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Negotiating Comfort in Low Energy Housing: The Politics of Intermediation

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Abstract
Optimising the energy performance of buildings is technically and economically challenging but it also has significant social implications. Maintaining comfortable indoor conditions while reducing energy consumption involves careful design, construction, and management of the built environment and its inhabitants. In this paper, we present findings from the study of a new low energy building for older people in Grenoble, France where conflicts emerged over the simultaneous pursuit of energy efficiency and comfort. The findings contribute to the contemporary literature on the sociotechnical study of buildings and energy use by focusing on intermediation, those activities that bridge the intentions of the design team and end users. Intermediation activities take many forms, and in some cases, can result in the harmonisation or alignment of energy efficiency goals and comfort goals. In other cases, intermediation is unsuccessful, leading to the conventional dichotomy between optimising technical performance and meeting occupant preferences. By highlighting the multiple ways that comfort and energy efficiency is negotiated, we conclude that buildings are provisional achievements that are constantly being intermediated. This suggests that building energy efficiency policies and programmes need to provide opportunities for intermediaries to negotiate the desires and preferences of the multiple stakeholders that are implicated in low energy buildings.

Keywords
Energy efficiency, comfort, domestic buildings, occupants, intermediation

Introduction

The building sector is under increasing pressure to reduce energy consumption. Energy labels are now routinely attached not only to refrigerators and light bulbs, but also to houses and commercial buildings. New buildings are increasingly 'branded' with energy performance standards such as BREEAM and LEED as well as labels such as 'zero carbon'. To attain these higher levels of energy performance, energy efficiency strategies frequently involve the application of technologies ranging from super-insulation and thermal solar hot water systems to ground and air source heat pumps and mechanical ventilation with heat recovery. However, the inclusion of these technologies in buildings does not guarantee optimal energy performance (Wilhite, 2008). The difference between modelled and actual energy performance can be substantial due to a variety of factors related to installation, operations, maintenance, and occupant activities. Numerous studies point to the discrepancy between a building's projected energy performance and its actual energy consumption which we shall call the 'energy performance gap' (Jaffe and Stavins, 1994; Gill *et* al., 2010; Menezes et al, 2012; Sunikha-Blank and Galvin, 2012; de Wilde, 2014).

Scholars in the social sciences, and particularly in the field of Science and Technology Studies (STS), have studied the social aspects of building energy performance (e.g., Lutzenhiser, 1993; Rohracher and Ornetzeder, 2002; Rohracher, 2003; Guy and Shove, 2000; Guy, 2006; Wilhite, 2008; Karvonen, 2013). They argue that energy performance is most frequently framed as a technical strategy that involves optimising the physical operation of the building with little regard for how these buildings are actually built, maintained, and inhabited over their lifetimes. Energy efficiency is thus reduced to either effective engineering or alterations in occupant behaviour. As Rohracher and Ornetzeder (2002, pp. 73-4) argue, low-energy building programmes and projects 'are at risk by focusing too narrowly on technological optimization and expected user behaviour'. The dramatization of this opposition between the technical and user sides of buildings is commonplace in the field of energy and buildings research (e.g., Janda, 2011) and one that we propose to call the 'building versus behaviour' approach. Instead this paper seeks to add weight to the view that energy use in buildings, like any other practice, is inherently 'socio-technical' meaning that it results from such a complex interplay of 'social' and 'technical' where one is no longer discernible from the other (see Law and Bijker, 1992; Aune and al., 2009). For example, the use of a programmable thermostat is simultaneously influenced by the user's desires (itself shaped by social and technical norms of comfort, see Shove 2003) and by 'affordances' of the material design of the thermostat (Norman, 1988) which also incorporates assumptions about the user (Akrich, 1992). This mixed nature of sociotechnical practices is overlooked by those who resort to the 'building versus behaviour' approach. We argue that it is necessary to study how energy performance is achieved 'in the making' without distinguishing a priori between social and technical explanatory factors.

The growing body of literature on intermediaries and intermediation provides a productive alternative to the 'building versus behaviour' debate and puts the sociotechnical approach to work. The emphasis on intermediaries and intermediation recognises that building energy use is a sociotechnical achievement that involves negotiation between a chain of actors who achieve energy performance in particular ways over extended time periods. We define intermediaries as those individuals, organisations and technical devices that facilitate, interpret, and negotiate the intentions of the design team during the entire building process, from design activities to construction, use and beyond. This intermediation work is often overlooked, resulting in a dichotomy between the building and occupants.

In the 'building versus behaviour' approach, the reason behind the energy performance gap lies in the contradictory aims of energy efficiency and comfort -- comfort being a socially-motivated trend toward increased energy consumption and energy efficiency being a technically-driven quest to reduce energy consumption. While strategies of energy efficiency and comfort can conflict one with the other - there is usually more energy efficiency when there is less comfort and more comfort when there is less energy efficiency – it is not always the outcome. Living in an apartment that is over-heated in winter because there is no individual regulation of the collective boiler is considered quite uncomfortable by many who have had such an experience. In other words, the relationship between energy efficiency and comfort is not a zero-sum game. Various arrangements between energy efficiency and comfort can be found in the built environment were both aims are successfully attained. In addition, it is important to note that comfort and energy efficiency do not represent respectively the social and the technical side of the matter. Comfort is not a pure 'preference' or 'habit' of occupants but also a building parameter that is defined, regulated, calculated, and designed by building professionals and is done so differently depending on historical periods and the habits of professionals (Shove, 2003; Chappells and Shove, 2005). Similarly energy efficiency strategies are not strictly technical endeavours but do take uses and the user into account even in a minimal fashion (otherwise maximizing energy efficiency would mean simply not installing a heating system). Energy efficiency and comfort are socio-technical undertakings and we argue that they are best achieved when 'intermediated' that is negotiated one with the other rather than determined in the closed circle of building experts. Indeed when a building is designed, it embodies a certain arrangement of energy efficiency and comfort that is physically embedded in the building's infrastructure. This physical embedding is part of what Shove and her colleagues call the 'hidden politics of comfort' (Shove et al., 2008). We argue that when energy efficiency and comfort are intermediated and negotiated, compromises can be made in such a way that the energy performance gap is reduced or even closed down (or perhaps improved i.e. the actual energy performance might be better than the modelled one).

In this paper, we aim at tackling the issue of the gap between a building's projected and actual energy performance with an intermediation approach to the problem. Our analysis is centred on the pre-arrangement of energy efficiency and comfort and the way it is negotiated once the building is inhabited. We focus on the occupation stage of the building life because it is usually not considered as a stage in the design and building process but as a stage that comes after, when the building is done. Much attention is paid to the optimisation of energy performance at the design stage but we argue that the occupation stage reveals interesting tensions between the energy efficiency and comfort. Rohracher (2003, p. 184) notes that 'If we approach the process of early diffusion of a technology from the user perspective, we find that users are far more actively involved than generally expected.' Users appropriate and domesticate technologies rather than simply being passive receivers of design strategies (Sørensen, 2005). We argue that no perfect arrangement of energy efficiency and comfort can be delivered as ready-made with the building and that intermediation efforts are key to reducing the energy performance gap. In any building, there is a diversity of users with different expectations, tastes, needs and skills who would want a different arrangement of energy efficiency and comfort. Also the lives and needs of inhabitants vary during their lifetime (they have children, become ill or retire for instance) and the profile of occupants change during the building's lifetime. In pointing to the use stage and to the variety of intermediation processes and possibilities of remediation, we demonstrate that the dual aims of energy efficiency and comfort cannot be permanently fixed. Thus, there is a need for designing flexibility rather than rigidity in a building's energy efficiency and comfort parameters.

We begin with a review of the literature on intermediaries and how it relates to energy performance in buildings. We then apply these ideas to findings from fieldwork on a newly built, low-energy residential building for older people in Grenoble, France. As is often the case, the introduction of inhabitants to a new building involves failures, complaints, tinkering, and repairs. Our focus on this 'domestication' or teething phase of the new building provides an opportunity to study the period of mutual adjustment of the building and its inhabitants. We focus specifically on intermediary activities that bring together humans (occupants, the building manager, maintenance staff, contractors) and non-humans (technical devices, infrastructure, etc.) into particular configurations and reveal how they achieve or do not achieve the dual aims of comfort and energy efficiency. By highlighting the multiple ways that comfort is negotiated in the pursuit of lower energy consumption, we conclude that buildings are provisional achievements that are constantly being intermediated. This suggests that policymakers should consider how energy efficient building designs and technologies are not only conceived and implemented in the design and construction stages but also how they are interpreted by building occupants in the long term.

Intermediaries and Building Performance

The notion of 'intermediaries' is increasingly being used to describe those individuals or organisations that create a bridge between producers and end-users (Rohracher, 2003; Medd and Marvin, 2008; Stewart and Hyysalo, 2008; Beveridge and Guy, 2009; Moss, 2009; Moss et al, 2009; Guy et al, 2010; Heiskanen and Lovio, 2010; Strebel, 2011; Janda and Parag, 2013). In simple terms, intermediaries 'work in-between, make connections, and enable a relationship between different persons or things' (Moss et al, 2010, p. 5). From a relational perspective, an intermediary is 'an entity that stands at a place in the network between two other actors and serves to translate between the actors in such a way that their interaction can be more effectively co-ordinated, controlled, or otherwise articulated' (Kaghan and Bowker, 2001, p. 258). In effect, intermediaries redefine the social organisation of technological systems; they are bridge builders who form and fix relationships between actors and processes of innovation (Beveridge and Guy, 2009).

Moss and colleagues (2009) argue that there is no shared understanding of what constitutes an intermediary and Stewart and Hyysalo (2008, p. 319) suggest that it is more helpful to think of an 'ecology of intermediaries in and between supply and use'. Intermediaries are part of the production-consumption nexus while also mediating between scales, technologies and social contexts, and different meanings and sets of interests (Moss and Medd, 2005; Beveridge and Guy, 2009). With respect to the built environment, intermediaries include those individuals and organisations that are involved in the design and construction process, ranging from planners and design team members to installers, regulators, and building managers (Rohracher, 2003; Strebel, 2011; Janda and Parag, 2013). In their work on low-carbon and low-energy houses, Janda and Parag (2013, p. 42) focus on the related concept of 'middle agents', those 'building professionals and practitioners who neither produce nor consume energy, but through their work they shape and can alter the ways in which it is used.' With both middle agents and intermediaries, the significance is in their ability to translate, interpret, and facilitate innovation processes related to building energy performance. They shape the energy practices that can increase or reduce carbon emissions.

The work of intermediaries is often characterised as 'hidden' or 'invisible' (Moss, 2009; Moss et al., 2009; Strebel, 2011). This is often because they do not fit in the standard categories of provider, user, or regulator. As Moss (2009: 1484) argues, 'Just as the governance concept leads us to consider less familiar processes and structures of collective action, so the notion of intermediaries encourages us to look beyond the provider-regulator-user triad when investigating the governance of infrastructure systems in transition.' In effect, intermediaries blur the boundaries of clear-cut responsibility for the provision of building services. An example of the invisible work of intermediaries is illustrated in Strebel's study of the activities of maintenance staff on tower blocks in Glasgow. These staff perform mundane but critical everyday tasks of inspecting buildings to identify leaks, blocked corridors, broken doors and windows, faulty lifts and other conditions that hinder the operation of the building as intended. Strebel (2011, p. 244) argues that these individuals perform 'invisible maintenance work that keeps a piece of infrastructure, such as a high-rise, together, and allows it to operate effectively.' In effect, intermediaries bring buildings to life and ensure that they function properly over time.

This suggests that more important than defining who intermediaries *are* is to understand what they actually *do*. Stewart and Hyysalo (2008, pp. 296-7) argue that intermediaries 'create spaces and opportunities for appropriation and generation of emerging technical or cultural products by others who might be described as developers and users.' Intermediaries are involved in transformative activities of networking, aligning, and translating sociotechnical assemblages (Moss et al, 2009). Moss (2009, p. 1481) argues that 'Whether facilitating dialogue, providing guidance, bridging gaps, advocating reform, or pioneering novel forms of interaction, their arenas of action are defined by their `in-betweenness'.' In effect, intermediaries enact particular sociotechnical alignments in buildings.

To focus on what intermediaries do rather than who they are, we will use the phrase 'intermediation process' rather than 'intermediaries'. Intermediation processes can involve both social actors and technical devices. Technical devices such as thermostats and other control interfaces play a crucial role in the intermediation processes between a technical system and its users. Akrich (1992, p.218) reveals the way technical objects such as electricity meters can intervene as 'referee and manager of the relationship between supplier and consumer, regulating behaviours and policing irregularities in consumption patterns.' Developing this work, Marvin and Guy reveal how new smart meters installed as part of a liberalised energy sector can reconfigure the boundaries between producers and users which can open up new forms of engagement but can equally distance users from control over the management of their energy use (Marvin and Guy 1997, p. 131). In this study, we are particularly interested in how processes of intermediation are deployed to negotiate the twin goals of energy efficiency and comfort. It involves processes of facilitating and brokering to change attitudes, build trust, network stakeholders, and bridge discourses (Moss et al, 2009). It also creates an arena of learning between providers and users of buildings (Rohracher and Ornetzeder, 2002; Rohracher 2003). This negotiation of energy efficiency and comfort has important implications on building performance and on long-term goals of reducing the energy consumption in buildings.

Methodology

Our case study involves a newly design and constructed residential building for older people in Grenoble, France that was built to the French standard 'Bâtiment Basse Consommation' (Low Energy Building). The standard requires primary energy consumption of less than 50 kWh/m2/year with some variations to account for climatic differences (in Grenoble where winter are colder, the standard is raised to 60 kWh/m2/year). The case study building was designed and constructed when the standard was voluntary and included tax incentives. It is important to note here that although this building represented a novel technical configuration with a learning and appropriation need on the part of the professionals involved, the individual technologies are increasingly being adopted for new building designs. The construction phase ended in late 2011 and the first inhabitants began to occupy the building in December. One year later, in January 2013, the voluntary energy efficiency standard became compulsory for all new buildings. Thus, the building serves as an early adopter for the latest energy performance standard in France.

The case study building is a private development and includes 90 apartments (mostly studio and one-bedroom units) spread over three stories built on top of a two-storey 'base' comprising offices, shops and a cinema. About a third of the occupants are owners and two-thirds are renters. The building includes an array of technologies to reduce energy consumption including superinsulation, a district heating system, mechanical ventilation with heat recovery, and green roofs. Most of the flats have balconies that are designed to avoid thermal bridging.

We conducted fieldwork activities between February and July of 2012, the six-month period after the building was completed and the owner-occupiers and renters were moving in. This was a pivotal moment in the building's life when the first inhabitants domesticated it.
A unique characteristic of this building is that it was designed specifically as a residence for older people and includes a building manager (*régisseur*) with an office and residence on-site. The building manager oversees maintenance and upkeep of the communal areas (either himself or through service providers) and manages the process of renting out apartments to new tenants. He is also charged with organizing social activities for the occupants including games, workshops, and exercise sessions in the large (90 m^2) communal room next to his office. The communal room is unique to this building and is uncommon in France. As one might expect, the building manager played a crucial intermediary role during the adjustment period and in the everyday life of the occupants.

Fieldwork activities included semi-structured interviews with 14 occupants and 7 building professionals. Seven occupants and two building professionals were interviewed twice to compare and contrast seasonal differences, for a total of 30 interviews. The occupants interviewed were representative of the building occupants as a whole, with a mix of owner-occupants and renters ranging in age from 60 to over 85, with most over the age of 70. Interviewed occupants were diverse in their technical skills and physical abilities, with some in the process of losing their sight or showing signs of dementia while others were no signs of physical and mental disabilities due to older age. Overall, we did not find that age the age of the occupants was a determining factor in the fieldwork findings. The building professionals included all of the key technical and design team members including the scheme developer, building developer, architect, builder, consultancies, district heating company, rental agency, and building manager. A key building professional who was not interviewed was the mechanical contractor who was experiencing problems with the ventilation system and was unavailable.

Interviews were conducted in February and July to coincide with the coldest and warmest periods in Grenoble. In February, the temperature hovered around 0°C during the day and fell to -10°C at night. In July, typical daytime temperatures were between 26 and 30°C (although one day the temperature exceeded 35°C) and night-time temperatures were around 20°C. These two periods allowed us to study the indoor environmental conditions at times when there were strong tensions between achieving energy efficiency and comfort. And because this was the teething period of the building, it meant that the inhabitants were experiencing these extreme temperature conditions for the first time. This allowed us to witness first-hand the domestication of the building's comfort systems and the sometimes conflicting agenda of reducing energy consumption.

Fieldwork findings

To examine the domestication of the case study building, our fieldwork focused on the frictions between the occupants and the physical structure and technical devices of the building. These frictions can be understood as open conflicts, tensions and maladjustments. There were essentially three thermal comfort building strategies that caused these frictions: heating, ventilation and hot water. We identified ten instances of frictions between energy efficiency and comfort, with some frictions affecting most or all of the occupants while others affected only a few. We were particularly interested in the ways that these frictions were addressed through intermediation and identified three general categories:

1. Frictions where there had been an intermediation process that resulted in a satisfactory adjustment of the building systems to the occupants;
2. Frictions where an intermediation process was underway but the outcome was still being negotiated; and
3. Frictions where there was no intermediation or the process failed and the discrepancy between the energy efficient technology and the occupant's comfort remained.

In the following sections, we review each of these categories in turn. Due to space limitations, we only describe four instances of frictions. The aim of these sections is to demonstrate the multiple ways that intermediation is performed.

Harmonising technological systems with occupant activities

<u>The building manager as intermediary</u>

At the start of our fieldwork activities, it quickly became apparent that the building manager was the most influential intermediary between the occupants and the building professionals who designed and maintained the building. This was confirmed time and again during the first set of interviews in February when the inhabitants recounted how they contacted the building manager to fix a multitude of small and large problems, including the need for surnames on mailboxes, the need for signage on each floor and in the staircases, doors that did not open and close smoothly, lost residents who could not find their apartments, and so on. Many occupants had the building manager's personal mobile phone number so they could contact him at all hours. The manager described his role as an intermediary between the various building professionals and the occupants. By default, he filled this role in the absence of other obvious intermediaries and in response to numerous requests by the occupants.

During the second wave of interviews in July, many of the teething problems identified in February had been resolved and the residents had domesticated the novel technical systems of the new building. This meant that the building manager's role, while still important, was less salient. He was in the process of transitioning from being a technical mediator to a social mediator. For instance, his main activities in July involved the coordination of a daily card club, a weekly memory training workshop, and on one evening, a 'crêpes party'. However, a number of frictions that arose in February remained unresolved. These frictions frequently involved the building systems that provide comfort services through heating, hot water, and ventilation.

<u>Interpreting the programmable thermostat</u>
One prominent example of how the building manager served as an intermediary involved the programming of the thermostat to provide heat. Every apartment is equipped with a sophisticated thermostat that can be programmed using a device that resembles a complex remote control (see **Fig. 1**). The interviews with the occupants revealed that the design of the thermostat was not intuitive.

Fig. 1. Programmable thermostat.

By default, the thermostat was programmed to a 19°C temperature during the day and then to approximately 17°C at 10pm. During the winter when the residents moved into their new apartments, the thermostat caused considerable discontent as they did not understand how to programme it and thus, could not adjust it by themselves. As an owner-occupier noted during this period:

> You see these things, they're the devices for regulating the heating. You need to be a rocket scientist to understand something like that. […] From 10 o'clock onwards, we had no more heating. It shuts down at 10pm. At the moment, at 10 in the evening, it's pretty cold. We watch TV, the films end at 10:30. If it at least shut down at 10:45, it would give us time to wash and go to bed. If we want to read in bed, it's freezing.

The default settings of the thermostat were not aligned with the preferences of the occupants and thus, a conflict arose that required resolution. The building manager played a central role in assisting the occupants in programming their thermostats. Upon request, he programmed their thermostat with setpoints for the daytime and night-time temperatures. As such, the residents used the building manager to translate their comfort desires to the thermostat without understanding how to programme it themselves. This was a simple but necessary intermediation process to domesticate the heating system. An owner-occupier provides a typical response about the function of the thermostat:

> Interviewer: Do you know how to do the settings yourself?
> Respondent: I've no idea, I've never touched it.
> Interviewer: Who did the settings for you?
> Respondent: [The building manager and mechanical contractor] came to do them. I told them, 'I'd like them to set it at 22°C', but take a look, what are we supposed to touch? I have absolutely no idea.

Other occupants had a different attitude towards the thermostats. They learned how to programme their thermostats with assistance from the building manager. While they did not have a comprehensive understanding of the device, they had sufficient knowledge of the basic functions so they could maintain the desired comfort conditions in their apartments. Other occupants received help from family members and two of the youngest respondents had recently retired and were more technically skilled than the others and were able to interpret the instructions in the thermostat user guide.

These findings illustrate three different intermediation processes being facilitated by the building manager, a family member, and the user guide. The selected intermediation process was dependent on the occupant's position and skills. As Moss and colleagues (2009, p. 28) note, 'Critical to the impact of intermediaries on innovation and governance processes is their ability to learn and to promote learning amongst others.' In this case, there was the need for learning to align the heating system with the preferences of the occupants rather than the standardized 'imagined user' represented by the default thermostat settings. These adjustments influenced the balance between energy efficiency and comfort. While the optimal energy operating conditions reflected in the energy modelling were altered, the residents continued to adopt a programme where the temperature was reduced at night. And in general, the dual aims of energy efficiency and comfort were reconciled through intermediation.

<u>Adjusting the ventilation system</u>

The building manager did not receive training on the design intentions and operating procedures for the building's low-energy features. Instead, he learned about these features on the job, specifically the comfort systems that provide hot and cold air as well as hot water. This 'on-the-job' training was informal and occurred when he met the technical actors who regularly came through his office (to get keys to various parts of the premises, for example) and through his own personal experience as an occupant. The building manager notes:

> It wasn't easy for us [manager and rental agency agent] either, to get information. When we arrived, no one told us anything, we had to drag it out of them [the technicians]….And there were quite a few of them, because there were several people involved….The contractor told me he'd give me a guided technical visit of the building, but I'm still waiting.

One of the energy efficiency strategies that proved highly problematic was the mechanical ventilation with heat recovery (MVHR) system. MVHR is a relatively novel ventilation strategy in France. The system includes supply and return vents to provide continuous flow of conditioned air. It also recovers heat from the exhausted ventilation flow to pre-heat the incoming airflows to reduce heat demand. And the heat recovery system works in reverse in the summer to preserve the coldness of indoor air. As in most installations, the MVHR system in the case study building was designed to be fully automatic with no opportunity for occupants to turn it off or adjust the airflow. Furthermore, the system provides no feedback about its operation. Instead, the MVHR system is designed to function as an automated ventilation system that operates continuously in the background (Macintosh and Steemers, 2005). Occupants can hear the system functioning and feel the draught produced but they have no control over it.

Fig 2. MVHR vent in an apartment

Inside each apartment, the MVHR system includes small air vents for supply and return air flows (Fig. 2). The occupants frequently complained to the building manager about the MVHR system during the winter months due to the continuous draught that created uncomfortable conditions. The building manager had his own personal experience with the system as an occupant in the building and observed the mechanical contractor inverting the vent to direct upwards towards the ceiling rather downwards towards the occupants. The building manager copied this strategy in several apartments where occupants complained about draughts. An owner-occupier described the process as follows:

> Respondent: That room, when we went in, when we went inside, we felt the cold air and we told the manager about it. He said: 'But it's upside down!' So he took it off and turned it around.
>
> Interviewer: What do you mean?
>
> Respondent: Well look, you see, the blades are like that. They used to be in the opposite direction. So the cold air arrived like that. It was the same in his apartment. He removed it, turned it around and put it back.

Despite the lack of user configuration options of the MVHR system, the building manager was able to intermediate through a simple physical alteration. As was the case with the thermostat programmer, a new alignment of energy efficiency and comfort was achieved. It is not clear if this revised configuration of the ventilation system has compromised the energy performance of the building as a whole but it did result in acceptance of the system by the occupants. This represents another case of compromise between energy efficiency and comfort aims that was deemed a success by all involved. Through intermediation, the intentions of the designers and the preferences of the residents were aligned. However, other frictions between the occupants of this building and the heating and ventilation systems had less satisfactory outcomes.

Politicizing the energy efficiency – comfort (dis)junction

Comfort and energy efficiency standards

During our first visit to the building, the building manager told us that the new occupants had already made numerous complaints to him about the heating system. The developer also received multiple complaints because they were responsible for resolving problems during the first few months of operation. 'I'm inundated with recorded-delivery letters', reported one of the developer's representatives one month after the building had been open. During the first month of operation, a series of incidents with the heating system occurred, with many apartments having little or no heating for several days. Some of these issues were due to improper commissioning of the building and were resolved relatively quickly. However, complaints about heating continued after the installation issues were addressed.

The issue of maximum temperature in each apartment was significant for many occupants. They complained that they could not heat their apartments to a comfortable level. As it turned out, the centralised heating system was set by the mechanical contractor to operate at a maximum temperature of 19°C. The developer turned on the heating in unoccupied apartments (more than two-thirds of the apartments at the time) and sent a contractor to verify the central temperature setpoint in the boiler room where the district heating system connects to the building's heating network. At the same time, he issued a reminder to the occupants of the Low-Energy Building label and the 19°C heating standard of the national building code. In practice, this upper limit is never respected except in social housing. However, energy performance estimates are calculated on the assumption of the 19°C heating standard.[1]

Increasing the central temperature setpoint beyond 19°C had both political and technical ramifications. It was political because the decision to turn up the heating would have repercussions

[1] On the notion of comfort and standardised temperatures, see Shove, 2003; Shove et al., 2014.

on the bills paid by the owners. Heating is paid collectively while water and electricity are metered individually while electricity for ventilating the apartments is paid in common. Such a decision would therefore need to be made collectively by the owners' association rather than the developer. And the maximum setpoint of 19°C was technical because the developer erroneously believed that the system was not designed to operate above this temperature. There was an assumption that 19°C was an operational limit rather than a regulatory standard.

For the occupants, the developer's argument about the 19°C heating standard was simply unacceptable. Not only did they deem it to be inadequate from a physiological point of view (i.e., they were cold) but they felt that the maximum temperature limit of the centralised system infringed upon their individual rights to decide on the appropriate temperature in their own private space. Because they were 'at home', they felt that they should have the ultimate decision about what temperature was adequate to maintain comfort. An owner-occupier noted during a winter interview:

> [The technician] told me that it was working and I said: 'No, it isn't working, it's 19°C and that's impossible'. He said: 'Yes, but you need to wait until the neighbours move in, because there are no neighbours below you and next door, that's why you're at 19°C'. I said: 'Hang on, no, I don't need to wait to have neighbours for it to be 21°C in my own home, because no way, that's just not possible'. I thought it was quite scandalous.

After the central heating setpoint was raised by the mechanical contractor, the occupants were able to maintain temperatures of 21-22°C in their apartments and were satisfied with the new configuration. The intermediation process was extended in this case because it involved occupant complaints that gradually percolated up to the building manager, the developer, the contractor, and the owner's association. The emphasis on individual rights meant that comfort trumped energy efficiency in this case and the modelled calculations of energy savings were compromised.

It should be noted however that had the intermediation process lasted longer and involved a wider search for a new arrangement of energy efficiency and comfort, another perhaps better compromise might have been found. Temperature regulation in the building is not only achieved by the central setting of the thermostat. To regulate the temperature, the heating network needs a relief valve that has been placed on the bathroom radiator. The valve allows a small amount of flow thus avoiding that the heating circuit pump breaks down in case all radiators are turned off at the same time. This resulted in very warm bathrooms that contrasted with the usually moderate warmth of the rest of the apartment. To avoid overheating, the valve has been put in a room where comfort is supposedly not affected, the engineer explained to us. Here we see how a certain arrangement of energy efficiency and comfort is embedded in the technical design of the heating system in the apartments. The choice to put the relief valve on the bathroom radiator is not a 'pure technical choice'. Instead, the engineer made assumptions about how the technical system would function and how it would affect occupant lifestyles. This is a non-intermediated design choice as the engineer alone made the decision, resulting in a specific arrangement of energy efficiency and comfort. But what would have happened if the valve had been part of the conversation about the temperature provided by the heating system of the building? Perhaps valves could have been relocated in living rooms and perhaps a different compromise would have been reached in the harmonisation of energy efficiency and comfort.

<u>Ventilation and overheating</u>

In the summer, new problems with the MVHR system emerged that were more serious than the draught issues experienced in the winter. Upon arriving in the building to carry out interviews with the occupants at the beginning of July, we were met in the communal room by the building manager. He was perched on a chair, holding a thermometer to measure the temperature of the air coming out of a vent (30°C, the same as in the room). He was struggling to work in his adjoining windowless office where the temperature was even higher. He had received numerous complaints from occupants who were suffering from high temperatures in their apartments. They reported that the MVHR system was blowing hot air into their apartments, increasing the temperature rather than cooling the space as expected.

One of the occupants became so incensed with the MVHR system that he contacted a local newspaper. This resulted in several articles claiming that this new energy-efficient residence for the elderly was putting the occupants' lives in danger by magnifying the effects of the July heat wave. The innovative building was not only uncomfortable but had serious health implications. When we visited the occupant who had contacted the local newspaper, we noted that his apartment was 30°C and had recently been outfitted by the developer with temporary sensors to record temperatures at various points in the apartment as well as outside. Two weeks later, the building manager sent us a copy of the results of the temperature readings along with a report written by the mechanical contractor. Interestingly from a (dis)intermediation point of view, this report had not been initially sent to the occupant whose apartment had been monitored. The report concluded that there were no anomalies in the MVHR system, the temperature measurements confirmed that the system was functioning as designed. It was not intended to provide cool air but to ventilate the room without the need to open windows. The temperature of the air supplied by the MVHR system was in fact 1 or 2°C below the outside air temperature, the report said. However, this 'cooled' air was still too hot to maintain comfortable conditions and the sensation of warm air emanating from the vents was unacceptable to the occupants.

To appease the complaints, and in accordance with the energy consultant's advice, the mechanical contractor disconnected the heat exchanger function to guarantee that the outgoing air did not heat the incoming air. However, it was impossible to shut down the MVHR system completely because it is needed to remove humidity and maintain air quality at all times. In effect, the system did not allow for modification that would create acceptable conditions of comfort.

The ways that the alarm-sounding occupant configured the comfort conditions in his apartment also played a role in the story. During the day he left the bay window and shutters in his living room partially open so he could smoke on the terrace. And at night, he closed his windows to prevent a neighbour's cats from coming into the apartment (another neighbour had initiated a petition against this neighbour and her cats). If he had managed his apartment in exactly the opposite way, with the windows and shutters closed during the day and open at night, he could potentially have mitigated some of his overheating issues. But this would have entailed more than behavioural changes to align the occupant's desire to smoke with the energy efficiency aims of the building designers. Novel devices would be needed to allow for smoking without filling the apartment with outdoor warm air and to prevent the cat from visiting the apartment while keeping the windows open. Since such devices were not available, the discontent persisted and the alarm-sounding occupant continued his mobilisation efforts until, at the end of the summer, local councillors got involved in the matter.

Here we have an intermediation process going on even longer and more complex than the previous one about the 19°C central setting. Intermediation here involved not only the building manager and the mechanical contractor but also the local newspaper and local councillors. The situation was not resolved and quite the contrary, it erupted into a heated debate about the ability for low-energy buildings to provide adequate comfort conditions for occupants. In this case, energy efficiency and comfort appeared to be at odds as two separate and irreconcilable issues. The MVHR system as designed was understood to be inappropriate for the climate and these occupants. The implications on the health of older people, who are perceived to be frail and less able to cope with extreme temperatures, added fuel to the flame. A few months after the end of the fieldwork, the situation was still under discussion. In other words, the intermediation process was still going on and it was unclear if a resolution could be identified and if so, what it might be.

In this example, the building manager acted as a broker between the occupants and the mechanical contractor. He was not qualified to diagnose the problem with the MVHR system or to enact a solution but he served as a liaison that supported dialogue and learning between the various parties (Stewart and Hyysalo, 2008). The energy consultant also proved to be an important intermediary, providing expertise and guidance to disconnect the MVHR flow exchanger at night to directly introduce outside air.

Unsuccessful intermediation processes

While protests over the 19°C temperature standard and the difficulties in operating the thermostat were resolved, we also observed several other problems related to the heating system without any available remediation/intermediation solution. These were localised and dependent on specific individuals and apartment layouts. With the system's restriction to 19°C being resolved, occupants started querying other aspects of the heating system and its ability to provide the desired comfort conditions. For example, an owner-occupier questioned the number and size of the radiators provided:

> We'd have needed at least two [radiators] here. They really made a mistake with that. […] Because this lady next door [the neighbour], she doesn't have a big place, she has a studio, she has the same [radiator]. I spotted that immediately and I thought: 'they've screwed up', but there you go…

In this case, a single radiator is indeed installed for a relatively large lounge-kitchen, whereas in the smaller studio apartments, there is one radiator in the lounge and another in the corner sleeping area that connects to the lounge. Visiting these apartments and listening to the arguments of the occupants, it was difficult to counter their arguments about the radiators being improperly sized. In another case, the thermostat was installed next to the kitchen and therefore to the oven. This caused problems for regulating temperature while cooking as the thermostat detected warmth (from the oven) and turned off the radiators, resulting in the rest of the apartment getting too cold. In both cases, the occupants were questioning the design decisions with respect to the comfort systems.

In some cases, the building manager was able to intervene. For instance, he reassured occupants that their heating system was functioning even if the radiator was cold. And he tried to convince people of swapping their sensory perception for a measurement given by the thermostat. In other cases, the building manager could offer no solutions and this resulted in feelings of resignation by the occupants. The following interview excerpt is of a woman who directed us to her thermostat ('that's 20°C' she said but it seemed to us that it was a bit below 20°C). She would have preferred 21°C or 22°C like her neighbour who has a much smaller but warmer apartment because with this apparent 20°C, she feels the cold in her apartment.

> I'm a bit disappointed, yes. […] I complain and I'm told that this is it, it must be accepted that way. […] One gets stronger, that's all. […] Tiling, this is not warm. If this had been a wood floor. You know, they sell you that [the apartment], they don't explain it all. But if I had known, I would have installed wood flooring, I'd be less cold. Now I don't want to spend more, I won't install it for the moment."

There was no escalation of the problem to other building professionals or local councillors; this was simply understood as an inherent feature of the building that could not be changed.

In these cases where previous intermediation process proved unsuccessful and there is no longer any intermediation process underway, energy efficiency and comfort stand in opposition. The adjustment is unsatisfactory, either from a comfort or energy efficiency point of view, and one takes precedent over the other. There is a problem that remains a problem and which is then labelled either as structural (built-in) or behavioural and cannot be remedied.

A typology of intermediation processes and their outcomes

Based on our empirical findings, we developed a typology of intermediation processes and their outcomes (see *Table 1*). The table summarises four specific outcomes of intermediation. However, it should be noted that this is intended as a dynamic rather than static typology where comfort and energy efficiency are continually being negotiated rather than delivered as ready-made with the building (even if this may be the wish of buildings designers).

The functionalist view where the intention of designers and the desires of the occupants are aligned is represented by the bottom right quadrant. Here, no intermediation is required because the there is no friction between energy efficiency and comfort. Our fieldwork findings show that comfort and energy efficiency do not adjust spontaneously. This functionalist view is an ideal situation that we did not encounter in the real world (bottom left quadrant).

The other three quadrants of the table represent three different conditions that we observed in our fieldwork, providing different perspectives on the alignment of comfort and energy efficiency. The top left quadrant represents a resolution of the conflict between the occupants and the technical system. In our fieldwork, the building manager played a critical role in identifying and realising a compromise between the design strategy and occupant desires in the thermostat programme and the configuration of the MVHR vents. The building manager was able to align the needs of the occupants without compromising the energy performance. This was straightforward with the thermostat and only slightly more difficult with the MVHR vents. Although fully automated, the MVHR system had a small area of flexibility that was exploited by the building manager by flipping the vents.

In other cases, the inflexibility of the system prevented the alignment of energy efficiency and comfort aims. This is represented in the bottom right quadrant of Table 1. The MVHR system is designed to operate in all seasons and this causes problems in the summer months. As a result, some occupants exercise alternative means to maintain comfort (e.g., clogging the MVHR vents in their apartments)

Table 1. A Typology of Intermediation of Energy Efficiency and Comfort in a Low Energy Building

	The aims of energy efficiency and comfort are	
	reconciled	*opposed*
Intermediation	**Negotiated Comfort** Harmonisation of building aims is achieved	**Politicisation** A transitory stage when a conflict is unresolved
No Intermediation	***Functionalism*** Design intentions and occupant preferences do not conflict [Not found in fieldwork]	**Building vs. Behaviour Dualism** The technical and the social are incommensurable

that has a negative influence on energy efficiency, airflow, humidity, and air quality. This represents a breakdown in intermediation and a divergence of comfort and energy efficiency as the occupants actively resist the designer's energy efficiency agenda. The situation results in the dualist perspective of 'buildings versus behaviour'.

The upper right quadrant represents the fourth condition of 'politicization' where comfort and energy efficiency are in a transitional state between negotiated comfort and the building vs. behaviour dualism. The outcome of politicization might result in the harmonisation or compromise between energy efficiency and comfort or it might result in the dualist stance of building vs. behaviour. The central setting of the temperature at 19°C led to a collective mobilization of inhabitants and written protests to various actors of the building chain. These political activities did not go further as the problem was solved. The MVHR system that contributed to the overheating of some apartments in summer led to petitions, articles, visits by elected officials, and so on. In this case, comfort and energy efficiency are not harmonised but intermediation processes are underway. The role of the intermediary here is to attempt to broker a solution to the conflicts but it is unclear if the solution will result in negotiated comfort or a dualistic opposition of building (energy efficiency) vs. behaviour (comfort).

Conclusions

In this study, we explored how the dual aims of comfort and energy efficiency were negotiated in a newly built low-energy building for older people in Grenoble, France to highlight the intermediation processes at play. We argue that energy performance is achieved rather than prescribed in buildings and that intermediation processes are critical to harmonising the desires of occupants and the designed strategies for energy performance. We found various examples of intermediation involving the building manager as well as the other building actors and devices. As an example, we've seen that the skills of the building manager are as important as the capabilities of the thermostat to implement individualized compromises between energy efficiency and comfort. Another example is the flexibility provided by the MVHR although minimal and its exploitation by the building manager who flipped the vent to suppress the draught; these are inseparable elements of an intermediation process during which energy efficiency and comfort were accommodated.

Intermediation can lead to the harmonisation of energy efficiency and comfort, to an unstable but conflicting state between these two conditions or to a stabilized arrangement where one has precedence over the other so that it seems that dualist views of building versus behaviour are accurate. The persistent discontent over the MVHR in summer is such an example of conflict between the aims of energy efficiency and comfort which is however still under an intermediation process. The changed setting of the general thermostat of the building to 21°C on the other hand lends itself to an interpretation in terms of building versus behaviour (a social norm of comfort having trumped technical requirements of energy efficiency). However this was not the obligatory outcome as other parameters of the technical system might have been changed to reconcile energy efficiency and comfort. This would have required an intermediation process that did not take place.

The relevance of the concept of intermediation reveals that energy performance is not fixed by the design team but is continuously negotiated. The alignment of the technological system and the user is a process that continuously unfolds in multiple arrangements with different stakeholders and varying interests. Instead of assuming the static, techno-material quality of a building, this concept invites us to consider energy performance as a more fluid socio-technical process to be performed throughout the life of the building and its inhabitants. As we have argued elsewhere in relation to debates about sustainable architecture more generally, a focus on the fluidity of design foregrounds an analysis that is sensitive to the interpretive flexibility and plasticity of technology and which explores the choices and interventions of designers and occupiers alike as flexible, situated, pragmatic and participative (Guy, 2009, 2012). Practices of intermediation are central to this process and key to resolving the various 'frictions' that emerge from design through to occupation as we have illustrated in our case study. As such the value of intermediaries is apparent at all points and arguably it is at the point that intermediation fails or is removed from the sociotechnical process that frictions become endemic and 'locked-in', which can only serve to enlarge the 'energy performance gap'.

From a policy perspective, our research suggests the need to design flexible technical devices that allow for intermediation and encourage users to be active and have the ability to make choices as well as support dialogue between technical experts and occupiers. This suggests that policies and programmes for reducing energy consumption in buildings need to provide spaces of negotiation for intermediaries at all stages of design and occupation to allow and encourage the negotiation of occupants' desires and preferences. in this way, such flexible devices would give users more agency in the pursuit of both energy efficiency and comfort.

Overall, the findings suggest that there is a particular need for policymakers and designers to pay more attention to the process of managing energy in buildings long after the building itself is completed and occupied. As Heiskanen and colleagues (2013, p. 242) argue, 'There is indeed a need to bring the energy end-users' and energy experts' worlds closer to each other.' The notion of intermediation provides a way for greater understanding and learning between the different stakeholders who are involved in energy consumption in buildings.

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References

Akrich, M. 1992. The de-scription of technical objects, in: Bijker, W.E., Law, J. (Eds.), Shaping technology / building society. The MIT Press, Cambridge, Mass, pp. 205-224.
Aune, M., Berker, T., Bye, R. 2009. The missing link which was already there: Building operators and energy management in non-residential buildings. Facilities 27 (1-2), 44-55.
Beveridge, R., Guy, S. 2009. Governing through translations: intermediaries and the mediation of the EU's Urban Waste Water Directive. Journal of Environmental Policy and Planning 11 (2), 69–85.
Chappells, H., Shove, E. 2005. Debating the future of comfort: environmental sustainability, energy consumption and the indoor environment. Building Research & Information. 33 (1), 32–40.
Gill, Z.M., Tierney, M.J., Pegg, I.M., Allan, N. 2010. Low-energy dwellings: the contribution of behaviours to actual performance. Building Research & Information. 38 (5), 491-508.
Guy, S. 2006. Designing urban knowledge: competing perspectives on energy and buildings. Environment and Planning C. 24(5), 645–659.
Guy, S., 2009. Fluid architectures: Ecologies of hybrid urbanism, in: Wilbert,C. White, D.F. (Eds.), Technonatures: environments, technologies, spaces and places in the twenty-first century, Wilfred Laurier University Press, Waterloo, pp. 215-237.
Guy, S., 2012. Whither 'early' architectures: constructing sustainability, in: Crysler, G., Cairns, S., Heynen, H. (Eds.), The Sage handbook of architectural theory. Sage, London, pp. 555–572.
Guy, S., Shove, E. 2000. A Sociology of Energy, Buildings and the Environment: Constructing Knowledge, Designing Practice. Routledge, London.
Guy, S., Marvin, S., Medd, W., Moss, T. (Eds.) 2011. Shaping Urban Infrastructures: Intermediaries and the Governance of Socio-technical Networks. Earthscan, London.
Heiskanen, E, Johnson, M., Vadovics, E. 2013. Learning about and involving users in energy saving on the local level. Journal of Cleaner Production 48, 241–249.
Heiskanen, E., Lovio, R. 2010. User-producer interaction in housing energy innovations. Journal of Industrial Ecology 14 (1), 91–102.

Jaffe, A.B., Stavins, R.N. 1994. The energy-efficiency gap: what does it mean?. Energy Policy 22 (10), 804-810.
Janda, K.B. 2011. Buildings don't use energy: people do. Architectural Science Review.54 (1), 15-22.
Janda, K.B., Parag, Y. 2013. A middle-out approach for improving energy performance in buildings. Building Research and Information 41 (1), 39–50.
Kaghan, W.N., Bowker, G.C. 2001. Out of machine age?, Journal of Engineering and Technology Management 18, pp. 253–269.
Karvonen, A. 2013. Towards systemic domestic retrofit: a social practices approach. Building Research & Information 41 (5), 563–574.
Law, J., Bijker, W.E., [1992], (2000). Postscript: technology, stability, and social theory, in: Bijker, W.E., Law, J. (Eds.), Shaping technology / building society. The MIT Press, Cambridge, Mass, pp. 290-308.
Lutzenhiser, L., 1993. Social and behavioral aspects of energy use. Annual Review of Energy and the Environment. 18(1), 247-289.
Macintosh, A., Steemers, K. 2005. Ventilation strategies for urban housing: lessons from a PoE case study. Building Research & Information, 33 (1), 17–31.
Marvin S and Guy, S. 1997. Smart meters and privatised utilities, Local Economy, 12 (2), 119-132.
Medd, W., Marvin, S. 2008. Making water work: intermediating between regional strategy and local practice. Environment and Planning D: Society and Space 26, 280–299.
Menezes, A.C., Cripps, A., Bouchlaghem, D., Buswell, R. 2012. Predicted vs. actual energy performance of non-domestic buildings: using post-occupancy evaluation data to reduce the performance gap. Applied Energy 97, 355–364.
Moss, T. 2009. Intermediaries and the governance of sociotechnical networks in transition. Environment and Planning A. 41, 1480–1495.
Moss, T., Medd, W., Guy, S., Marvin, S. 2009. Organising water: the hidden role of intermediary work. Water Alternatives. 2 (1), 16–33.
Moss, T., Guy, S., Marvin, S., Medd, W. 2010. Intermediaries and the reconfiguration of urban infrastructures: an introduction, in: Guy, S., Marvin, S., Medd, W., Moss, T. (Eds.), Shaping Urban Infrastructures: Intermediaries and the Governance of Socio-technical Networks. Earthscan, London, pp. 1-13.
Norman, D. 1988. The design of everyday things (The psychology of everyday things). paperback edition. New York: Doubleday/Currency.
Oudshoorn, N., Rommes, E., Stienstra, M. 2004. Configuring the user as everybody: gender and design cultures in information and communication technologies. Science, Technology & Human Values, 29 (1), 30–63.
Rohracher, H. 2003. The role of users in the social shaping of environmental technologies. Innovation 16 (2): 177–192.
Rohracher, H., Ornetzeder, M. 2002. Green buildings in context: improving social learning processes between users and producers. Built Environment 28 (1), 73–84.
Shove, E. 2003. Comfort, Cleanliness and Convenience: The Social Organisation of Normality. Berg, Oxford.
Shove, E., Chappells, H., Lutzenhiser, L., Hackett, B. 2008. Comfort in a lower carbon society. Building Research & Information 36 (4), 307–311.
Shove, E., Walker, G., Brown, S. 2014. Material culture, room temperature and the social organisation of thermal energy. Journal of Material Culture, 19 (2), 113–124.
Sørensen, K.H. 2005. Domestication: the enactment of technology. In: Berker, T., Hartmann, M., Punie, Y., Ward, K.J. (Eds.) Domestication of Media and Technology. Open University Press, Maidenhead, pp. 40–61.
Stewart, J., Hyysalo, S. 2008. Intermediaries, users and social learning in technological innovation. International Journal of Innovation Management 12 (3), 295–325.
Strebel, I. 2011. The living building: towards a geography of maintenance work. Social & Cultural Geography 12 (3), 245–262.
Sunikka-Blank, M., Galvin, R. 2012. Introducing the prebound effect: the gap between performance and actual energy consumption. Building Research & Information 40 (3), 260–273.
de Wilde, P. 2014. The gap between predicted and measured energy performance of buildings: a framework for investigation. Automation in Construction 41, 40–49.
Wilhite, H. 2008. New thinking on the agentive relationship between end-use technologies and energy-using practices. Energy Efficiency 1, 121–130.