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A DOMESTIC PRACTICES PERSPECTIVE ON PASSIVHAUS LIVING

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ABSTRACT

This paper uses social practice theory to explore the implications of new low carbon dwellings upon energy consuming practices. The handover period for a small to medium sized UK Passivhaus development was investigated, predominantly using interviews as well as informal observation and participation at key events (e.g. move-in day technology tours, information sessions, post-move-in landlord visits). Evidence showed the introduction of technology could provide scope for certain performances, but did not linearly result in energy savings, as per design intent. The Passivhaus technological configuration contributed to a pronounced nonlinearity and unpredictability due to a messy integration of practices surrounding heating and ventilation energy services – the focus of much of our discussion.

Residents primarily showed a willingness, conscious or not, to refine heating and ventilation practices either to ease worry of unfamiliar technologies and/or to yield the benefits offered by their new residence. Practical understanding seemed pivotal in learning new skills and adapting practices, partly due to minimal and relatively mistrusted institutional guidance.

The dominance of learning by doing in shaping and holding practices together meant misinterpretation was common since understanding was reliant on past technological experience. 'Misuse', as a product of past practice trajectories, could be mitigated against through a combination of technological design that aligns with earlier generations of technologies and information provision that is empathetic to the role of know-how and embodied habits (e.g. active participation, regular household contact, seasonal sensitivity). Appreciation of such influences is essential to ensure handover support and technological design enables energy savings and helps fulfil policy ambitions.

Keywords: Domestic energy consumption, social practice theory, energy practices, low carbon housing, Passivhaus

3S Strand: Sustainable Consumption

INTRODUCTION

The culture of the UK building industry favours refurbishment over demolition and building new, contributing to one of the oldest building stocks in Europe. Of UK dwellings, 39% were built before 1945 and 23% before 1919 (UK Department for Local Communities and Government 2010). Therefore current decisions concerning the design of new housing will have a bearing on households' technological configurations for decades, potentially centuries, to come. There is a pressing need for more research on the implications of tying future generations to the design strategies produced on the basis of designers' preconceptions of (fictive rational) users (c.f. Jelsma 2003). Evidence is needed regarding the actual interpretation and use of new low carbon housing, the building of which government policies target to lower emissions. The UK domestic sector is responsible for 25% of emissions and 40% of final energy use (UK Department of Energy and Climate Change 2011b).

Relatively little work has been conducted on obtaining this evidence because most policies and domestic energy research inherently assume technological provision will linearly reduce emissions. A social practices approach helps fill this neglected void, and is thus being increasingly used to examine residential energy consumption (e.g. Bartiaux *et al*. 2011; Strengers 2010). Existing research has largely focused on the elements that shape domestic energy consuming practices (e.g. Gram-Hanssen 2010a), and less on the actual performance of these practices and its implications on everyday life. More research is needed to delve further into how applying practice theory can aid learning about the failings and successes of government strategies that hinge on everyday life.

Few studies have explicitly examined the transitional period where a property is handed over to new residents (e.g. Egginton 2011; Stevenson and Rijal 2010), none of which adopt the practices lens that this study does. The handover period considered here includes approximately the time between 2 months before and 12 months after the move-in date. The handover period is insightful when examining the impact of changing domestic technological configurations, which are targeted by international policy agendas, since this is exactly when residents are first exposed to that change.

The aim of the paper is therefore to investigate the influence of a new and very unfamiliar domestic technological configuration on residents and the performance of their energy consuming practices. Through a practice theory lens, the implications of moving into a contrasting (low energy new build) dwelling upon energy consuming practices are explored. The empirical basis is the resident handover period for a Passivhaus-certified UK affordable housing development, with the focus largely on the initial destabilisation and transformation of practices.

This paper begins by critiquing the dominant technoeconomic approach and outlining how practice theory can be utilised to understand household energy usage. Following explanations of what the Passivhaus[1] standard entails and the methods employed, resident interpretations and experiences of the handover are explored. Discussion focuses on why and how practices are changed, the role technology plays within that, and the complex interconnections between the elements that shape practices – particularly in the context of how new skills are acquired as residents adapt to new technologies and different ways of heating and ventilating their home. How past technological experience directs the performance of heating and ventilation practices is given explicit attention.

We conclude by reflecting on possible improvements to the handover process and wider policy initiatives, in addition to considering the broader implications of applying social practice theory to similar domestic energy studies.

THEORETICAL CONTEXT

The majority of policy-making and indeed mainstream research within the household energy arena can be classified under the 'technoeconomic paradigm' (Guy and Shove 2000). Technoeconomic policies focus on technical and economic considerations, typically assuming individuals to be profit-maximisers who rationally make decisions. The paradigm therefore assumes building research knowledge is incorporated into lifestyles and actual action through technology transfer which enables users to take action, or through information provision which demonstrates that the use of that technology can provide a net benefit. The consequence is that policy can assume technology will solve the problem. For example, technological upgrades are targeted in the UK by Building Regulations (zero carbon home standard), the Green Deal (loan system to enable energy efficiency projects in existing homes), Carbon Emissions Reduction Target (subsidised insulation for existing homes), and Feed-In Tariffs (pays householders for microgeneration). Lutzenhiser and Shove (1999) argued that this paradigm had been widely adopted internationally by energy researchers, contributing to a shared technoeconomic perception of how best to tackle as well as define the problem, and we believe little has changed since this publication despite a slight shift in focus through the development of similarly linear social marketing and behavioural economics.

An implication of the technoeconomic paradigm is that technologies are used exactly as designers envisage. This is implicit in much of the low carbon building commentary. The assumption is that a technological 'fix' can provide a magic bullet solution. Therefore when predicted savings are not achieved in reality, poor use, rather than poor design, is argued. However, social practice theorists claim that it is not the building or indeed the occupant that is responsible for energy consumption. Householders do not make the conscious decision to consume energy, it is instead a by-product of certain practices (e.g. watching television, washing, cooking, hosting guests) which come about at the intersection between the building and its occupants. Gram-Hanssen (2008) argues that a priority for the development of policy, information campaigns and technological design is the investigation of components pulling practices in (un)sustainable directions. It is such analysis that would help identify either approaches that do not rely on technologies or the most appropriate technologies, which could help, but by no means ensure, subsequent behaviour change.

A 'practice', through a social practice theory perspective, is a habitual and routinised type of behaviour "*in which bodies are moved, objects are handled, subjects are treated, things are described and the world is understood*" (Reckwitz 2002: 250). A practice is a rather dynamic concept in that one can occur within and across other practices of different scales and contexts. Practice theory has its roots in the work of Bourdieu (1977; 1984) and Giddens (1979; 1984), being developed more recently by Schatzki (1996; 2002), Reckwitz (2002), Shove and Pantzar (2005), Warde (2005), and Gram-Hanssen (2010a). The latter works are more relevant to the field of sustainable consumption. No one absolute practice theory exists; it is instead an approach within sociological theory and the topic of continued debate. For instance the role of materiality within practice theory is not agreed upon (Gram-Hanssen 2011), although its inclusion has increasingly become the norm

after the work of Reckwitz (2002). In this paper subject-object (i.e. person-technology) relationships are viewed as an equally important influence of practices as subject-subject (i.e. interpersonal) relationships.

The following framework suggested by Gram-Hanssen (2010a; 2010b; 2011) is adopted in this paper. The changing of an element (e.g. technological change) can 'puncture' a practice (Hitchings 2011), thus potentially destabilising, destroying, or creating practices. Using Schatzki's (1996) terminology, such frameworks offer a basis for lessons from empirical studies focussing on 'practices-as-performances' (how practices are undertaken in reality) to provide insight into, and to a certain degree test, how we view 'practices-as-entities' (social organisation of a practice):

- *Technology* – anthropogenic infrastructure and physical environment.
- *Engagements* – associated meanings which provide motivation, consciously or not, to take action or not, i.e. why is it a good idea to undertake that practice? Why should a practice change on the basis of new experience and/or information?
- *Know-how and embodied habits* – practical understanding acquired through experience, which is unconsciously embodied in physical everyday habits.
- *Institutionalised knowledge and explicit rules* – less intuitive, explicit 'rule-based' information, e.g. expert guidance, instruction manuals.

The salient feature of social practice theory is in putting practices at the core of understanding the social. By moving conceptually from individuals and technology to technology-in-practice, invisible energy usage which is tied to practices should start to come to the fore. Part of such a transition demands that citizens are seen as practitioners 'carrying' collective practices, instead of individual consumers. Since a practice is a type of behaviour or pattern of routinised actions (Reckwitz 2002), empirical investigation of 'practices-as-performances' (and its consequential consumption) can pull the researcher towards examining individual behaviours. As practices are collectively created and maintained but performed by individuals, investigating specific actions and behaviours of individuals would provide a greater understanding of the performance of practices in situ. The key point is that practices are collective and historic realisations, developing over time through the sociotechnical interaction of groups of individual practitioners. Therefore during practice-oriented analysis this must be appreciated with practices, rather than individuals, being the focal point. Scope does, however, exist in investigating the individual differences of performing a practice and its constituent contextual routines and behaviours (Gram-Hanssen 2008). This is supported by Gram-Hanssen who proposes practice theory's use in investigating why changes, such as technological provision, do not have the anticipated effect on everyday life:

> *"Practice theory does not have an individualized approach to practices, though it is open for understanding how changes in practices may start in the everyday life of individuals, following from both change in engagement and from the introduction of new knowledge or new technologies. The theory can thus also be useful in describing why changes do not always appear even though authorities or organizations try to introduce them into people's everyday life".*
>
> (Gram-Hanssen 2011: 76-7)

By concentrating on practices the broader social dynamics that guide technological interpretation and use are given more credence. Practice-based studies that focus on performances may engender better representations of what actually happens in an individual or household's everyday life. Often a practices approach may not provide neat and orderly answers - unlike technoeconomic study outputs - but since consumption is anything but straightforward, the approach does provide much needed insight into these fluid and often rather cluttered and chaotic sociotechnical interactions.

The practice theory framework will be used here to examine the implementation of Passivhaus standards on bundles of domestic everyday practices. Since Passivhaus is still an innovative design approach for the UK and is rarely undertaken, its technological configuration is sufficiently novel to challenge the status quo of resident practices. The following section provides background to the Passivhaus concept.

INTRODUCING PASSIVHAUS

Passivhaus is a voluntary German standard for building energy efficiency and comfort (Feist *et al*. 2005). It has been applied to all tenures and building types, although most have been new build owner-occupied houses to date. The main purpose is to minimise the need for space heating/cooling, thus energy consumption during operation. Passivhaus homes stay warm 'passively' from people, solar gain and appliances, as well as often relying on renewables and mechanical ventilation. One could even heat a house with a hair dryer or a small number of candles. Practices themselves are thus a main source of heating, contributing to a different way of living.

Certification stipulates demanding minimum energy efficiency standards covering space heating/cooling consumption, total energy consumption, and air leakage. Very high insulation, minimal gaps in the insulation materials that wrap around the building (i.e. minimal thermal bridging) and an airtightness barrier are essential in achieving these challenging standards. Certain design characteristics are also typically employed such as south-facing orientation, triple glazing, renewable energy generation, and highly efficient mechanical ventilation with heat recovery (MVHR). Energy demand reduction removes the need for a conventional heating system. By focussing on energy demand, not supply, Passivhaus buildings are said to be easier to use as there is less confusing 'eco-bling' such as renewables.

Recent growth in western and central Europe has been considerable, from only approximately 200 Passivhaus buildings in 2000, to best case scenario projections of 65,000 in 2012 and 260,000 by 2015 (Establishment of a Co-operation Network of Passive House Promoters [PASS-NET] 2012). There are very few elsewhere globally, and relatively few in the UK: currently only 35 certified and 17 'in-the-pipeline' projects (UK Passivhaus Trust 2012).

The CEPHEUS (Cost Efficient Passive Houses as EUropean Standards) project – covering 221 Passivhaus homes across 11 projects in Sweden, Germany, France, Austria, and Switzerland – showed Passivhaus homes to consume 80% less space heating and 50% less total energy usage compared to conventional new builds (Schnieders and Hermelink 2006). Comparisons to European standards hence show Passivhaus favourably in terms of energy saving. In response to fuel poverty concerns and challenging emissions targets, Passivhaus is thus gathering increasing momentum and

widespread support across, particularly central and northern, Europe. It is already legally required for all new buildings in vast areas of Germany and Austria. Uptake is set to increase over the next eight years as European nations begin to respond to the legislative demands, which Passivhaus was instrumental in defining, of all new buildings being 'nearly zero energy buildings' from 2020 onwards (Official Journal of the European Union 2010). For example, from 2015 onwards all retrofits and new buildings in Brussels (Belgium) must be Passivhaus. Equivalent standards, based on similar 'Passive House' definitions, are also coming into force in numerous other European countries, such as Finland (2015) and Norway (2017). Moreover, a failed European Parliament Resolution had proposed that all new EU buildings reach Passivhaus equivalent standards (Official Journal of the European Union 2008). Chris Huhne, when he was the UK Secretary of State for Energy and Climate, also stated that he "*would like to see every new home in the UK reach the standard*" (UK Department of Energy and Climate Change 2010). Passivhaus is thus set to be a key contributor to Europe's future housing stock.

Passivhaus has gained additional traction in policy and research circles due to its framing as a technological 'fix' in guaranteeing energy savings. In the UK this is built on the back of deemed successes in continental Europe, only enhancing the perception of the fix's reliability. The following quote from a Passivhaus co-founder, which is frequently used in pro-Passivhaus commentary, illustrates how the origins of Passivhaus are embedded in rational and individualistic linearities surrounding the translation of the material world by fictive users.

> "*I was working as a physicist. I read that the construction industry had experimented with adding insulation to new buildings and that energy consumption had failed to reduce. This offended me – it was counter to the basic laws of physics. I knew that they must be doing something wrong. So I made it my mission to find out what, and to establish what was needed to do it right*." (Feist, in Reason and Clarke 2008: 2)

The mentality that the failure of one technology can be wholly fixed by introducing another technology alone is futile - changes to the physical environment are quite often essential, but usually only part of the puzzle - yet over 20 years on from Passivhaus' conceptualisation, this framing continues in its analysis. The following quote is from an investigation into occupant behaviour in some of the first Passivhaus-certified Danish dwellings; the belief is that better knowledge (e.g. through information provision that reveals the potential for monetary savings) on how to use better designed technologies will ensure 'correct' usage.

> "*The occupants have to know how to handle the system or understand the strategy to perform "correctly". It is believed that both the combination of "wrong" occupant behaviour and poor design is responsible for the lack of thermal comfort in the summer in all these three cases.*" (Larsen *et al*. 2011: 7-8)

Passivhaus is therefore an interesting case study because not only does it provide a radically different technological configuration relative to conventional UK housing, but it is a technoeconomic policy fix that, counterintuitively perhaps, depends on everyday practices to successfully lower (heating) energy consumption to the levels that its certification expects.

METHODOLOGY

The case studied for this paper is a small to medium sized UK Passivhaus social housing development. Of the properties, 29% are shared ownership tenure. To enable construction in a rural area where house building is usually prohibited (e.g. due to 'green belt' restrictions), the local planning authority granted planning permission under a 'rural exception' policy in order to meet a local housing need. This means that all new residents need to have a local connection to the village (e.g. they or their family live there already). Residents were exclusively selected by the area's local authority on this basis since relatively few interested parties had local connections. This was instead of assessing their environmental credentials which is typical in social housing projects so as to 'ensure success'. The households are therefore not a sample of environmentalists or Passivhaus enthusiasts. Of the households, 43% are single occupancy (all flats), 14% are dual occupancy, and the remaining 43% are (predominantly young) families. There are no elderly individuals living at the development, with the average adult age being 36 years (range: 18-53). The majority of employed adults have partly skilled (e.g. agricultural worker) or skilled (e.g. electrician) occupations, whilst only 8% are in professional (e.g. accountant) employment.

The technical specification of all dwellings is the same. Conventional gas boilers, supplemented by solar thermal systems, are coupled to large thermal stores. The stores supply hot water and feed top-up heat into the air supplied by the MVHR system. This is instead of a conventional central heating system which 89% of UK homes have. In the UK the proportion of mechanical ventilation systems is so small that UK Government figures make no effort to disaggregate it within its broader 'Other' heating system classification[2] (1% of UK homes) (UK Department for Local Communities and Government 2010).

The methodological focus is on how changing the technological configuration of one's home affects domestic energy consuming practices in general, particularly through how it punctures the other three practice elements (engagements, institutionalised knowledge and explicit rules, know-how and embodied habits). In realising this, empirical attention is given to the performed output of organised activities. Passivhaus and non-Passivhaus dwellings are not directly compared (e.g. with two samples), though by having a longitudinal approach which focuses on the trajectory of practices from 2 months before to 12 months after move-in, investigation of such technological differences is inevitably implicit.

Institutionalised knowledge was mainly provided by what is referred to as resident 'support institutions' which advised residents on various issues, and these will be specifically explored within this element. Support institutions include (1) the housing association which, as landlords to the non-shared ownership residents, provided ongoing support and pre-move-in information evenings, and (2) the construction company which contractual obligations included leading the handover day tour of technologies, producing simplified paper-based guides, and fixing any technological problems.

Pre-move-in interviews were conducted with at least one member of each household to introduce the research project, get to know the participants, explore how they used their previous technological setting, and gauge prior expectations of Passivhaus. Although interviews can be very

useful in researching practices (Hitchings 2012), the first round's purpose was predominantly supporting and contextual, laying the foundations for the research described below.

In reference to researching practices, "*there is no alternative to hanging out with, joining in with, talking to and watching, and getting together the people concerned*" (Schatzki in press). Practice-oriented research should involve the researcher getting to know participants on a day-to-day, and perhaps a resulting informal, basis. This way the subtleties of practices can be uncovered since its spatially and temporally abstract nature can be better understood. Observation and in some instances participation was thus undertaken at key events including information sessions, construction site tour, handover day tour of technologies, visitor days, 2 week post-move 'de-snag' visit (which solely focuses on mitigating early problems, or 'snags'), and 6 week post-move-in resident meeting. In addition, informal and ad-hoc contact was maintained, largely stimulated by operational problems occurring.

Around 9-12 months after move-in, 64% of households (due to dropout) were involved in a second round of interviews. In addition to allowing residents to comment directly on the handover process (e.g. asked for recommendations for future handovers), they were given the time and space to reflect more generally on living in their new homes as part of a walkthrough interview. This more interactive interview situated the discussion of use exactly where that use, and thus performance of that practice, occurred.

The identities of the residents and the relevant institutions are protected. Quotations are referenced using, for example, '1A', whereby 1 represents a randomly assigned resident number for one of the 28 residents that were contacted during the study, and A represents the method of data collection (A = pre-move-in interview; B = walkthrough interview; C = informal interaction), thus 1A and 1C quotations refer to the same individual.

The following section loosely uses Gram-Hanssen's (2010a) interconnected elements as a structure. The role of new technologies is more generally discussed first, regarding its role in directing energy consuming practices. On the basis of technological change, the remainder of the Findings section addresses the other elements in the context of heating and ventilation related practices – the rationale for choosing which is explained. The section climaxes in discussing how technology's relationship with the know-how and embodied habits element significantly shaped the performance of practices.

FINDINGS

Technology: its role in changing practices

Moving into a new dwelling provides residents with a very different materiality to their previous residence. Such differences have the potential to change how energy consuming practices are performed. Whilst technology's influence on everyday living is not linear and certainly not guaranteed, Table 1 does detail some examples (raised independently by residents) of how technology provided opportunity and scope for actions, which residents could choose to exploit or not. Technology thus takes the role of a steer, not dictator, through the options it facilitates.

Table 1 – How introducing different technologies as part of a new domestic setting can implicate practices

New Technological Configuration	***Impact on Energy Consuming Practices***
No external outlet for a (non-condensing) tumble dryer's vent hose due to airtightness concerns	Can only use a condensing tumble dryer, forcing some to stop using their old dryer.
Garden washing line	Can hang washing outside, instead of using a tumble dryer.
No kitchen gas connection	Electric cooking only.
Limited kitchen space (especially in the flats)	Had to prioritise selection of white goods leading to few householders using dishwashers.
Bath with shower attachment	Allowed those who could previously only shower to bath.
Plug socket and light switch locations	More convenient plug sockets made it easier to turn electrical devices off standby. Some poorly placed light switches increased the effort required to switch lights off.
Smaller garden	One household decided to throw away their electric lawn mower, mowing manually instead.

It clearly is not as simple as introducing a technology to alter one's daily living. Residents do not necessarily make rational decisions. For example, almost all residents independently acknowledged that free hot water would be available from the solar thermal system after the sun had been out for a few hours, yet no-one changed when they showered or bathed. Technologies are very often not used as designers intend. Would the designer approve that the airtight dwelling's front door is kept open continuously to allow access for a cat? The impact of residents potentially choosing to not purchase the expensive (Passivhaus Institute approved) cat flap, yet still own a cat, was seemingly not given enough consideration. The practice of looking after a cat was non-negotiable for some households. It is thus a good example of how technological interventions can be ineffective: a robust practice can have considerable flexibility (e.g. regarding technological interaction) in how it is performed so as to meet a desire or need (e.g. owning a cat).

In contrast, the performances of some practices were very readily changed when the new technologies were complementary to certain modes of previously unachieved energy services. Technological configurations can inhibit one undertaking a practice in a certain way to yield a specific energy service. Therefore for most residents, having moved into a Passivhaus dwelling gave them scope for new performances. Many of these were not necessarily anticipated or Passivhaus-related. For example, one household bought a deep fat fryer because the boost function of the MVHR (if used like an extractor fan) would prevent "stinking out their house" (22B) like in the past. Moreover, the spray and aerator functions of water saving taps was said to "give better [more] bubbles" (10B), leading to 14% of households having considerably more baths. Perhaps most unexpectedly is how one household turns on their water heating as part of making homemade bread: the bread is placed on top of boiler for 45 minutes since the heat it gives off helps to give the bread "just the right texture" (25B).

The reason behind these unexpected uses is practices, hence further investigation is needed into how technology interacts with engagements, institutionalised knowledge and explicit rules, and know-how and embodied habits in shaping and holding practices together. The remainder of the Findings section attempt to tease out these complexities with a focus on practices that link to the energy services of heating and, to a lesser extent, ventilation. The residents were clearly disconcerted about heating and ventilation, raising it most frequently prior to move-in. Although an open investigative frame (targeting energy consuming practices in general) was initially adopted, both these services emerged as clear recurrent linchpins entwining and being implicated by every domestic practice. Consequently, the proceeding discussion is able to integrate the substrates of everyday life; from ventilation system controls, appliances, hosting guests, cooking, to washing and beyond. This high degree of overlap and integration means that to a certain degree generalisation across practices and its elements is enabled (e.g. engagements are widely applicable to almost all domestic practices), despite an elements framework typically being used to detail what holds one discrete practice together (e.g. turning electrical appliances off standby (Gram-Hanssen 2010); Nordic walking (Pantzar and Shove 2010); car driving (Shove *et al.* 2012)).

Engagements: why learn new skills and consider changing domestic practices?

Around 4% of residents had heard of Passivhaus (from television) and that was limited to recognising the name as a low energy building initiative. The key reason for applying for the move was therefore not Passivhaus-related, with only 7% of households having at least one resident that could be described as environmentally conscious. Instead it was rooted in wanting a new home (e.g. safer, rural, more convenient location; more adequately sized property; independence from parents), the aesthetics offered by a modern new build, the security and support offered by social housing, and/or the opportunity for shared ownership. These aspirations were largely in response to entrenched social constructions of what a home should be and how life can be displayed as a success. The willingness to learn new skills for refinement of existing practices, particularly relating to temperature regulation, seemed tied into these motivations in that 'change' was deemed as what was needed if all these desired benefits (associated with moving) were to be obtained. Therefore comfort was, initially at least, a secondary reasoning for households wanting to change how they interacted with a technology as part of a practice. The engagements associated with moving into a new home were more prominent than usual because the Passivhaus development had the only social housing available at that location with limited accommodation alternatives elsewhere, in addition to the housing association employing an authoritative rhetoric in its guidance (e.g. "if you are to live in these dwellings you must use the ventilation system in a certain way"). Although the guidance's 'orders' were not necessarily followed, the wrongly assumed underlying message that one would not get their new home unless they were seen to be 'following orders' did seem to prevail. As more low energy housing is built, more residents may be in a similar position whereby no (non-low energy dwelling) alternatives are available, potentially reinforcing these types of engagements.

After attending Passivhaus pre-move-in education sessions, monetary gain from energy saving and, to a lesser degree, the possibility of a more comfortable (warmer) environment, became additional engagements. This said, most residents still did not believe the extent of the likely savings; e.g. one

six-person household set aside £50/month (around half of previous bills) for gas payments, but their actual bill for six months (July-January) was £30. Whilst such bill savings certainly seemed to motivate them more to adapt, whether this actually triggered action and change was not clear. Indeed after the experience of living in their homes, beyond the first year, it would be interesting to see if and how engagements change.

Households were divided between indifference and real worry regarding moving in to a Passivhaus dwelling, the consequential engagements of which shaped how they prepared and initially appropriated the dwellings. Some households did not even entertain the prospect of having to change their everyday routines. The blind faith that the status quo would be maintained because "they [housing association] wouldn't give it to us if it didn't work" (6A), and was not "easy to use" (1A) or "low maintenance" (20A). The perception was that those in continental Europe had proved it suitable ("tried and tested" (5C)) for their use. These pre-move-in expectations aligned nicely with technoeconomic linearity and the mentality that technology will solve our problems. It was clear that their prior expectations were very different to those actually experienced post-occupancy. For instance, indoor temperatures were anticipated by some to be very similar in their new homes, yet the provisional average indoor temperature (over August 2011 – July 2012) of 23.7^{o}C was 6.5^{o}C higher than the UK 2009 indoor average (UK Department of Energy and Climate Change 2011a). Residents only seemed comfortable yet not overly hot because they responded to Passivhaus technologies by using other technologies differently (e.g. no-one wore jumpers or used blankets which had previously been the norm). In contrast, those residents that were genuinely worried by the new technological surroundings – in particular, the "really complicated" (11A) MVHR – were intent on minimises the disruption to their homely vision, facing fewer post-occupancy surprises.

All residents received the same resident handbook (included Passivhaus background; advice on Passivhaus living; instruction manuals) and were taken on roughly the same technology tour on move-in day itself, despite no formal tour procedure or even checklist of points to cover. Yet the residents who were more worried initially better grasped the concepts presented within these forms of institutionalised knowledge. Indeed it was largely the worried residents who talked of the tour, and included the only one resident who mentioned the resident handbook when justifying how they operate their home. It would seem that these residents were more motivated when participating in the handover process in a bid to mitigate any problems. The enhanced knowledge they acquired through heightened participation (see 'Know-how and embodied habits: experience matters' section for more on learning by doing) became embodied in their everyday routines. For these residents, engagements surrounding fears of halting everyday life therefore featured more strongly in shaping and holding domestic practices together, and to a small extent helped overcome the limited capacity of institutionalised knowledge in transitioning household practices (discussed in detail in the next section). In contrast most of the more complacent residents were more susceptible to confusion around move-in (e.g. regarding how to maintain comfortable air quality and temperature) as a result of half-hearted participation.

Institutionalised knowledge and explicit rules: inhibited by innovation

Residents spoke fairly positively about the housing association (landlords), describing how they are "trying their hardest" (25B) and "really want[ing] this to work" (16B). On the whole there was a fairly good rapport. From our past experience with support institutions from other innovative housing developments, the housing association did actually do much better than most. Yet despite this, the provision of institutionalised knowledge in many ways seemed destined to be relatively ineffective with the integrity and trustworthiness of the institutional guidance being questioned, primarily as a product of the development's innovativeness.

A few households talked of how when they had telephoned the housing association for assistance, no-one knew what Passivhaus was. This was not a common occurrence across all households but did happen, and is perhaps understandable given that it was the association's first Passivhaus scheme. However expertise of the wider workforce was out of the association's control, consequently outsourced workers struggled with the Passivhaus concept. One household talked of a plumber visiting who had no idea how the plant room worked, so after asking the resident and telephoning a German contact, he left without rectifying the problem. A resident compared this to "going into a secondary school to teach French, when you don't know French" (11B). Indeed another resident was similarly critical regarding the construction company's lack of knowledge: "I'm not a builder, I just assume that they know what they are doing. They know their job, I know my job. I do what I'm supposed to do" (10B). Wasting one's time was a clear frustration, but such problems are difficult to avoid before these approaches have transitioned from niche to mainstream. However, in the meantime, institutions ('help') were being collectively judged in terms of value and competence.

Further trust was lost due to contradictory advice being given both across and within support institutions. It was therefore "less hassle" (8C) for residents to "work it out by ourselves" (20C) based on their limited knowledge then overcome significant obstacles by increasing their existing, but very minimal, interaction with informal (e.g. neighbours, friends) or formal (e.g. housing association) institutions for additional guidance. Whilst emphasising how habits are not changed solely through individual self-reflexivity, this also reveals how institutions of whatever form were only consulted in light of problems. Building trust and the foundations for regular interaction is especially challenging if the few moments of contact consist of resident frustration and support institutions struggling to answer queries.

Social relationships evidently influenced how information was assimilated. The likeability of individuals directly affected their trustworthiness as an information source, impacting how residents would use the information afforded to them or even whether they would take notice of the information at all. Numerous tales of "rudeness" (1C) were described; for instance, specially booking the day off work only for the builders not to show. One individual, who was described as "a pain" (26B), would just "turn up on the doorstep and say "I need to get in" as it was almost sort of his right...but on a technical side he clearly knew his stuff" (25B). Technical expertise was inconsequential to many households.

Despite all this, institutionalised knowledge did still play some role in shaping practices. One resident said "I can't remember [how and when we change the MVHR filters], but what we are doing must be

right as that is what the information said" (25C). To enhance this further, how the information is actually provided needs to be more relevant and appropriate to the households to help establish and maintain resident interest and trust - some of the potential mechanisms of which are now discussed.

Information provision needs to be set in a household context (Hargreaves *et al*., 2010), such as taking all family members on the move-in day technology tour, rather than just one adult householder which was generally the case here. Individuals within the same household responded differently to institutionalised knowledge as well as having different techniques for learning about new technological surroundings. As a result, everyone in a household did not necessarily change domestic practices in the same way, or even at all. How a practice was performed was usually negotiated amongst household members (e.g. husband-wife power struggles over thermostat settings). Often roles or responsibilities were shared across the household, all of which were essential to each individual performance of a practice. For example, perhaps showering relied on one technically-minded individual who "sorts out the hot water controls because I haven't got a clue" (8B). Setting information provision in a household context will ensure it reaches all those negotiating and shaping practices, ultimately giving its central message more traction.

It is essential that the information is targeted and, as one resident suggests, taking account of seasonal context could be useful due to markedly different temperature regulation strategies being required:

> "It would have been much better if they had said that in the summer these hints may be helpful for you, and in the winter use these set of rules. I was not interested in how to heat my house [at move-in, in summer]; it was really hot in here. All I wanted to know was how to keep it cool. And I knew that come the winter I was not going to remember anything that he'd said anyway." (10B)

'Drip-feeding' may also help to overcome the obstacle that residents have other priorities on move-in day. The development's innovative nature led to a stretching of construction timescales, such that completion was on move-in day itself, thereby making move-in even more stressful:

> "The problem was that you're so excited that you're moving house and you're flapping because everything's trying to get done, and we had the carpet fitter in on the same day we moved because you wanted the carpet in first before the furniture that you don't pay too much attention...So much is going on, removal vans all over the place. It wasn't actually finished because they were still putting up the sheds and laying our grass. So then you worry: don't leave without leaving our grass, don't leave without putting the shed up properly." (21B)

By not taking a seasonal approach and "overloading" (23C) residents on a move-in day that was already more stressful than the norm, residents may have been lost early on. Contradictory and mistrusted information from then on only cemented the reliance on 'learning by doing'. The dominance of know-how and embodied habits, rather than institutional knowledge and explicit rules, in adapting practices was clear in that the more independent shared ownership residents, who

received much less guidance and ongoing support, showed no less competency than the tenants renting their homes. The skills required to adapt one's routines and lifestyles to Passivhaus conditions were hence largely acquired through 'giving it a go'.

Know-how and embodied habits: experience matters

Active learning seemed to be in many of the residents' mindsets prior to move-in in that every resident who had concerns about Passivhaus seemed to think that confidence would be gained through experience and "actually living it" (6A; 19A). An acknowledgement beforehand perhaps that a setting so different would eventually fade into the background and embed its position within the norm. The novelty of the development only made learning by doing more inevitable because the lack of resident knowledge could not be adequately compensated by institutionalised knowledge, as previously discussed. Even those residents who had general building-related technical knowledge were resigned to tinkering with the controls and making mistakes (e.g. overheating) which were then embodied into daily habits, although they were somewhat more comfortable doing this than the less technically minded residents.

Most residents, some consciously, others not, therefore attained competency through 'trial and error' with domestic practices refined until optimal conditions were achieved and/or services obtained. Residents adapted underlying behaviours that make up certain practices based on how their own contextual situation sat within the new Passivhaus setting. For example, one household that washed clothes every day began switching when they used their tumble dryer, from the middle of the day (which had been routine for years) to the evening, so that the heat it gave off would help heat the house. When discussing this change, the resident spoke largely of experiences (demonstrating know-how) explaining that in the evening there is no heat gain from the sun, the "children are in bed so they aren't running around, and cooking is over" (21C). More 'hands-on' involvement, of which there was little, during the handover day technology tour would provide residents with early experience of using Passivhaus technologies, thereby helping them learn such strategies sooner.

Know-how seemed to develop much more quickly, consequently changing practices more readily, when interacting with institutionalised knowledge and explicit rules, or engagements. In this case, engagements were shown to significantly help embed know-how in everyday habits. For instance, the aim of being a good host was enough of an engagement to spearhead a tacit understanding of altering the ventilation controls to mitigate higher temperatures and "that stuffy, uncomfortable feeling" (16C). Being proud of one's home was a recurrent theme that aligned with escalating know-how. One household talked of how they "want a house that looks like the owners care about living in it" (13C). Such sentiments seemed interlocked with others' perceived sensory readings of one's home, beyond just visual appearance (e.g. the MVHR system stops it "smell[ing] of boy" (2B)). Therefore whilst being tidy was essential to most, the even more essential cleanliness 'requirement' included evading the feel and smell of hot and/or humid conditions. Social dynamics dictated what constituted a welcoming environment, and as the residents reflected on their time in their homes it was clear that experiencing what they deemed social awkwardness once was enough, and this manifested itself in unwitting changes to their practices.

It was through the build up of know-how and its infiltration into habits over time that the entanglement of practices became increasingly clear. Residents had to reorganise bundles of practices, rather than just one practice in isolation, to obtain their desired heating and ventilation levels. For example, one household learnt through experience not to cook any meal that used the oven for long periods on warmer days as the house got too hot. However on the days that were not as warm or if they really wanted a certain meal, they began to strategically change when they watched their large LCD television or did physical activity (e.g. children running around; playing on the Wii; cleaning). Further, almost every household referred to experiencing higher temperatures because of vacuuming and as a result many now never vacuum when the oven is on. In preparation for hosting guests, residents similarly had to think more carefully about when to vacuum to combat the common complaint of temperatures being too high when guests arrive, having usually only vacuumed minutes before arrival. Residents have therefore seen a domino effect across practices. The gradual evolution of assemblages of practices were in part a consequence of not learning (by doing) to use the MVHR as designers had envisaged, making altering the performance of various practices the primary means of temperature regulation.

Practices have trajectories and journeys all of their own, the influence of which is only strengthened by a reliance on know-how in accumulating knowledge and shaping practices. Past experience of performing practices, which depends on previous combinations of elements, shape interpretation and resulting usage of new technologies. Therefore frequent attempts were made by the residents to normalise their new materiality through parallels with their previous home's technologies, despite fundamental differences. The following five examples illustrate how such a lens can cause misunderstanding and misuse, relative to design intent.

1. *Warmth without radiators:*
   A common concern prior to move-in was "how can I stay warm without radiators?" (19A). Most previous homes had been heated by central heating and radiators, whilst those 'off-gas' used electric storage heaters. There had always been a visually distinct object that one could also feel as a heat source. Such was the worry this created that the support institution's most consistent and clearly communicated message – a Passivhaus home will maintain a warm temperature throughout the day – was ineffective in countering the dominance of past know-how. After realising that keeping warm would not be a problem, almost all households described how they preferred having no radiators (e.g. "you can put your furniture anywhere you want now" (12A)).

2. *Controlling the MVHR:*
   Several residents compared the MVHR controls to their boiler controls, describing how radiators are warmed by turning the thermostat up. The rationale was then that to heat one's home, one puts the ventilation system on a higher setting ("turn it up" (7C)). However a higher MVHR setting increases the rate at which (warm) internal air is removed. A lower setting, and lower removal rate, ensures temperatures would rise as there is a greater accumulation of heat passively generated through general living. Interestingly one resident made a parallel to a cooling fan, saying that you turn it up to cool and down to warm. This was probably stimulated by the guides constantly referring to the MVHR as "a fan", in a bid to use less intimidating and more familiar terminology.

Yet previous technological encounters indicated something similar to a cooling fan, or for others, an air conditioning unit. Therefore terminology that support staff often took for granted was frequently misinterpreted by residents on the basis of past experience.

3. *Regulating summer temperatures:*
   Past experience told them to open windows for cooling during hot spells. However this was on the basis of a building that was not heavily insulated and airtight, producing a very definite internal-external divide and relatively constant year-round temperatures. If it is warm inside, but even warmer outside, opening the windows would allow warmer air to enter and the limited throughflow of air would increase temperatures. In addition, external blinds were provided to help control the amount of solar gain, yet several residents initially considered their presence primarily for privacy purposes, as that was the context in which blinds had always been used previously. Indeed half the households still do not have curtains a year on, using the blinds as a direct substitute. Residents would need to prevent overheating during prolonged very hot spells through opening the windows at night to allow cooler air to enter and using the blinds for shading to minimise solar gain during the day. Complicating matters further, this strategy need not be employed during typical summer days when window opening, for example, would have little impact on internal temperatures (i.e. practices can align more with their previous home). These nuances led to contradictory advice being given on window opening, leaving residents confused as to what was appropriate. During the study period, there was no hot spell of sufficient duration and/or temperature to explore how resident know-how developed to achieve adaptive heating habits.

4. *Drying plaster in airtight dwellings:*
   As a consequence of initial high humidity, a few of the residents had some mould issues particularly in enclosed spaces such as cupboards. They lacked the knowledge that a dwelling built using a 'wet trades' approach (i.e. using wet plaster as the internal air leakage seal) with extremely little natural ventilation requires higher than usual mechanical ventilation to aid 'drying out'. The relevant support institutions were also unaware of this to an extent, even after mould growth on the construction site, emphasising how innovative constructions require the development of skills from those other than the occupants. A well ventilated construction site will lessen the ventilation burden placed on the household practices as well as reduce the chance of damp getting into the MVHR ductwork.

5. *The rate of internal temperature change:*
   Since the MVHR only needs to input a small amount of heat (very low power) into the incoming air because of the system's high heat recovery and dwelling's low heat loss rates, attempts to control temperature usually took longer to come to fruition. This slow change, sometimes taking several hours, was not anticipated by residents as it is so very different to the previously used thermostat and radiators which provided immediate feedback. They were informed by the support institutions of this prior to moving in, but very few incorporated it into their daily lives until they actually experienced it themselves. However, the housing association did not follow its own logic when

> conducting the only winter handover, leading to the new residents relying on portable heaters for the first two days. A neighbouring household commented on how "they were expecting that when you put the heating on it would be red hot in an hour like a conventional house. But you've got to get your head round that it's not like that. Ideally what you [the housing association] should do is put the heating on a couple days before move-in, so that when you [new residents] move in it is warm enough" (26B).

The interconnectedness of the practice elements is clear. These comparisons demonstrate how technological explanations can be interpreted through a lens created by one's previous technological setting. Crucially it is not actually the setting that is important, but instead the social expectations and sociotechnical knowledge surrounding how those technologies are used. Such a lens has the potential to detrimentally affect the learning of new skills and thus adaptation to one's new environment. This barrier had to be overcome with residents realising that learning, in many cases, had to start afresh.

With this realisation some households began to question an array of issues, most of which could be answered by common sense. However due to past mistakes and misinterpretations, some residents began to lack confidence in their own convictions. For instance, one household was still unsure 10 months after move-in whether pictures could be hung on internal walls due to the fear of "damaging the thermal seal" (14B). They had incorrectly scaled up a passing comment by the housing association at a pre-move-in information session about not damaging walls to effect heat loss. However the comment was more to discourage residents drilling holes in external walls for pipework or electricity connections. The resident handbook would have clarified the stance on "holes and fixings" but, as previously discussed, was very rarely consulted.

CONCLUSIONS

Changing practices to save energy cannot be stimulated by introducing technology alone. Technological provision does not guarantee predictable outcomes on one's everyday life, nevertheless Reckwitz (2002) and others were right to include technology as an element that shapes a practice. A significant change to the technology element (moving into a Passivhaus) altered the inter-element relationships that bind everyday practices together. The technological change also served to establish deeper horizontal linkages across practices through the energy services of heating and ventilation, ensuring that the already messy integration of practices is made even messier in low energy homes that employ super insulation and high airtightness, whether Passivhaus certified or not. Since international policy agendas and building codes are targeting these new build design approaches, such deep-rooted integrations mean that actual outcomes are even more unpredictable and nonlinear than in the past. Therefore a salient consequence of significantly lowering domestic heating and cooling energy consumption is that almost every aspect of domestic everyday life (practices) implicates heating and/or ventilation, potentially having major repercussions for how households live their lives.

Residents were primarily willing to learn new skills and disrupt existing practices because it minimised their apprehension regarding the new Passivhaus setting, or it was deemed necessary in order to obtain their new home and the benefits which accompanied it. Indeed relativity to previous

experience (e.g. one's past home) was a recurrent theme throughout the paper. Based on these engagements, residents used basic institutionalised knowledge (e.g. from information sessions, instruction manuals, move-in day tour) mainly as part of a trial and error approach where everyday know-how was altered and embodied in a new set of domestic practices. In part because the institutionalised knowledge was at times contradictory and limited, due to the development's innovative nature, the reliance of the residents on their previous technological know-how became increasingly dominant, hindering adaptation to their new dwelling. Residents interpreted and used new technologies through the lens of past experience. To enable low carbon living further the need thus exists for more intuitive design whereby new and old technologies are analogous, especially but not limited to instances where institutional knowledge may be lacking. Where technologies are incomparable, 'hands-on' experience under the mentorship of an 'expert' (e.g. during the move-in day tour) could help equip households with practical knowledge. It is important that residents gather as much experience as soon and as quickly as possible.

Dependence on experience emphasises how practices have evolutionary trajectories. Very rarely is there an instantaneous switch to new habits and routines (e.g. through an elemental change) since continual adjustments are typically made as practices are (re)performed in reality. To increase residents' confidence with new, and perhaps daunting, technological configurations they are encountering for the first time during the handover period, continual support and regular interaction is vital to help them find their way through experiencing the technology. This also provides the support institutions with the opportunity to learn more from the residents, facilitating improvement to future handovers and thereby lessening know-how's dominance (and its interpretative pitfalls) in shaping new practices. This is especially crucial to social housing where there can be a high resident turnover. Improved knowledge should be provided to the residents at a household-level taking into consideration their previous know-how, thereby helping to avoid misunderstanding. In conjunction with this, and although only subtly different, buy-in should be sought by emphasising the benefits of residents *adapting* their practices and *learning* new skills, and not simply the benefits of *living* in a Passivhaus dwelling as that creates the assumption that the benefits are attached to the technology, not its practical use.

These insights into how everyday life is rarely pushed and pulled at the mercy of information and new technologies were made possible through a practices approach. By going beyond the restrictive and narrow-sighted technoeconomic paradigm we could delve deeper into what the often irrational and abstract reality of everyday life actually involved. Adopting the elements framework presented by Gram-Hanssen (2010a) helped structure an investigation into the mechanics underlying practices that are punctured by an elemental (in this case, technological) change. The framework's distinction between 'institutionalised knowledge and explicit rules' and 'know-how and embodied habits' proved crucial, emphasising the need to appreciate and research how experience shapes practice trajectories, whether Gram-Hanssen's framework is adopted or not.

More work is needed on trajectories and how practices are, and thus perhaps can, be steered in certain directions. The tracking of performance trajectories is essential. By taking a longer study period we could see to what degree practices are in flux or settle as residents become used to their new homes. In light of future climate change predictions, trajectory investigations into how experience of seasonal extremes shape practices in Passivhaus dwellings will also be vital. For

instance, will adapting to a prolonged heat wave induce zero to minimal, clear but temporary, or salient step changes to everyday domestic practices? Will the residents resent making changes, such as reorganising timings, to existing practices? Understanding how households change how practices are performed in response to future climates, or indeed any elemental perturbation caused by certain policies and designs, is critical in anticipating and preparing for ground-level impacts on everyday life.

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[1] Its original German name, Passivhaus, is used throughout this paper. This paper examines a development that was designed to meet the certification criteria of the Passivhaus standard. Using the English translation (Passive House) could indicate a different design approach based on, for instance, different kWh/m^2a targets or even non-mechanised natural ventilation which (though perhaps hypothetically achievable) is very rarely considered.

[2] A mechanical ventilation (or even a MVHR) system may have been installed in a building without the purpose of providing heat. Heat input could be, for example, through radiators or under-floor systems. In the Passivhaus context though, mechanical ventilation systems usually have the dual-purpose of heating and ventilation for increased efficiency.

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