are identified both as “enablers” of different solutions, and as “aggregators” of knowledge and understanding from a range of businesses and trades [24]. In some retrofit cases, the home owner is also the retrofit installer. Analysis of the characteristics of these innovators and the STS they are part of has revealed that the interplay between amenity and energy efficiency is important, and that individuals often engage in mutual learning with their advisers and tradesmen [9].

The issue of skills and capacity in the retrofit sector provides a further rationale for a focus on intermediaries. A review of retrofit projects across five European countries found that the skills of stakeholders, including installers, were critical to the success of refurbishment in both financial and carbon terms and that intermediaries were

often key actors in a local area [26]. An analysis of why energy efficiency measures are not adopted at an economically efficient rate generated a list of market failures, including constraints on intermediaries' knowledge and information [27]. Equally, a lack of "suitably skilled installers" is recognised as a limiting factor on microgeneration in the UK [28], with a deficit in installers' skills also identified as a barrier in the specific case of heat pumps [29].

Before installation begins, even before retrofit measures have been identified and specified, decisions to incorporate new energy technologies into the home, and how to use them, are shaped by the advice and action of several intermediaries, including energy efficiency advisers and technology installers [30]. Nosberger et al. [31] discuss the professionalisation of retrofit work and suggest that the required competences or capacities of these actors in the retrofit industry need to cover not only technical knowledge and skills, but personal and professional skills too. However, whilst standards of professional practice in the UK have been developed and updated to underpin retrofit activity [19, 32] these standards focus on technical issues rather than the personal capacity of individuals in carrying out retrofit. While interacting with customers is considered, the emphasis is on high levels of customer service and responding to customer demands, rather than on shaping or influencing the customer expectations and later behaviours [19].

It is worth noting that the influence of intermediaries on energy use is not automatically positive or directed at reducing energy use. Retrofit activity, and the resulting potential changes in energy use, may be constrained by intermediaries who lack certainty over the outcomes and householder concerns over "construction mess, associated stress and dubious contractors" [33]. The lack of knowledge and/or

experience of particular tradesmen is also thought to limit the retrofit options considered, as in, for example, the case of a joiners' lack of experience with highly insulating window technologies [8].

The range of technologies which can be retrofitted to modify energy use is wide (Table 1). Conceiving these technologies as innovations is helpful as this allows us to draw on innovation diffusion theory in which change agents are key actors who enable change, and may specifically have a role to promote change [34]. However, in the context of building retrofit, the motivations for change agents are not always clear. Energy assessors and advisers will advocate measures to reduce energy use as part of their role, but a tradesmen, designer or installer advocating a particular technology can be counterproductive, with householders being suspicious of those who promote a specific option.

Given this background, and the clear need to improve our understanding of the influence of the intermediary in energy retrofit, we now turn to an empirical analysis to identify the nature of that influence.

Method

We draw on qualitative data gathered in a study of household adoption of low carbon energy technologies across five area-based schemes in England. Each scheme aimed to increase adoption of energy technologies (conservation, microgeneration, or a specific form of microgeneration such as photovoltaic cells) but did not encourage or facilitate a whole house approach. Using a semi-structured interview

technique, data was gathered from householders, scheme managers, and the advisers and tradesmen who specified and installed energy technologies [35].
In total, 54 individuals were interviewed across the five, a sample which provided representation across three roles (householders, scheme managers, installers/advisers) and which appeared to lead to data saturation for the original research questions [35, 36]. These data were collected with the aim to understand better the process of energy technology adoption and not from a starting point of considering home retrofit. However, from analysis of the 54 interviews, the importance of intermediaries (specifically advisers and installers) emerged and was mentioned explicitly, without prompting, in 22 of the interviews. This subset comprises interviews with individuals across all three main roles (householder, scheme manager, advisor/installer) and a wide range of technologies (Table 2).
The origins of the data in a study of technology adoption means that the sample has not been developed in a more formal structured manner, as would be the case if the original primary focus was on intermediaries. Nevertheless, this subset of 22 interviews represents a substantive body of primary data that points to the influential role of intermediaries in energy technology adoption and use, and which merits further exploratory analysis.

Technology	**Role and number of sources**
Insulation	Installer Programme Manager
Air Source Heat Pumps	Homeowner and adopter (3 homes) Surveyor and installer (2 individuals) Programme Manager
Photovoltaic cells (PV)	Homeowner and adopter (2 homes) Installer Programme Manager
Energy conservation technologies	Installer (2 individuals) Programme manager (2 individuals)
Micro hydro	Homeowner and adopter Homeowner and non-adopter Installer

Solar thermal	Homeowner and non-adopter
Biomass	Homeowner and adopter
All renewable microgeneration	Surveyor and installer

Table 2: Data sources for analysis of role of intermediaries

Framing retrofit measures as innovations to existing buildings allows theoretical models of innovation diffusion to be used as the starting point for analysis. The basic innovation chain describes the innovation adopter (here, the householder), gathering knowledge, being persuaded to adopt an innovation, making a decision which is implemented and, finally, receiving some sort of confirmation which embeds the innovation [34]. A similar pattern is found in the "expectancy value" psychological models used to explain environmental behaviours by individuals (here, again, householders). In these models, a set of starting conditions (antecedents) form an intention which leads to an action with some result from that action [37]. Where analysis has been directed at energy retrofit specifically, the householder remains the focus with households thinking about renovation, deciding to renovate, planning the detail of renovation and then experiencing renovation [10]. The background section above has highlighted that this householder focus overlooks the role of the intermediary adviser or installer. To structure our analysis, we integrated the stages from the theoretical approaches, separating process stages where a distinct intermediary influence might be identified. This gives the following stages:

a) Pre-installation: Identifying the retrofit opportunity;
b) Pre-installation: Identifying retrofit options ;
c) Pre-installation: Selecting options ;
d) Installation: Retrofit activity;
e) Commissioning retrofit measures;
f) Post-commissioning: Use and maintenance of retrofitted home.

The original research collected data in order to analyse the roles of retrofit scheme managers and householders [35]. Consequently the innovation diffusion process stages reflected the innovation user's perspective: knowledge, persuasion, decision, implementation and confirmation [34]. The importance of intermediaries emerged from this analysis as an unforeseen factor. However, the initial innovation diffusion stages are not best suited to analysing the role of intermediaries, so instead we structure our analysis around the stages of the retrofit process [38]. This structure allows us to analyse the data so that the changing role of intermediaries at different project stages can be assessed. Since policymakers and practitioners typically think about retrofit activity as a staged process, at least in the UK [38], structuring our analysis along these lines makes findings more relevant to policy development.

Qualitative data from transcripts and field notes of semi-structured interviews were analysed for statements or assumptions with respect to the following questions: At what stages of thinking about changing energy technologies in the home do intermediaries have most influence? What types of roles have distinct influences and how do these relate to the capacity of the intermediary and the capacity of the household? How do these personal capacities connect to what is technically feasible in the home? This was, in effect, a form of template analysis [39]. Data collection was designed to investigate householder behaviour, and not these research questions specifically, so the findings discussed below are indicative, but do suggest areas which would be fruitful to explore further in order to understand, and change the influence of intermediaries on the behaviour of building users.

Findings

We organise the findings from our analysis using the six stages identified above. Because our data is drawn from case studies of energy retrofit activities, we could not identify distinct influence of intermediaries in the very first stage: exploring the opportunity to retrofit. At each stage we indicate the types of activities that the intermediaries (installers and advisers) undertake which influence how households later use energy. One notable exclusion is the dominant role of the intermediary identified in innovation diffusion literature: promoting an innovation [34]. This does not arise in our data because the cases we draw on are area-based schemes intended to increase the amount of energy technology adoption and promotion of energy conservation technologies is implicit in the work of advisers and installers on these schemes.

Pre-installation – identifying options

At this stage, the intermediaries' role is in identifying technology options and, potentially, introducing the idea of low energy retrofit through highlighting the opportunity it provides (or the problem it might fix). From our data, the opportunities introduced by intermediaries in their conversations with householders included increasing usable warm space, reducing bills or, very occasionally, reducing carbon impacts. An important capability for the adviser at this stage is to link householder interests and motivations to changing (reducing) energy demand. What building users most want from retrofit activity is likely to be a change in amenity, such that the retrofitted space is better suited to their lifestyle needs [38, 40, 41]. When identifying the options available the adviser must, therefore be able to understand the

householder's perspective and desired outcomes, and link the aspects of retrofit which reduce energy demand to those features desired by the householder. For example, an extension, to provide a play room or a larger family kitchen, needed to be cosy and so high levels of insulation could be justified.

How the 'problem' being fixed by the retrofit activity was viewed by the intermediary was based on their perception of what householder's priorities. This framing then led to the intermediary taking decisions as to which technologies they identified as feasible. For example, if retrofit was intended to reduce energy costs, then intermediaries would not consider interventions with a high capital cost (e.g. heat pumps) unless grant aid was available to cover the capital. Options were identified by the intermediary on a simple payback basis considering how rapidly the initial outlay would be seen in reduced bills. Most intermediaries in these case studies believed that bill reduction was the primary concern for the householders, generally reflecting the purpose of the area-based schemes and the perceived problem to be fixed. Installers recognised and respected householder priorities, as this comment illustrates:

> "I'm there to give advice, make observations. The clients pay the bills so if they want to leave all the lights on in the house then that's their choice." [Energy assessor/installer]

Pre-installation – selecting options

Within the pre-installation stage, intermediaries then influenced, or directed, option selection. The activities of intermediaries at this stage encompass design, specification and procurement or purchasing. In some circumstances, specifically

with microgeneration technologies, ensuring compliance with technical regulations was also part of the installer's role at this stage, although this did not extend to planning or financial regulations (see "householder expectations of intermediaries" below). How an intermediary selected the technical options for the retrofit project was based on their interpretation of the user's needs, on prior experience, or on information received about the user from the manager of a wider scheme. The intermediary then combined this needs assessment with assumptions about the suitability of given technologies to meet those householder needs. Thus solar hot water installation might be deemed appropriate for a household with children, whilst a constant low level heating solution might be considered more important than a timed facility for older occupants with limited mobility. In terms of prior experience, an installer may have had poor experience with a particular manufacturer (in our data, this was the case for biomass boilers) or with the rapid development of a particular technology, as illustrated by this comment from a heating engineer referring to air source heat pumps:

> "But I still believe we're not there. With the technology. And I think we're still in the scenario, you know your colour television you bought six months ago and now there's something better on the market? We are in that situation, I'm sure we are." [ASHP installer]

The well informed intermediary needs to be able to counter the beliefs and experiences of other actors, deploying persuasion and reasoning skills, whether those other actors are the householder client, individuals that the client respects in their social network, or even other tradesmen:

> "It's sometimes difficult when you get what I call an old time builder, where he'll talk to you 'til he's blue in the face that he's right and your way's wrong. ….They still associate cavity wall with damp problems. It doesn't matter what you're putting in, what material, they still associate it with problems." [Heating engineer]

One of the issues associated with individual building retrofit is that every building and householder will require a bespoke solution, with cost implications that are particularly important for small and medium enterprises (SMEs) that dominate private property retrofit. In one case study, the heating engineer observed:

> "Every house was different, so you had to do a measure up and a sketch of every property so then … then you were looking at an hour in each property." [Heating engineer]

Thus, in addition to the technical and customer-focus skills required in the previous "identifying options" stage, the intermediary also needs an understanding of the costs of measures, in the specific context of this retrofit project, in order to assess financial feasibility.

Installation

The installation (adoption) stage, is when intermediaries are in homes, installing new equipment. Installation was experienced as a disruptive process by householders, with both short term disruption and inconvenience in the home environment, and longer term disruption to the habitual use of the home. For example, installing a heat pump requires significant changes in the householder's expectations about the ability

of a heating system to respond rapidly, or of radiators to feel hot. The actions of intermediaries during installation in our case studies influenced how people felt about the retrofit activity in their homes. This in turn affected the level of engagement building users (householders) had with the potential to reduce energy use after retrofit. There was near-universal dislike from householders of the disruption caused by retrofit activity, and if this was not managed well, the resulting negative impression stayed with the householder and influenced their belief about the effectiveness of the retrofit actions. With an air source heat pump, a particularly bad experience of installation in terms of disruption and damage to property, led one building user to believe that there was no difference in energy consumption before or after and doubt as to whether the equipment was working properly at all. In comparison, another householder who found the installation process well managed, had affectionate feelings towards the new heating system and overlooked teething problems with operation as unusual occurrences, easily overcome [42].

Installers recognised the vital importance of the householder's experience during installation, while also recognising that different rules might be applied to their work compared to the householder's usual standards:

> "If you've caused it [damage to the property] you have to put it right. You're always told as a fitter to leave that job better than what you arrived in, in a better condition than what you arrived in. Always. It's hard sometimes, I tell you. I mean you do go in some customer's properties and one or two have got animals living in there and let's say they're not the cleanest of people. I've had to step over everything, and I mean everything." [Insulation Installer]

Similarly, installers we spoke to had a clear idea of the information that customers needed well in advance of the installation for it to be successful. This included information that the installer felt should be obvious, such as the need for someone to be present to let the team in on the day that cavity wall insulation was to be installed, as well as the need to balance technical and non-technical information:

> “And believe it or not we had a lot of customers given dates and just nobody in. … The customer’s had a letter saying ‘We're coming on da da da’ ….so the lads have turned up, can't do it. And when you've rung customer to say, they say, "I wasn’t told I had to be in". So the more, I know there's a lot, a lot of information to take in for that customer and like I say … it’s not just that you drill a hole and fill it in. There's so much more that if the customer can be told pre-fitting, the more the better for me. But keep it not too technical.” [Insulation Installer]

The skills that intermediaries needed to deploy during installation included being technically adept, but also being flexible and able to solve problems as the inevitable issues arose during retrofit so that the technology could still be installed and function effectively. Another important skill was planning and implementing actions to make the installation experience a positive one for the householder.

Commissioning

For large retrofit measures, such as the installation of new heating systems, commissioning was recognised by installers as part of their role, but the need to communicate the commissioning process to the householder was not always considered important. Commissioning activities include finalising the installation,

switching on or initiating technologies, testing the retrofit measures and making alterations as required to ensure they functioned as expected. Where the technology was perceived to be complex, such as with heat pumps, an installer may assess the householders' ability to understand technical information and so limit information conveyed at handover. By contrast, a small number of householders pressed for as much information during commissioning as possible, motivated by a desire to understand and maintain the equipment in their homes. Some felt dissatisfied when the further information requested was not provided.

With some retrofit measures that could reduce energy use, the intermediary played an important role in installing retrofit measures in such a way that they were used as intended. For example, one energy conservation adviser recounted how free, low energy light bulbs mailed by electricity suppliers were rarely installed. However, after the adviser put in the new light bulbs (he carried a small step ladder to ensure he could access light fittings and complete the task), replaced the householder's light shades and switched the lights on to illustrate the quality of light, he felt confident that those light bulbs would stay in place. The main skills we observed intermediaries using to ensure energy demand was reduced after retrofit activity thus centred on technical competence in commissioning retrofit technology and their ability to communicate with householders in terms that match their priorities and interests, providing information in a form that householders can use.

Post-commissioning: use and maintenance

For these case studies, post-commissioning work was minimal. Installation was seen by building users (householders) as the end point of the retrofit process. Whether the

installer influenced the building users during and after commissioning was largely dependent on whether the building user expressed an appetite for behaviour change. Even the installer who described himself as “evangelical” about the need to change behaviours and reduce energy demand did not broach the subject if the client did not ask for more information. This installer had, however, written some supplementary guidance on energy use in the home which he left with his clients as part of their information pack when installation work was complete.

Installers were aware that their influence might not last long after they had left and the following comment illustrates the importance of supporting householder action after any direct contact was complete:

> “With the thermostat ….. you might say, ‘Well, you might just want to nudge it down and shall I just do that?’ Obviously somebody could whack it up a bit later on. With the heating controls, that's obviously quite an important area because a lot of people are baffled by little LCD screens, so I will do it there and then, to say, ‘Well it’s a bit more efficient if we have it on between these times and shall we just do that now?’ … and I believe in empowering people, you know, the best thing is if they understand their systems.” [Energy assessor / Installer]

Several individuals expressed a desire to go back a month or two after their installation visits and remind clients how to operate their retrofit measure effectively, or how their habits might be altered to make the most of the opportunities they

provided. However without funding for the additional time involved, such follow up visits were not viable.

The difficulties of effective commissioning and post commissioning are implicit in advisers' and installers' preferences for 'fix and forget' technologies. In microgeneration, photovoltaic cells are an example of 'fix and forget'; once correctly installed they will generate electricity whenever there is incident sunlight. The additional behavioural changes required by the buildings users, such as changing the time when appliances are used to make best use of PV-generated electricity, are rarely actively promoted or explained. These behaviour changes rely on user motivation, and yet they could be encouraged by small shifts in intermediary behaviour at the commissioning stage, and post-commissioning, with a follow up to tweak both technology performance and user response to the technology.

Householder expectations of intermediaries

In addition to characterising the influence of intermediaries at different stages of retrofit activity, our analysis also revealed householders' uncertainty over the intermediary's role. Our data suggests householders are confused as to the extent of the installer's role, particularly when installing renewable microgeneration. The householder typically saw installation as covering all activities associated with getting the technology installed and operating as desired but there were two main areas where their view of the work was not aligned with the installers' views. The first was in gaining planning permission, if required, which was treated by installers as a householder activity that they might support, but not lead. However, householders

felt they lacked the capacity to navigate the planning system, as these comments illustrate:

> "So I was trying to work the paperwork through, which is not easy when you're not used to Council paperwork to be fair, and the kind of restrictions that you have to go through. …you've got to use the right coloured pen….." [ASHP adopter]

> "[The] planning department … were wanting me to go out and lean through attic windows with a tape measure, which I did actually…Leaning through the Velux window, trying to measure with a tape measure the distance, you know what I mean? And I felt, 'I shouldn't be doing this! Somebody else should.' " [Solar thermal non-adopter]

Second, as the decision to retrofit microgeneration was often driven by financial incentives for the householder, through the Feed in Tariff for electricity, or the Renewable Heat Incentive for heat, registering for these incentives was seen by householders as an essential part of the installation and commissioning process, which the intermediary would take responsibility for:

> "I was under the assumption that the guy who installed it would automatically fill in the forms and send it to the suppliers and after that I wouldn't have to do anything apart from read the meter once every few months. " [PV adopter]

Both these areas of work, particularly the application for financial incentives, require different skills and knowledge to those required to specify, install and commission retrofit measures, and the question arises as to how much they could or should be

legitimately wrapped up in an intermediary's role. The extent of this role will have a direct bearing upon the skills and knowledge that the effective intermediary requires.

Implications for the indoor and built environment

Our exploratory dataset showed that intermediaries (specifically advisers and installers) influenced householders at several stages of the retrofit process, affecting whether they adopt technologies or commit to some kind of associated behaviour change. Intermediaries' influence is related to their technical and social capacities [30] so successful transformation of our built environment to support reduced energy use will require changes in installer and adviser behaviour, reflecting the particular socio-technical challenges of current homes and households.

Much of the focus of current building policy is on the technical competence displayed during retrofit activity and quality assurance of the job done. Green Deal installers must be accredited, and microgeneration installers must also register under the Microgeneration Certification Scheme [43]. Accreditation is, however, perceived as a cost by many of the micro-enterprises who carry out retrofit work and, if higher value work cannot be assured, there is little motivation to undertake the extra activities to gain accreditation particularly if they entail financial or opportunity costs. Equally, the Building Regulation process and inspection, while considered essential as providing a set of minimum standards and providing some protection to building users in terms of quality assurance, does not provide any incentive to increase the focus on reducing energy use, as long as current regulations are met.

Perhaps it is fortunate then, that the influence of intermediaries at both pre- and post- adoption stages appears to be more significant, since there may be opportunities to change intermediaries own behaviours, and therefore impact, at these two stages. For intermediaries who work at the pre-adoption stage of retrofit activity, a clearer and more consistent understanding of how to link what their clients see as the problem to be solved through retrofit (e.g. high energy bills, more usable space), with opportunities to reduce energy use through behaviour would be helpful. The householder's perception of the intermediary's technical competence and expertise is closely linked to the other competences they display in communicating with the householder and the care they display towards the home being retrofitted. Our findings in this study, which focussed on private owner-occupiers, are echoed in studies of social housing tenants where trust is a critical part of the relationship between expert and householder with a direct influence on householders' responses to retrofit technology [44].

The period immediately after installation or retrofit, when the building is handed back to its users, is a critical stage. Extending professional and technical standards to cover a wider definition of commissioning activities, beyond simply installation in accordance with the manufacturer's specification, would provide a consistent level of expectation. If the manufacturer has not specified how technology should be commissioned to ensure the user operates it optimally (and there is little incentive for a manufacturer to do so at present), then the installer is not required to think about information provision and support to the user. After commissioning, standard expectations of follow up and maintenance activities, with routine recognition of the

costs of these activities as part of the required package, would reduce the risk of behavioural changes associated with retrofit being ephemeral.

At each stage, the influence that an intermediary might wield, using the skills summarised in Table 3, interacts closely with the interests, capacity and motivation of the building user. Being able to respond to a user or client's interests, and identify ways to motivate behavioural change appears to be an opportunity to use intermediaries to help realise the full potential of energy retrofit measures.

Stage in retrofit process	**Intermediaries skills and capacities required**
Pre-installation –identifying options	- Ability to understand customer priorities - Ability to link customer priorities with energy efficiency interventions - Technical understanding of built environment and relevant energy efficiency measures
Pre-installation – selecting options	- Ability to understand customer priorities - Ability to link customer priorities with energy efficiency interventions ('needs assessment') - Technical understanding of built environment and relevant energy efficiency measures in order to assess technical feasibility - Understanding of costs of measures, in the specific context of this retrofit project, in order to assess financial feasibility. - Persuasion and reasoning skills to respond to existing norms and beliefs.
Installation	- Technical understanding and ability - Problem solving during retrofit so that the technology could still be installed and function effectively, - Ability to recognise customer / householder perspective and priorities - Planning and implementing actions to make the installation experience a positive one for the householder.
Commissioning	- Ability to communicate with householders in terms that match their priorities and interests - Ability to provide information that householders can use. - Technical competence in commissioning retrofit technology.

Post-commissioning: use and maintenance	- Ability (and capacity) to solve problems during early use of retrofit technology

Table 3: Summary of skills deployed by intermediaries at stages of a retrofit project.

Analysing how the installer's role varies along the retrofit chain leads to implications, and opportunities, for a range of actors, summarised in Table 4. There are also likely to be interactions between the stages of the retrofit chain; certainly our interviewees suggested that a negative experience at any stage will cast a shadow over the wider perceptions of energy retrofit.

Actor	**Implications and opportunities**
Manufacturer (of energy retrofit technology)	Risk associated with innovation may be a significant barrier to the take up of new products through intermediaries who are small businesses. How can the financial risk be reduced through product design, guarantees or costs?
Local authority planning policy makers and decision makers	Consider requirements on intermediaries to implement retrofit activity e.g. what information is needed to support permitted development, and who can supply this?
National energy policy makers	Align policy objectives with drivers for householders and retrofit intermediaries – notably they expect consistent policy instruments. Extend incentives supporting energy retrofit to include the costs of post-installation measures. Extend the definition of energy retrofit to include post-installation measures.
National business support policy makers	Extended energy retrofit could be incentivised by aligning policy objectives (which might include levels of enterprise and economic growth) with SME drivers (which might include customer satisfaction, profit margin, consistency, income and taxation levels).
Trade bodies	Promote opportunities for intermediaries to add value for their clients through delivering energy retrofit alongside amenity improvements. Extend the definition of energy retrofit to include post-installation measures.
Training providers to the construction industry	Non-technical skills impact on the effectiveness of the intermediary's work.

Table 4: Implications and opportunities for retrofit system actors arising from recognising the role and influence of intermediaries

Conclusions and implications for policy and practice

Energy retrofit of the scale required by carbon reduction targets requires rapid acceleration of innovation diffusion so that it becomes mainstream. While the role of designer and users in shaping energy use is readily recognised, intermediaries – specifically advisers and installers - who are external to the building also appear to be an important and influential part of the building's socio-technical system**.** Intermediaries play a particularly important role during installation and commissioning where a technology is unfamiliar to the household, suggesting that shifts towards novel technologies will require changes in the approach and capacity of installers and advisers. In our case studies the influence, and legitimacy, of intermediaries waned rapidly once technology had been installed.

Our analysis is exploratory, drawing on a modest number of research participants in a study originally designed for another purpose. Having revealed the importance of this group of actors, the intermediaries, further research which focuses on these practitioners would help to develop confidence in the measures proposed in Table 4. For example, if national business/enterprise policy focussing on SMEs is to be adjusted to align with the real drivers for SME decision making, then a better understanding of SME drivers is required. Underpinning this is the need to understand drivers and constraints on intermediaries in the retrofit system and how energy retrofit activities fit into mainstream repair and refurbishment work. Equally, intermediaries can be considered in the context of innovation diffusion as adopters themselves, deciding what technologies are brought into the pre-installation stages

of the retrofit chain. As with householders, intermediaries will vary in the degree to which they are keen to innovate.

Our data also suggested that networks (spatial, technical, commercial and social) play an important role in shaping the intermediary's ability and willingness to deliver energy retrofit measures. More detailed and systematic study of these networks could lead to more comprehensive understanding, and potentially modelling, of how building retrofit functions, and therefore how it might be enhanced.

Intermediaries take account of a range of factors in their work, including perceived client motivation, previous experience, availability of knowledge and experience in their networks, and risks and costs associated with innovation. We suggest that by thinking about the differing role and influence of intermediaries at stages of the retrofit process, policy and actions might be identified to increase the contribution that intermediaries can make to changing behaviours and reducing energy use. For example, funding for post-commissioning and maintenance appears to be a key constraint on intermediaries' behaviours, hence such costs could be included in installation costs, locking the intermediaries into follow up activity. By treating retrofit actions as a staged process, and by recognising the connected influence of intermediaries, building design considerations and householder's preferences, targeted measures might be introduced in the supply chain, and into professional and technical standards, such that intermediaries are empowered to act as more effective agents in the transition to a low carbon economy.

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