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Dragon-breath and snow-melt: Know-how, experience and heat flows in the home

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ABSTRACT

People manage heat flows in their homes through diverse skilful engagements, including interactions with a wide range of materials that help to generate heat, move it around, or prevent its movement. Using these strategies, we try to ensure that heat is where it is needed, when it is needed, and can also try to minimise its wastage (heat-out-of place and heat-out-of-time). However, the practical knowledge or know-how used in managing these thermal flows has received little attention to date, despite its relevance to topical debates on energy consumption. This paper explores how experience-based know-how is used in monitoring and managing heat flows in the home. I also consider three processes that stimulate the development of new know-how: changes in the life-course, in material arrangements, and in shared understandings. These themes are illustrated using quotes from various sources, such as web forums and advice sites. Finally, I consider how these ideas relate to wider theories of experience and know-how, and offer some reflections on what this approach might mean for research, policy and practice on sustainable energy use.

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1. Introduction

1.1. "My house is so cold right now"

My house is so cold right now, that...
The butter left out in the kitchen is rock hard and unspreadable...
The curtains in my bedroom flap in the breeze...
I could see my breath the other morning...
The wind whistling through the catflap...
The net curtains in my bedroom window were frozen to the window pane...
I got out of the bath, touched the door handle with my wet hands and actually froze stuck to the handle...
My dad's tooth glue... was so hard he couldn't get it out of the tube...
My sister sent back some toothpaste because it was rock hard... she won't believe that it's coz her house is icy... lol.

These lines, written by four women, are taken from a thread on the Netmums website in the cold January of 2010.[1] I start with these because they illustrate how people understand temperature in their homes not simply in terms of degrees centigrade, radiator settings or kilowatt hours, but also through their own experiences. This paper explores how experience-based know-how is involved in monitoring and managing temperature, through skilful engagements with flows of heat within the home. This is a topic which has received relatively little attention to date, though there are several areas of literature that are relevant. Work on thermal comfort often discusses strategies used in heating/cooling homes, and these involve some form of know-how. However, this know-how and its development have not generally been the focus of study. Meanwhile, some relevant work focuses more directly on know-how, but not specifically on heat management; for example, know-how around using stand-by [1] and living in a zero carbon home [2]. However, few studies have explicitly looked at know-how in relation to thermal management in homes. Those that have done so, such as Vannini and Taggart [3] (regarding "off-grid" heating), and Gabriel and Watson [4] (regarding solar water heating,

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[1] http://www.netmums.com/coffeehouse/general-coffeehouse-chat-514/coffee-lounge-18/368444-my-house-so-cold-right-now-all.html [accessed 10.03.14].

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but also thermal management more generally), suggest that this is an important topic, as know-how is fundamental both to current temperature management practices and to people's responses to technological change.

In exploring this topic, this paper engages with several issues highlighted by the first volume of *Energy Research and Social Science*, and responds to the call by Sovacool [5]; Stern [6] and other contributors for deeper explorations of the human role in energy systems. Building on Stern's argument that householders' understandings of energy often differ from those of experts, it provides an in-depth investigation of these "ordinary" ways of knowing. It also engages with Wilhite and Wallenborn's [7] call for attention to the body within energy research, by exploring the role of experiences, which are often intensely physical (as the Netmums quotes show), in the development of know-how around energy consumption. However, noting the arguments that "*energy is meaningful not by being consumed itself, but because it makes certain services possible*" [5] and that "*demand is an outcome of what energy is for*" [8], I do not frame the discussion around energy, but rather one specific area of practice that uses energy: the management of temperature within homes.

I have chosen to focus on thermal management because of its large contribution to energy demand and importance to consumers. For example, questionnaires [9] have shown that thermal comfort is the most important determinant of household energy use, while concern for warmth and comfort has been found to be the strongest driver of energy efficiency improvements in New Zealand [10]. A review of literature [11] suggests that thermal comfort is seen as the most important factor in a satisfactory indoor environment. Know-how around thermal management may be especially relevant at present, because the current older generation have skills in keeping warm which could be useful in promoting sustainable energy use [12], and if these are not passed to younger people, they may be lost. Meanwhile, Wilhite and Wallenborn [7] suggest that increasing standardisation of indoor climates (with heating and air conditioning) is leading to a weakening of adaptive capacity, or decline in know-how for adapting to temperatures. These trends make this topic especially timely.

This paper explores the core question: How is experience-based know-how used in the thermal management of homes? I first provide an overview of relevant literature on thermal management, and the home as a system within which energy flows between diverse material objects (Section 2). I then explore two broad themes around experience-based know-how: monitoring heat flows and managing them (Section 3). In Section 4 I consider how experience-based know-how is shaped by changing social, material and biographical contexts. The discussions in Sections 3 and 4 were developed by reviewing literature, drawing out key ideas and linking them within themes. Alongside quotes from the literature, I also draw on text from non-academic sources to provide richer and more experience-based illustrations.[2] Finally, in Section 5, I reflect on how these ideas relate to theories and concepts of know-how, and the directions this discussion suggests for research, policy and practice.

My focus is predominantly on the UK and North American contexts, because these are regions with high per capita energy consumption, and so particular significance in terms of global energy issues. Also, these are largely temperate/cold climates where thermal management of homes contributes a significant proportion of energy demand. I focus on keeping warm and not on keeping cool, to ensure a manageable scope. However, there is some evidence that similar themes emerge in other contexts where cooling is in question; for example, Strengers and Maller's [13] work on Australia. Many ideas suggested here about the role of know-how in thermal management are likely to have relevance across diverse contexts, albeit shaped by specific social, material and climatic conditions. Also, I am concerned predominantly with space heating and not person heating [14]. This distinction is not clear-cut, as thermal management involves diverse relations between clothing, housing, environments and bodies [15], however, it is helpful in delimiting this discussion. Use of person and space heating varies between cultures, and in some contexts there may be an ongoing shift away from managing bodies' comfort and towards managing indoor environments [14]. Given this, it seems particularly relevant to explore know-how that is involved in managing the temperature of spaces within homes.

2. Thermal management in a system of flows

Thermal management, or controlling temperatures, is a fundamental part of many people's daily routines. For most, the goal is thermal comfort; the feeling of being at the right temperature. However, this is not the only possible goal; others might include saving money, minimising environmental impact or maintaining the right temperature for another person, animal or object. Managing temperature means people have a constant and active engagement in practices including "*observing, controlling, recalling, regulating, and leaving traces (like carbon footprints), of their warming and cooling activities*" [3] (p68). Jalas and Rinkinen [15] recognise the active and skilful nature of these practices when they use the term "heating work" to describe things that people do to keep warm. Similarly, Vannini and Taggart suggest that, "*To heat... means to take part in practices through which heating skills are applied and developed, insightful observations are made, and understandings are refined*" [3] (p68).

As well as recognising these active and skilful engagements, the approach taken here draws on Shove et al.'s [16] novel understanding of indoor climate and energy demand, which focuses on thermal exchanges and flows. "*Another way to think about energy demand is to see the individual, their routines, their home, and all the objects within it, as making up a system. Energy flows through this system in the form of heat and power*" [17]. The work of thermal management involves governing these flows to ensure that heat is where it is needed, at the time it is needed. Doing this efficiently also means minimising unwanted heat flows: what we could call heat-out-of-place and heat-out-of-time. Drawing on this understanding means that I consider a wide range of heat flows; so while much past research has focussed on heat-generation, I am also concerned with how heat is transmitted or stored, and how it is lost from the home. This recognises that people do not wish to "heat" *per se*, but rather to feel warm (and/or achieve other outcomes), which can be achieved through managing flows in various ways. In particular, heat loss and the efficiency of building fabric have received relatively little attention so far within sociological studies of temperature management. However, these are especially important in the UK context, where cold winters and an old and inefficient housing stock [18] mean the efficiency of homes is a key public and political concern.

Taking this approach also means paying attention to arrangements of material objects, which play a crucial part in the system of heat flows. For example, Vannini and Taggart [3] argue that "*Insulation, thermo-mass, efficient windows and wood stoves are*

[2] My approach was to use search keywords associated with each idea (*e.g.* learn; experience; central heating). I then looked in particular for people's accounts of their own experiences, which were often to be found on weblogs and discussion forums. The content used is publicly available at time of writing and the web links are also provided. Where direct quotes from these sources are used, I have sometimes altered spelling and grammar for clarity.

Fig. 1. Some material elements involved in energy flows for keeping a home warm.

interveners: elements of a heating assemblage that make a crucial difference... working as the decisive force catalysing warmth as an event and an accomplishment" (p70–71). Fig. 1 shows some of the many material elements involved in energy flows that affect temperatures within the home. These materials can contribute to the generation of heat, and/or promote its movement through convection, conduction, radiation and other forms of transportation (such as movements of warm materials). Equally, they can be involved in limiting its movement, or insulating, and this can happen on diverse scales, from bed-socks to loft-lagging, echoing Hitchings and Lee's [19] concept of interlocking layers of encasement. While I am predominantly concerned with flows of heat, it should be noted that there are other forms of energy flow (such as electricity) involved in thermal management.

Of course, this is a limited representation, and the home is not a closed system (hence the dotted boundary); it is situated within a built environment and landscape, with inputs and outputs of energy associated with climatic and other processes. It is also situated within a wider thermo-material culture [16] (touched upon in Section 4). Also, these are only some of the most common materials used in the UK; other contexts will have different elements. Even the definition of material is challenging – how can we recognise the importance of spaces, cracks and gaps (as highlighted by DEMAND [20])? Nonetheless, the diagram highlights the diverse materials that are directly or indirectly involved in the thermal management of homes, through their role in energy flows.

These flows can be governed by human actors and/or by technologies. As Shove and Royston [17] explain, "*Shaping and controlling these flows depends on various forms of know-how, sometimes held by people, but sometimes embedded in objects, such as heating controls*". I am concerned here with the know-how that people use to govern these flows. The term know-how refers to practical knowledge, as distinct from factual or theoretical knowledge ("know-that" or "know-what") [21,22]. Know-how is "*a capacity to act in specific contexts*" [23] (p8) or "*the art of practice*" [24] (p113), and is closely related to Shove and Pantzar's [25] concept of competences or skills. Know-how may be embodied within physical routines and habits; for example, drawing the curtains at night, and adjusting radiator valves and windows [26]. It can also be more conscious; for example, the know-how used in setting a central heating programmer. Following Wilhite and Wallenborn [7] I do not view "mind" and "body" as distinct categories, but as overlapping, and I am concerned with both embodied and more cognitive forms of know-how. Another distinction concerns the origins of know-how. Know-how is often understood as being derived from direct personal experience [1,27]; however, some forms of know-how can also be transmitted through communication (*e.g.* in an instruction manual). I am concerned here with experience-based know-how, and the ways it is developed and used in managing temperature in the home.

3. Know-how and temperatures in the home

Various forms of know-how are involved in managing temperatures in the home. On a basic level, this know-how can involve ways of understanding and monitoring heat flows within the home,

including the different roles of the materials illustrated in Fig. 1. It can also be about managing these flows: interacting with them, adapting to them and changing them.

3.1. Know-how for monitoring heat flows

One of the most basic types of know-how involved in thermal management is that used in sensing temperature. On one level this seems simple – you either feel cold or you do not. However, people generally do not only consider their own body temperature, but also the temperature of the space around them (as discussed in Section 1). One important means of monitoring this is temperature perception through the skin (thermoception); however, as the Netmums quotes illustrate, other sensory experiences are also used, such as the feel of butter or toothpaste. A contributor to another parenting website used a visual indicator, saying, "*. . .nothing worse than a cold house. Ours was so cold we had dragon's breath every time we spoke!*".[3] Some people use thermometers, including coloured ones, to visually monitor the temperature of their home, and even smell can be used to indicate if a room is cold and damp. Some people can tell the warmest part of a home or a room because their cat or dog will sit there, perhaps moving with the sun.[4]

As well as an on-going process of monitoring, know-how about temperature can be cumulative; the thermal characteristics of a building can be learned about through the daily experience of living there. People may learn which parts of the home are warmest or coldest, and at what times of day and year; for example, an east-facing room that is warm in the morning. Similarly, the following comment on a US-based design blog[5] illustrates how people learn about sunlight in their homes:

> "*Like many others, we lacked for experience and it didn't even cross our minds when the home was purchased years ago. . . that the large covered porch in our southwest facing backyard would obscure the light all day. But. . . experience = knowledge*"

A related process is monitoring flows that are undesirable and lead to heat-out-of-place. This includes understanding how heat escapes from the home, and the role of different building elements in this. Temperature perception plays a part here; for example, regarding heat loss through the floor; "*A cold timber floor will make your feet cold . . .The under-floor space can be a very cold windy place*".[6] However, this is not the only relevant sense; vision is also useful in helping people understand heat loss. Energy advisors sometimes use thermal imaging to show people where heat is escaping from their windows, walls, roofs and so on, while a similar, but low-tech approach uses snow, as illustrated in this UK blog quote from winter 2009: "*at this time of year, there is a much easier way to see how much heat your roof is losing. . .the best insulated roofs will not melt the snow for days*".[7]

Draughts are one major form of undesirable heat flow, and can be felt as a breeze or coldness in a particular location, or heard as "*the whistle of wind as it sweeps through the property*".[8] They can be made visible by curtains blowing, or by "*light peeking in along your floor*" when a door is closed.[9] Spider-webs are also used as a sign of draughts[10] and in certain US locations, the presence of Chinese stink bugs can indicate that a house is not airtight.[11] Some people also engage in a more deliberate way, to identify undesirable heat flows. This can use touch, for example, they can "*press gently on the glass to see if there is any give in the way the glass sits in the frame. If the glass moves with a light touch [heat is being lost].*[12] They can also use vision: "*hold a smoking incense stick by your letterbox or at the junction of your floors and skirting boards – under kitchen units too. Is the smoke going straight up?*".[13] (Alternatively, they can buy a specially designed draught-detecting "smoke pencil"). Another method is to "*have someone on the outside blow a hair dryer around each window while you hold a lighted candle inside*" to see if it flickers.[14] The use of incense sticks, candles and hairdryers suggests creative improvisation – a theme I return to in Section 5.

In addition, people monitor when and how heat is being generated and transmitted by heating systems, using sensory experiences such as listening to the gurgle of pipes, seeing the glow of a gas-fire or simply touching a radiator. Some boilers produce steam that can be seen outside the home when they are on, if the day is cold, while radiators (especially if dusty) can produce a smell when they are hot.[15] Know-how around monitoring these heating appliances may draw on "folk theories"; for example, of how thermostats work [28]. As well as this day-to-day interaction, sensory engagement with heating systems and appliances can be more deliberate, and can be used to identify problems. A noisy central heating system can be a sign of a fault: one home improvement website says you should listen for "*Clanging Pipes*"; "*Humming Boiler*" and "*Tapping Radiators*".[16] Temperature sensing can be used to assess heat wastage from central heating: "*insulate any exposed hot pipework around the [hot water] cylinder*".[17] Feeling cold metal at the top and hot metal at the bottom of a radiator is a sign that it needs bleeding of air, while cold metal at the bottom may mean the system needs cleaning.[18] There are also sensory clues used to monitor the performance of building fabric; for example, some forms of condensation in double-glazing can be a sign it is faulty.

So it seems that one form of know-how used in keeping homes warm is a practical and home-specific understanding of heat flows, and ongoing monitoring of them. People may learn about these flows through daily experiences, and also, potentially, through more active or deliberate sensory engagements. However, controlling temperature does not only involve understanding and monitoring flows, but also managing them.

[3] http://www.essentialbaby.com.au/forums/index.php?/topic/789283-ducted-gas/ [accessed 10.03.14].
[4] http://www.catbehaviorassociates.com/keeping-your-indoor-cat-warm-in-winter/ [accessed 10.03.14].
[5] http://www.houzz.com/ideabooks/8745893/list/House-Hunting–Look-Carefully-at-the-Light [accessed 10.03.14].
[6] http://www.ecomaster.com.au/download/Fact_Sheet_ecoUnderfloor.pdf [accessed 10.03.14].
[7] http://www.libdemvoice.org/more-on-energy-efficiency-begining-at-home-11386.html [accessed 10.03.14].
[8] http://www.energysavingtrust.org.uk/Take-action/Improve-your-home [accessed 10.03.14].
[9] http://www.doityourself.com/stry/morereturn#b#ixzz2doxwAF20 [accessed 10.03.14].
[10] http://www.ccicenter.org/ViewArticle/tabid/109/ArticleId/6/Air-Sealing.aspx [accessed 10.03.14].
[11] http://www.treehugger.com/corporate-responsibility/how-chinese-stink-bugs-helped-inspire-one-man-to-save-35-on-his-home-heating-bill.html [accessed 10.03.14].
[12] See note 9.
[13] http://www.superhomes.org.uk/resources/green-your-home-building-fabric [accessed 10.03.14].
[14] http://www.franklamparelli.com/environmental/tips [accessed 7.04.14].
[15] http://www.ehow.com/info_12108475_causes-home-radiator-odors.html [accessed 10.03.14].
[16] http://homeimprovement-quote.com/noisy-central-heating-how-it-can-be-fixed/ [accessed 10.03.14].
[17] http://www.talkaboutdebt.co.uk/community/blog/nights-are-drawing-in-so-its-time-save-energy-and-money [accessed 10.03.14].
[18] http://www.mumsnet.com/Talk/good_housekeeping/a1342832-Help-radiator-cold-at-bottom-but-hot-at-top [accessed 10.03.14].

3.2. Know-how for managing heat flows

As Fig. 1 suggests, managing energy flows to keep a home warm involves interacting with a wide range of material elements, and experiential know-how seems to play a part in this. Vannini and Taggart focus on "off-grid" heating practices, and their findings provide a particularly clear illustration of experience-based learning. One of their participants said about his wood stove: "*Cooking is an art, and so is warming up a house. Finding the right intensity is not easy, but "you get a feel for it. . . you can almost feel when it's time to add another piece of wood to the fire to keep it going*"" [3] (p74). Drawing on Thrift [29] (p70), Vannini and Taggart argue that these off-gridders show a skilful comportment, as they go about "*improvising solutions, assessing failures, and exercising creativity*" (p79) within their heating practices. This know-how develops through:

> "*. . .a process of education of their attention (after Ingold, 2000 [30]). Throughout this process their sense of thermoception becomes "attuned" to the atmosphere of their homes (after Stewart, 2011 [31]), by becoming more sensitive to the changing temperatures of their domestic surroundings, by becoming more aware of the affordances of their technologies, of local climate and resources, and of global environmental forces, and by becoming more sensitive toward their needs and preferences*" [3] (p79).

It could be argued that this skilful comportment is not necessary for people with central heating systems. However, while recognising a difference in intensity of involvement, I would suggest that keeping conventional on-grid homes warm also involves a complex set of practices, demanding skills and drawing on sensory engagements. For example, Gabriel and Watson [4] (p228) found that one "on-grid" couple who participated in their Australian study, "*had an intimate knowledge of their house, including its heating and plumbing systems and thermal performance. They used passive methods (e.g. opening/closing windows and curtains) where possible. . . They monitored and measured their use*". Their know-how also meant they could use the waste heat generated by their poorly performing electric hot water system for bread-making and airing laundry [4]. Similarly, central heating systems are sometimes talked about as having their own "peculiar ways" to be learnt; for example; "*Boilers are notoriously temperamental, especially when they're old and are fired up again after the summer*".[19]

Electric storage heaters are often described as requiring a process of learning through experience because the user must set the controls to draw in the right amount of energy overnight, and also ensure they do not use up this stored heat too quickly: "*finding the "sweet spot" can be a matter of trial-and-error*".[20] So it could be argued that someone with storage heaters needs an engagement with technology, building performance, local weather and their own habits (where will I be tomorrow, when, doing what, and for how long?) that is as intense and experiential as someone with a stove. There is also experience-based know-how about other products and appliances, such as the best place to position portable heaters, how to use magnets to clean a central heating system, and ways of "balancing" radiators, among many other tactics and techniques. Heat flows are also managed through interactions with the more structural elements of the home, such as walls, floors, roofs, doors and windows, which are critical in preventing heat loss. For example, one way to reduce heat loss from the home is swapping light summer curtains for thick winter ones, and adding door curtains; this can be done each year, in response to weather changes.[21] Another form of know-how is skill in carrying out improvement works [32], such as installing loft insulation, which may be acquired through experience.

A final point is that people creatively improvise when using materials in temperature management. Examples of methods that have been attempted include using an oven to warm a house; using tea-lights under flowerpots to heat a room (as suggested by the Daily Mail newspaper, but not by fire-safety experts[22]); and leaving a hot shower running "*because the more steam in the air, the better the temperature will feel*".[23] (Although others suggest **reducing** humidity; for example by using a microwave rather than hob for cooking[24]). Other tactics include placing tinfoil behind radiators,[25] "*rigging a makeshift cloth "tent" over your bed*",[26] using a fan to blow air across a heater, or running a ceiling fan clockwise.[27] A commenter on one US advice site[28] provides details of how they make a bed-warmer;

> "*I pour 1-2 pounds of cheap white rice into a singleton cotton athletic sock. . . I often double bag the sock just in case I missed seeing any small holes through which the rice might leak. For our microwave it takes 1-3 minutes to heat it to the desired temperature - depending on the size of the rice bag and how hot we want it*".

Another commenter gives their own method: "*Take a clean hand towel, fold it in half, and tightly sew up two sides to form a sleeve. It's best with a sewing machine. Fill it to not quite full with uncooked rice. . .*", while a third says, "*I use an actual wine bottle. I heat the water up in the microwave, cork it and slip it into an old sock so the too hot glass doesn't touch my skin*." These tips on "the best way" to do it, and how to avoid potential problems, suggest know-how acquired through experience. Another US blogger writes that they once "*put a foil wrapped baked potato at the foot of my bed*".[29]

Improvisation also occurs with regard to people's management of heat loss from the home. Examples of this include applying clingfilm to windows with a hairdryer; using newspaper, bubble-wrap, duvets, rugs and old clothes as draught-excluders and window-insulators[30,31,32]; putting a pillow up an unused chimney; and using papier-mâché to fill floorboard cracks.[33] Much creativity seems to go into homemade draught excluders, from "*cutting an old pair of tights and stuffing them with socks*"[34] to elaborate animal-shaped designs. Whatever approach is taken to managing heat

[19] http://www.policyexpert.co.uk/how-to-avoid-a-home-emergency-this-winter/ [accessed 10.03.14].
[20] http://blog.sparksdirect.co.uk/how-to-use-a-storage-heater-to-stay-warm-in-this-cold-winter/ [accessed 10.03.14].
[21] http://canadianfinanceblog.com/top-15-ways-to-save-money-on-heating-your-house/ [accessed 10.03.14].
[22] http://www.dailymail.co.uk/sciencetech/article-2492549/Video-reveals-heat-home-using-just-TEALIGHTS-FLOWERPOTS–costs-just-8p-day.html [accessed 10.03.14].
[23] http://cynna.hubpages.com/hub/Handy-Ways-to-Keep-your-House-Warm-this-Winter- [accessed 10.03.14].
[24] http://www.nigelsecostore.com/blog/2013/11/06/top-20-low-cost-ways-to-keep-warm-this-winter/ [accessed 10.03.14].
[25] http://www.bbc.co.uk/news/magazine-24757144 [accessed 10.03.14].
[26] http://www.wikihow.com/Stay-Warm-at-Home-Without-a-Heater [accessed 10.03.14].
[27] http://housewares.about.com/od/coolingheating/f/ceilfanrotation.htm [accessed 10.03.14].
[28] http://www.thesimpledollar.com/ten-tricks-for-staying-warm-this-winter-without-huge-energy-bills/ [accessed 10.03.14].
[29] http://jezebel.com/5869444/how-to-keep-warm-in-your-freezing-cold-house [accessed 10.03.14].
[30] http://tlc.howstuffworks.com/home/winterize-home-poisoning-family.htm [accessed 10.03.14].
[31] http://www.bbc.co.uk/news/magazine-24757144 [accessed 10.03.14].
[32] See note 26.
[33] http://www.telegraph.co.uk/property/propertyadvice/propertyclinic/7306173/Mind-the-floorboard-gaps-use-papier-mache-or-foam.html [accessed 10.03.14].
[34] See note 31.

flows, sensory experience can play a part in assessing success; for example, feeling a room is warmer.[35] It seems that monitoring heat flows and intervening in them are ongoing and interconnected parts of the skilful and sensory work of thermal management.

4. Know-how as dynamic

While know-how seems to be built through experience, it is important to note that people and materials are not themselves static, and the home is not a closed system. This means that know-how does not accumulate in a simple, linear way, but forms and reforms in response to the changing relationships between people and their material and social environments. This section describes three forms of change: in the life-course; material arrangements; and shared understandings. It does not intend to fully represent these wide fields of inquiry, but to outline some relevant processes.

4.1. The life-course

A key source of change in know-how seems to be ageing. The links between age and thermal comfort have been explored from a biological perspective; for example, "*physiological changes associated with ageing affect an individual's thermoregulatory capacity and several respondents in their eighties commented on becoming far more sensitive to the cold with the passing years*" [33] (p494). People may develop new forms of know-how to manage this sensitivity; some examples are listed on a Johns Hopkins website, and include eating a meal before going outside, and avoiding alcohol.[36] Know-how may also be affected by changing physical capacities; for example, Gabriel and Watson [4] describe challenges an elderly couple experienced in controlling their heating system, partly due to impaired mobility. Other forms of know-how may change; for example, Day and Hitchings [34] identified tactics developed by older people to keep warm, while avoiding stigmatisation as "frail", such as using a blanket or hot-water bottle in the living room, but tidying it away before visitors arrive. Having an elderly relative move in may also mean that other family members develop new know-how; many specialised tactics are listed in one forum for carers struggling to keep relatives warm,[37] including ways of heating beds that are safe for older or ill people.

Even more noticeably, the birth of children seems to demand the development of new know-how, as evidenced by many publications and websites providing advice to parents on the heating needs of children, and how to monitor and manage temperature; for example, the use of colour-changing temperature sensors (some in toy form); placement of cribs relative to windows and radiators, safe ways to heat bedding, methods for checking a baby's temperature, and use of heaters at night.[38,39] In general, changes to the composition of the household (people joining, leaving, or changing in their needs) seem to have the potential to trigger new patterns of home-warming practice, involving new forms of know-how.

4.2. Material arrangements

Moving house is often described as a potential moment of change in consumption practices [35], and can trigger know-how development, as people gradually "learn their home". This may be especially notable if the home is different to previous ones; for example, a house instead of a flat, a larger/smaller property, or a different heating system. For example, a Netmums user writes of her storage heaters: "*I was leaving them on all day and night at first as I didn't know how to use them, then towards the end of winter I worked out how to use them. . . I'm used to good old radiators*".[40] The age of the building is also important, with many older homes having less efficient building fabric and more leaks to manage, while in a recent construction the challenge may be getting adequate ventilation or preventing over-heating; either way the new resident may learn through experience.

Even within one home, changes to material elements may stimulate new know-how. The nature of change will depend on the technology in question – it may require new expectations and routines; for example, a heat pump that provides heating at a constant low level. But even smaller changes like new thermostatic radiator valves or blinds will create new opportunities or limitations in the management of heat flows. Studies have explored householders' responses to micro-generation and cooling technologies [4,36–38] and smart meters [39–41]. However, to date, few studies have focussed explicitly on shifts in know-how associated with these changes. A key question is how technologies can shift the distribution of know-how within the system of the home, including its distribution between human and non-human entities [42]. Competence may be delegated [43]; for example to "smart" heating controls, such as those that learn the occupant's habits with the goal of minimising heat-out-of-time and heat-out-of-place. Further work on these processes, and their effect on human know-how, would help shed light on "*the mundane ways in which a home and its inhabitants transform one another*" [4] (p221).

4.3. Conventions and shared understandings

A third process that affects know-how is change in conventions and shared understandings on the social scale. Know-how for thermal management is not just about techniques, but also about what it means to keep a home warm, and what is normal, desirable and possible. For example, Hitchings [44] suggests that communities of practice and social networks have the potential to influence people's thermal comfort norms and behaviours. Another study found that older people prefer to keep windows open at night, due to beliefs about the associated health benefits that are prevalent in that cohort [45]. Experience seems to be important here; for example growing up without central heating, or seeing parents and grandparents live without it, can have a lasting effect on views of what is normal and possible. One UK blogger writes that many people,

> "*. . .seem to think it's a feat of human endurance to live without central heating. Like millions of people, I grew up without any heating. The fire was lit in the front room on a Sunday and we sat in front of it with drying wet hair. . . We have a wood stove in our living room . . .Living without heating certainly isn't a hardship. . ..*

[35] http://www.permaculture.co.uk/readers-solutions/cheaply-increasing-energy-efficiency-old-home [accessed 10.03.14].
[36] http://www.johnshopkinshealthalerts.com/alerts/healthy_living/metabolism_aging_3832-1.html [accessed 10.03.14].
[37] http://mikegamble.websitetoolbox.com/post?id=4973584&goto=nextoldest [accessed 10.03.14].
[38] http://community.babycenter.com/post/a23010113/is_it_okay_to_put_babys_crib_under_a_window [accessed 10.03.14].
[39] http://www.mumsnet.com/Talk/products/675833-Small-cheap-room-heater-for-keeping-baby-warm-at-night/AllOnOnePage [accessed 10.03.14].
[40] http://www.netmums.com/coffeehouse/house-garden-194/kitchen-household-14/66921-how-many-you-have-storage-heaters-had-oil-heatin-all.html [accessed 10.03.14].

In comparison to the home of my childhood, I live in the tropics and I certainly don't need central heating".[41]

In a study by Wright [33], older participants reported that in their youth, central heating was unavailable and they now consider it a luxury. It seems that experience of a particular object's presence or absence can lead to a lingering perception of its normality or abnormality. For example, one UK heat-saving blog says, "*The thicker the curtains the better. As a child my parents had both summer and winter curtains. The winter curtains were thick and velour*".[42] These perceptions shift with changes in an object's prevalence, as seen with the increasing normalisation of air conditioning in Australia [13]. Generational shifts in home-warming conventions are also exemplified by a US family forum thread entitled, "*When is everyone changing their winter curtains over to the summer ones?*". One poster replied (in early May), "*I do it in our bedroom & plan on doing it this weekend. . ..Growing up, my mom did the entire house!!!*".[43] This suggests that this practice may be persevering, but also eroding over time; what was once seen as normal is now seen as extreme. There may be an intergenerational transmission of warming practices and know-how, but this does not necessarily mean perfect replication. This brief review of the wider landscape around home-warming know-how reflects Shove et al.'s [46] idea that competences, materials and understandings co-evolve through mutual dependencies.

5. Reflections and implications

Having described some ways in which experience-based know-how is developed and used in managing temperatures in homes, it is possible to reflect on how this relates to theories and concepts of know-how, and the implications of these ideas for research, policy and practice.

5.1. Knowing-how: a conceptual framework

The question of how knowledge relates to experience is a complex and long-standing one, concerning thinkers at least as far back as Aristotle, and there is not scope for a detailed examination here. However, based on an overview of the field, and drawing especially upon Wilhite and Wallenborn [7], it is possible to identify and group the most relevant concepts, and build a (non-exhaustive) picture of some relations between know-how and experience. This conceptual framework can then be usefully applied to the practices of thermal flow management already described in this paper. First, a fundamental lesson from the literature is that know-how and experience are connected as part of a continuous and ongoing process. Know-how is "*an ongoing social accomplishment, constituted and reconstituted as actors engage the world in practice*" [47] (p249), so can be understood not just as a stock of knowledge but also as a process of knowing-how [21]. This fits the examples discussed in this paper, which illustrate the evolving nature of know-how for managing thermal flows. In looking more closely at how knowing-how occurs, two clusters of concepts emerge as significant. These can loosely be labelled as "negotiating with arrangements and flows" and "absorbing and embedding know-how". These are simultaneous and interconnected processes through which experiencing and knowing-how are mutually constructive.

5.1.1. Negotiating with arrangements and flows

This large category encompasses the processes of appropriating, accommodating, interacting and improvising that occur between a person and the materials, flows and social arrangements they encounter in daily life. Regarding materials, these processes include "tinkering" [48]; a process of getting things to work that is "*opportunistic, contingent, local and idiosyncratic*" [49] (p125). Pickering [50] similarly speaks of "tuning", or a "*dialectic of resistance and accommodation*" between human actors and material things; a reciprocal process in which habits, skills and ways of doing things are developed and applied. These negotiations involve responding to the affordances and scripts that are embedded in material things [51,52]. They also involve creative appropriation of materials for other purposes [51] and *bricolage* [53]; tactical re-employment of the materials to hand, improvising and making-do.

Of course, it is not only materials that are negotiated with; Collins [54] points out that some forms of knowing-how (such as knowing what it means to perform a practice in a particular cultural context) are gained through social interaction and negotiation with conventions. The communities of practice literature suggests that practical learning can be intensely social, as novices in a particular practice often gain know-how from interactions with more experienced practitioners through "legitimate peripheral participation" (taking a recognised "beginner" role in activities, such as being an observer or apprentice) [55]. As touched upon in Section 4, there are important social dimensions of know-how for keeping warm, though further exploration is beyond the scope of this paper; see Day and Hitchings [34], Hitchings [44], Hards [56] and Wilhite et al. [57].

Applying these ideas to thermal management, we can understand the various skills, techniques and improvisations described in Section 3 as negotiations with the material arrangements highlighted in Fig. 1, and with the thermal flows they carry. This echoes Jalas and Rinkinen's [15] understanding of heating work as involving negotiations between bodies, fuels, heating technologies and other forms of equipment. Practices such as adjusting thermostats, draught-proofing and insulating have many characteristics of tinkering or tuning, as people experiment, use feedback, and test the possibilities and limitations of specific materials. Pickering's [50] reciprocity is also apparent here; for example, when interacting with a storage heater, the person is "tuned" as much as the object, as they learn to use its input/output settings, or adapt their habits around it. (And some materials may resist human tinkering; for example, complex or inaccessible heating controls). When they experiment with homemade solutions, people are exploring the affordances of bubble-wrap, hot potatoes or even old socks, and engaging in forms of appropriation and *bricolage*. As Certeau's [53] concept suggests, these practices represent tactical alternatives to more permanent, structural and commercially provided (often expensive) options for home-warming. The Australian couple that used waste heat for airing and bread-making [4] took a slightly different approach – rather than tinkering with their "resistant" materials they simply appropriated the undesirable thermal flows.

These negotiations involve using and developing diverse forms of know-how, including practical skills and abilities – a form of knowledge that Baumard [58] labels as *techne*, drawing on classical Greek philosophy. Examples of *techne* would be the ability to programme the central heating, bleed a radiator or install loft insulation. But home-warming also draws on more subtle and creative skills, similar to what Baumard labels *metis* – a form of intelligence that is creative, intuitive and tactical, often drawing on "ruses" and "short cuts"; for example, inventing homemade bed-warmers, using snow-melt instead of thermal imaging, or an incense stick instead of a specially designed "smoke pencil". Negotiating with mutable or intangible things is a key dimension of *metis* [58], which

[41] http://www.frugalqueen.co.uk/2012/10/living-without-central-heating.html [accessed 10.03.14].
[42] http://blog.vebra.info/index.php/six-ways-to-keep-warm-this-winter-michelle-wilden/ [accessed 10.03.14].
[43] https://www.lifamilys.com/chat/topic-when-is-everyone-changing-their-winter-curtains-over-to-the-summer-ones-152535-1.html [accessed 18.01.14].

suggests it may be particularly relevant to the management of thermal flows. As well as heat constantly moving between materials and spaces within the home, outdoor temperatures fluctuate, and routines and needs vary both in the short and long term (for example, with the life-course changes mentioned in Section 4). This may be why the knowing-how involved in managing temperatures often seems to be flexible, responsive and creative.

5.1.2. Absorbing and embedding know-how

This category concerns the ways in which experiences become absorbed or embedded, and produce lasting changes in the body and mind, as a form of memory. Brain plasticity is a concept used in neuroscience to refer to the brain's ability to change as a result of experience. Wilhite and Wallenborn [7] extend this to discuss the plasticity of the body, referring to people's ability to learn new physical habits and capacities. This is related to the concept of habitus [59]; dispositions that are acquired through experience, and accumulate as a kind of sediment. Habitus is the process by which knowledge acquired from experience is "made one's own" [7]. These dispositions then make certain forms of action more or less likely in future. Duguid expresses a similar idea when he says that developing know-how "*can usefully be thought of as learning to be*" [24] (p113). This is a continuous process that occurs as part of the negotiations described above; with every new experience, dispositions are reassessed and refreshed with new possibilities [7].

Applying this idea to thermal management, we can understand many of the processes described in Sections 3 and 4 as involving the absorption of warming know-how and its embedding within the mind and body. This includes the development of embodied skills such as lighting and maintaining a fire, and of mental routines, such as adjusting the settings on storage heaters. The concept of absorption also applies to the perceptions of air-conditioning and central heating discussed in Section 4. When people are exposed to a particular technology they may absorb or internalise a sense of its normality, creating an enduring disposition to use it. Equally, childhood experience of seasonal curtain-switching seems to have, in one case, embedded a disposition to continue this, but one which is weakening over time, perhaps due to a changed social context. This fits with the concept of plasticity, which implies something can be continually remoulded, rather than setting rigidly into a given form. In addition, some authors suggest an underlying form of know-how involved in home-warming (or energy use more generally), which is variously described as a sensitivity or skilful comportment [3], responsiveness [4] or attunement [60]. These terms hint at an ongoing engagement that is not necessarily on a conscious level. These ideas build on the concept of plasticity and "learning to be", implying that minds and bodies can (in some circumstances) be reconfigured through experience, resulting in new "attuned" ways of sensing, thinking and acting in relation to thermal flows.

5.1.3. Sensation, situation and temporality

If experiential knowing-how involves two main processes (negotiation and absorption), it also has three important characteristics. First, both negotiation and absorption fundamentally involve sensation; they are grounded in physical cues [27], and bodily interactions [7]. This reflects the many examples cited here of how sensory experience is involved in negotiating and absorbing home-warming know-how, from seeing dragon-breath to feeling hard butter and hearing whistling draughts. Secondly, on a related point, these processes are situated and relational; the negotiation and absorption of know-how depend on people's physical presence, and are rooted in specific contexts [27]. As the theory of situated learning suggests, the formation of practical knowledge is dependent on the activity, context and culture in which it occurs [55]; this means know-how about keeping warm is often specific to a particular place and time, and embedded in a particular thermo-material culture [16]. People have to learn about their own homes and appliances, and when they move house, or install a new device, this triggers changes. Knowing-how can also be described as relational because it is bound up with the connections between people, materials and flows; as shown by, for example, the changes associated with family members and social conventions discussed in Section 4.

Thirdly, these processes are temporally complex. Negotiation and absorption occur simultaneously and affect each other, but there is also an inherent inertia or legacy: embedded know-how means that present and future actions are shaped by past experiences [7]. This is shown above in the cases of central heating, air-conditioning and winter curtains; "*previous socio-technical assemblages have left a residue*" in present practices [61] (p38). In addition to the temporalities of memory and social transition, there are also dynamics associated with people's life-course trajectories (as described in Section 4) and the ongoing accumulation of know-how within "careers of practice" [62].

In summary, we can describe two broadly defined processes that link experience and know-how: negotiating with arrangements and flows; and absorbing and embedding know-how. These processes are sensory, situated and relational, and also temporally complex. This provides a basic conceptual framework that helps to describe and explain the process of knowing-how in thermal management, and potentially also in other practices.

5.2. Reflections for policy and practice

It is also possible to offer some reflections in relation to policy and practice, in the context of current debates on public knowledge about energy. There is a common perception that many people suffer from a lack of basic know-how about keeping homes warm, with research highlighting incorrect understandings of thermostats in the US [28], "energy saving myths" in the UK [63] and poor understanding of low-carbon technologies [2]. A recent review by the UK Energy and Climate Change Committee [64] emphasised the need for greater "energy literacy", while a newspaper called the country "*a nation of buffoons who can't work thermostats*" [65]. The most basic policy response to this problem – simply providing factual information – is now seen as largely ineffective [66]. This is often linked to the fact that energy is invisible [39] and intangible [60], with the corrollary that we need to find more effective ways to transmit energy knowledge, such as smart meters.

However, this view has been critiqued by those who suggest that "*people are never just using energy*" [17] and so we should rather focus on the practices they perform, which may happen to require energy consumption. If we are interested in the knowledge that is relevant to these practices, this paper suggests that a key concern should be the competences, skills, routines, attunements and working knowledge of the home that are involved in the monitoring and management of energy flows. The nature, role and development of these different ways of knowing-how are areas requiring further work, but these ideas could have significant implications in the context of the "energy literacy" agenda. Wilhite and Wallenborn [7] argue that energy policy should promote "*exposure to new ways of doing things, such as demonstration home projects allowing people to observe and experience new technologies and life in low energy houses*". There are already early signs that experiential learning is being used in policy, for example, with the new "Green Open Homes" Network set up by the UK Department of Energy and Climate Change, and some evidence [67] suggests hands-on learning has the potential to change attitudes and behaviours around energy. Know-how-sharing approaches might benefit particularly

from considering the practical knowledge held by older people, and how this could be passed on to younger generations.

However, exploring know-how should not mean adopting a simplistic approach that focuses only on individuals, and neglects wider practices and systems. It is important to consider how know-how relates to wider social and technical contexts (as touched upon in Section 4). There is not scope here to explore these ideas fully; however, one example of an integrative (non-individualistic) approach to know-how might be to examine its relationships with the design of materials. Strengers and Maller [13] argue that policies should prioritise infrastructures which provide "adaptive opportunity"; contexts in which people can control their own thermal environment. In a similar way, it might be valuable to design objects and homes in ways that support knowing-how. An example of where this has **not** happened is described by Brown et al. [68]. They noted that some tenants were told by their landlord not to touch the controls of their new solar systems, and that,

> "*Such an approach serves to frame the technology as potentially mysterious and possibly risky... Of particular concern to a number of tenants was the lack of intuitive design of the controls of heating and ventilation systems which made using them increasingly frustrating for the user.... the tenants in this research report a sense of powerlessness and resignation when confronted with control systems*" (p2171–2173).

This suggests that one consideration for policy and practice could be the creation of affordances for the development and application of knowing-how. This might mean designing the material things that are involved in heat flows to be more user-friendly, transparent and accessible. In addition, evidence suggests that expectations around cooling can be modified by prioritising adaptive methods of achieving comfort [13], so it is possible that expectations of warmth might also change if people have more opportunities to develop and use know-how. Policy and practice might benefit from considering technologies, expectations and knowing-how in this interconnected way.

These ideas complement very recent work on the social dimensions of energy, such as Shove et al.'s [16] work on thermal flows, Wilhite and Wallenborn's [7] work on the body in energy practices, and Gram-Hanssen's [1] work on know-how. Building on this literature, this discussion suggests new ways of talking about energy, and its consumption in the home. First (as noted at the start of this paper) it may be unhelpful to talk about "energy" *per se*, but rather about practices that involve the use of energy [5,8]. This approach could have wide-ranging effects on policy discourses at all scales, for example, rather than discussing energy security, with its connotation of plentiful fuel supply, we might focus on thermal security (alongside other energy services); a concept that perhaps suggests more diverse opportunities, from adaptive practices to improved building efficiency. Secondly, rather than seeing home-warming as a simple linear process where electricity and gas are inputs and heat is the output, it is helpful to see it as a system of flows [16]. This reminds us of the complex and dynamic processes through which heat is generated, transmitted, contained and released, and of the roles played by numerous material elements. Thirdly, rather than talking about thermal comfort only as an outcome, it is helpful to talk about thermal management as an ongoing achievement, or form of "work" [15], involving diverse tactics, techniques, habits and skills. Bringing these ideas together, we can say that managing the temperature of a home involves monitoring and intervening in thermal flows, and that this demands various forms of know-how. This seems to be true even for those in homes where a significant amount of work is delegated to technologies, albeit perhaps to a lesser degree.

Finally, this paper highlights the role that experience plays in the ongoing process of knowing-how. This suggests a need for more experiential language in policy, practice and research; a recognition of how people understand and monitor heat flows using their vision, hearing, touch and so on, and how they use their senses in managing these flows. This is already done to an extent by actors such as the Energy Saving Trust, for example, in its online advice about how to identify heat wastage. However, more generally, "*Current energy policy largely collapses perception into visual and cognitive learning (relative prices, rebates, payback times, coloured and numbered energy efficiency rating systems), ignoring the other senses (including proprioception and sensory-motor perceptions) that are involved when a practice is performed*" [7]. It might be valuable for engagement activities or interventions to pay greater attention to the experiential know-how used in other energy-using practices, such as lighting, showering, food preparation, laundering, and home entertainment.

This brief exploration suggests that there may be many ways in which experience-based know-how is used in the thermal management of homes. However, it is important to note some limitations. First, there are other forms of knowledge which are also important in home-warming, such as factual or theoretical knowledge. Experience-based know-how may be imperfect or inaccurate, and does not inevitably facilitate effective, efficient and sustainable forms of energy use. In addition, know-how is not only formed through direct personal experience – it can also be transferable through communication and social interaction (as discussed in the communities of practice literature [55]). It would equally be simplistic to suggest that experiences have straightforward or predictable effects on people's know-how. People sense differently, and learn differently, and this means that generalisations on this topic are problematic (though there may be collective and cultural patterns in perception) [7].

However, this exploratory review suggests a valuable opportunity for further empirical work. As well as the main issues already raised here (how is know-how involved in monitoring and managing temperature? How does it develop through experience, and change over time?), there are other research questions to consider. For example, how is knowing-how differentiated (*e.g.* gendered) and how it is evolving through the generations? What know-how is being lost, and why (are some forms of knowledge becoming devalued or stigmatised)? What new ways of knowing-how are emerging? Another question concerns how know-how for home-warming is integrated with other aspects of people's lives, and the "transferable skills" used in managing temperatures. Given the subject matter, appropriate methods could include "sensuous ethnography" [3], home visits, tours, photos and videos, within a hands-on and experiential approach to data-gathering. Experimental approaches could also be used to explore ways of sharing know-how about keeping homes warm, and their effects. Empirical work to test, develop and apply these techniques would be valuable.

The ideas outlined here are necessarily tentative and require further investigation. But this review suggests that thermal management does not only involve knowledge about kilowatt-hours, degrees centigrade and *U*-values, but also the experience-based know-how that enables people to monitor and manage heat flows. Because this is constantly reconstituted through experience, we can speak of a process of knowing-how. This process occurs through two main dynamics: (1) negotiation with material and social arrangements, including the many materials that help to generate heat, move it around, or prevent its movement; and (2) the absorption and embedding of know-how within the body and mind. Physical and sensory experiences are fundamental to these processes. In addition, ways of knowing-how are situated and

relational, evolving with shifts in material and social arrangements. Finally, knowing-how is a temporally complex process, bound up with the dynamics of habit and memory, as well as with life-course trajectories and wider transitions in social practice.

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