‘It’s ffffffrrreeezsing! . . . thought thermal imaging might shed some light as to where the heat’s going!’ Can visualisation shed a light on heating?

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Abstract

This paper approaches the phenomenon of energy visualisation (eviz.org.uk) by investigating the expectations of building householders when they sign up for a thermal image to be taken of their own home.

It can take something of an ‘act of faith’ for householders to believe that energy efficiency actions will translate in to greater comfort and lower energy use (Shove, 1997). Technologies that visualise energy (specifically heat) can be used to infer and locate building defects in order to improve energy efficiency. Thermal imaging is of interest as a communication tool; offering householders an ‘independent’ analysis of building performance, providing an image outside of the human visual field. The image of radiant surface temperature can be used to infer where unwanted heat loss or cold air ingress occurs in a building. Recent research has shown that using the images as a behavioural intervention can trigger efficiency actions and reduce the carbon footprint of a home (Goodhew, Pahl, Auburn & Goodhew, 2014). The present paper aims to understand householder expectations of thermal images, in order to develop better protocols and address potential misunderstandings.

We discuss householder’s expectations of thermal images, drawing on findings from a UK study. As part of a wider thermal imaging intervention study, 231 residential building householders explained why they were interested in accessing thermal images of their own home. Thematic analysis of the data showed a preoccupation was specifically pinning down ‘where’ their home ‘lost heat’ as an adjunct to prioritising future improvements, informing investment strategies and to confirming the efficacy of previously taken energy efficiency measures. But the responses suggest another narrative; of building behaviour mysterious to the householder, of elusive heat loss (‘how much loss’/‘where?’) of uncertainty over the efficacy of energy efficiency measures already taken (the ‘act of faith’).

We discuss what it is about heat that needs visualising for households, what this tells about the context of domestic heat conservation and whether energy (heat) visualisations, such as thermal imaging, can meet these householder expectations.

Introduction

Thermal imaging as a means of communicating energy issues in buildings has received much interest in recent years. In some instances, thermal images have become the image to link to advertisements for energy efficiency products such as double glazing (e.g., Anglian Home Improvements) or for the media to attach to an article discussing energy waste or efficiency (e.g., MP’s Really Are Full of Hot Air, 2014). They are perceived to be able to prove claims of energy efficiency. In addition local councils and community groups in the UK (e.g., Newburgh, The Blewbery Energy Initiative, Low Carbon Oxford North), and further afield (West Vancouver, BC) have used thermography as an engagement tool for communicating energy conservation in buildings. The UK provides an interesting scenario within which to study householder response to interventions such as thermal imaging, since the UK has ‘one of the oldest and least efficient housing stocks in Europe’ (Boardman et al., 2005, p. 38), and householders are encouraged to upgrade their homes.

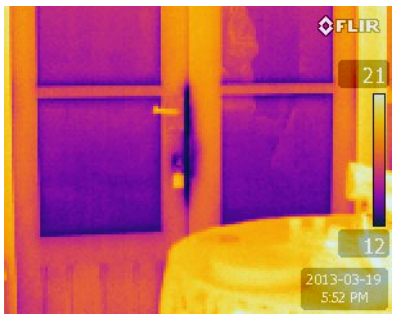

Figure 1. Thermal image showing a draught or cold air ingress entering the house from the join at two doors.

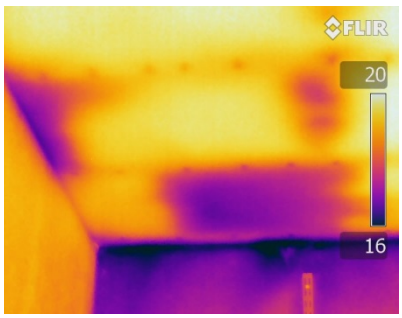

Figure 2. Pointing the camera at the ceiling can reveal patches of missing loft insulation.

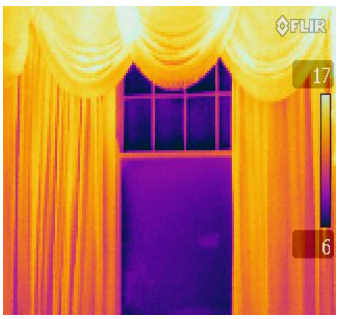

Figure 3. Pointing the camera at the window can reveal the extent of the cold ingress from windows where the curtains are open at night.

Thermography can be used as a technology to render the normally invisible flow of heat, around and through the home, visible. Thermal imaging technology aids the diagnosis of specific building related defects and can be used as a means of inferring heat escape from a building, such that action can be taken to limit that escape and conserve energy (Pearson, 2011). Thermal images show the infrared radiation from the surface of the building and the apparent surface temperature of the house. In colder climates, by comparing temperatures in the image, it may be possible for the viewer to infer where heat, and so energy, could be conserved in the home. Thermal images can be taken from the outside (on cold, dry, windless, dark evenings) or the inside of the house (Pearson, 2011). The images tend to demonstrate where curtailment or efficiency energy saving measures could be applied, such as draught proofing (Figure 1), loft insulation (Figure 2), closing curtains (Figure 3). Of course, the images are dependent on each individual house and while images are specific to each house, they also have the potential to illustrate issues common to a range of houses.

The rationale for community groups and councils using thermal images seems to be underpinned by the assumption in the title of this paper, that thermal imaging can visualise heat and so can 'shed a light' on the use of heating in buildings. In the sense that thermal images can visualise unexpected heat loss and thereby suggest energy efficiency actions, community groups are correct in this basic assumption. The term 'shed a light' on is an idiom referring to illuminating revealing or clarifying an issue, but, when something needs illuminating; it suggests that it is hidden. If so, what exactly about heat needs illuminating?

Many researchers have recently called for energy visualisation (e.g., Hargreaves, Nye & Burgess, 2010) although what exactly the visualisation entails varies. For example, Hargreaves et al. (2010) suggests that representing energy use on a smart meter counts as visualisation; arguably this is more abstract than our thermal imaging approach, which directly converts heat loss in to a visual format. None the less a 2013 follow up of householder response to such visual information detailed a mixed effect. Householder's knowledge and confidence about energy consumption increased, but so did their awareness of the 'limitations to their energy saving potential' (Hargreaves, Nye & Burgess, 2013, p. 126).

There is a wealth of information available on retrofit measures (insulating the loft, floor, walls, hanging curtains, closing windows, draught proofing) available in the public domain (Energy Savings Trust, 2015). So why would householder's desire further 'revelations' using a thermal camera? One possible reason is that taking energy efficiency measures relies on practical knowledge or know-how (Gram-Hanssen, 2010). Thermal images can (but not always) provide that know-how in revealing the location of missing insulation or draughts, (where in the building it is) and providing a hint towards how to fix it (In Figure 1 for example, placing draught proofing at the door or even putting curtains up at the doorway might mitigate the cold air ingress). Do householders require this practical guidance, when requesting a thermal image of their own home and if so why?

Simple energy efficiency measures can be taken easily by the householder but more complex measures such as cavity wall insulation and the installation of more efficient glazing require specialist expertise, provided at a price. Images might be regarded as an independent source of such information. But the advice given by installers and building surveyors is sometimes clouded for the receiver by the knowledge that those providing advice have an agenda; to make some sort of sale. A thermal image might be regarded as a means of corroborating energy efficiency advice to add independent weight to a decision to proceed with a retrofit measure. Further, it can take something of an act of faith for householders to believe that energy efficiency actions will translate in to greater comfort and lower energy use (Shove, 1997). There is a certain quality of 'the emperor's new clothes' about some actions. Improved glazing for example, looks very similar to the unimproved glazing, the householder has to believe the promise of the installer of higher efficiency and it is not possible to see how glazing works to warm the home. Take the installation of cavity wall insulation in UK homes. A householder signs up to allow a company to pressure insert a material that expands and spreads in to the gap in the walls of the house, but rarely is it seen and it has to be taken on faith that it is there, until after the work is done, when the householder should feel the warmer home as the benefit. In this context of invisible measures, it might be reasonable to require a thermal image to help in assessing the efficacy of such actions.

Additionally and related to above, domestic energy use is a difficult topic to communicate easily and intuitively. So are householders interested in thermal images to help them understand energy efficiency in a different, more intuitive format? Researchers have argued that energy conservation should be communicated in a manner which has meaning for the householder (Parnell & Popovic Larsen, 2005) and so that energy use

becomes conspicuous (Burgess & Nye, 2008). Midden, Kaiser and McCalley (2007) have described technology as having the capacity to mediate our experience of the natural world, providing new views, emphasising certain aspects, transforming perceptions of a phenomena by providing direct sensory experience. These can go beyond traditional verbal communications and can better reveal cause and effect relationships. Thermal images, it has been argued, can enable learning about 'the nature of physics and the dynamics of the energy system' (Giacomin & Bertola, 2012, p 550) in the context of physics education. However, taking 'real time' images of people's own domestic homes is more personal and idiosyncratic. In seeing heat, do householders want their experience of heat use to be mediated by technology; to 'shed a light' on the physics of heat? Or is it pure curiosity? Thermal images use the infrared spectrum. This is a part of the visual spectrum a phenomenon which we humans cannot view, unaided, and in this sense it is tantalising to have an opportunity to have this viewpoint 'revealed'. The opportunity to see that which is normally invisible can attract attention to issues of energy conservation (Gardner & Stern, 1996).

So, when householders take an interest in seeing images of their home in heat, what are they hoping for, what do they want to 'shed a light on' and what can these expectations tell researchers about energy conservation? This paper turns the focus not on a thermal image intervention but on householders' interest in that intervention. As part of a wider study, the opportunity arose to ask householders about their interest in receiving thermal images of their own home. An open ended, survey response format was used to capture householders' free and unconstrained explanations.

Method

PARTICIPANTS AND DESIGN

Participants were householders in Cornwall, South West England who were offered a free thermal image visit as part of a wider research project which used thermal imaging as a behavioural intervention. Participants were recruited via social media and with email invitations sent to 9,000 householders who had expressed an earlier interest in joining the Cornwall Together project (a project aimed at enabling householders to switch to a cheaper energy supplier). Initially 980 participants (542 males) signed up for the project. Of these, the majority were homeowners (94 %) who lived in houses (86 %) as opposed to flats or mobile homes, maisonettes. Two hundred and thirty one of the initial cohort completed the survey. Householders were randomly allocated to one of 3 conditions for the behaviour intervention study and received one of 3 intervention types: 1) A tailored thermal image of their home (this involved a visit from a thermographer and images taken of the inside and outside of the home) or 2) a report on energy efficiency containing thermal images of generic homes (displaying typical energy efficiency defects) or 3) a text only report on energy efficiency (Boomsma, Goodhew, Goodhew & Pahl., 2014, under review). About 2 weeks after receipt of the intervention, householders were asked to complete an online survey. Within this survey one question was included 'Can you explain briefly, in the box provided below, why you were interested in having your home imaged? Feel free to write as much or as little as you want to'.

ANALYTICAL APPROACH

The qualitative responses to the question were captured in a spreadsheet format and analysed per participant using a thematic approach, through NVivo software. Themes were generated from recurring words, ideas and reasons given in the response. These were captured and counted. Using a constant comparison approach, themes were compared and refined to develop a final set of themes which emerged from the cohort of responses.

Results and Discussion

THEMES

Two hundred and thirty one participants responded to the by writing short paragraphs that explained their interest in having the thermal images taken of their homes. Five themes were common and recurring amongst the cohort (Figure 4). Each theme is explained below and illustrates sample quotes.

Theme 1: Where we lose heat

Participants most frequently cited the theme of 'where' or 'where we lose heat' as a reason for wanting to see the thermal images of their home (Figure 4).

1. "To see **where** heat was escaping."
2. "To see **where** the heat was leaking out."

So, whilst on one level it is obvious that participants would want to use the thermal imaging for such a purpose (seeing heat is the main function of the camera), on another level these responses suggest a certain amount of mystery about where the home leaks heat. Quotes 3, 4 and 5 explain that the source of the coldness in their home is not clear to them and that it is in fact difficult to detect where heat in the home goes to. Quote 5 refers to heat having a route of heat loss.

3. "Interested to see **where** the cold comes from."
4. "It is hard to detect **where** heat is being leaked."
5. "To understand the main route of heat loss"
6. "Keen to minimize the amount of money spent on heating my house. Without technology like thermal imaging it is hard to detect **where** heat is being leaked away."
7. "Although I knew which parts of my house FELT cold, I wanted to see if there were any areas that I had not noticed."

Some participants added a little more rationale. Participant 8 is a little puzzled, s/he is a householder who appears to acknowledge that energy is wasted but left wondering 'where'.

8. "Would like information as to **where** our energy resources are wasted."
9. "Hoped I could find **where** best to spend time & money on economically reducing my heating bills."

Additionally, the need to know where the heat loss occurs has a rationale. Participant 9 and 13 want to prioritise the 'greatest' heat loss so that the heating bills can be reduced and Participant 9 and 11 have a problem; that of maintaining heat in the house. Participant 11 feels there are aspects of the home which

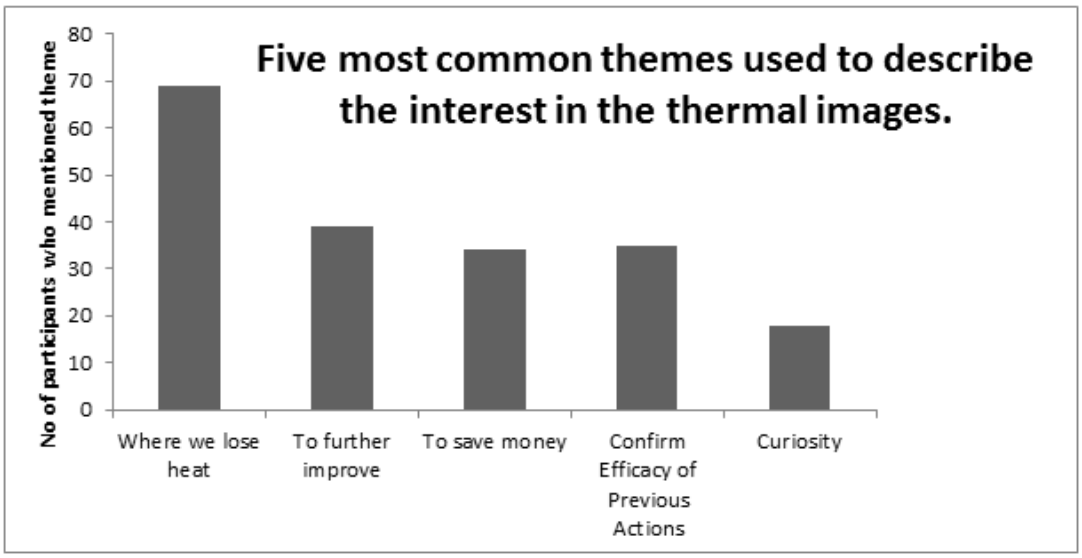

Figure 4. Five most common themes used to describe the interest in receiving thermal images.

are as yet unconsidered and mentions reducing the carbon footprint as a motivator.

10. "We have problems maintaining heat in the house. As we only have one storage heater when the house gets cold it gets very cold indeed and is difficult to warm up again. We supplement our storage heater with panel heaters in the bedrooms and an electric fireplace, but rather than generating expensive heat I was keen to find out **where** we are losing heat and how to go about fixing the problem."

11. "I am happy to embrace any technology which enables me to reduce my carbon footprint, and so was interested in seeing just **where** in my property improvements could be made that maybe I had not considered."

12. It's ffffffrrreeezsing, heating costs a fortune, I'm fed up being cold … thought thermal imaging might shed some light as to where the heat's going!"

13. "We hoped to have some evidence of where heat was escaping and so be able to act to ameliorate the worst areas first."

Participant's desire to find out where heat was leaking was often very situation specific.

14. "An opportunity to see **where** heat loss is happening therefore incurring higher energy costs. We have wood suspended flooring and always felt that heat was being wasted through them."

15. "Just to see how much heat I was losing through my old Georgian sash windows, and thick walls."

16. "I have an old grade 2 listed house and know it isn't insulated as well as modern houses. We have old thin glass in our windows and doors and floorboards with gaps where drafts come through. I wanted to know **where** the worst hotspots are."

Theme 2: To Further improve

A second theme was the desire to further improve the home. This was generally where households had already taken well-known measures and were unsure how to obtain any further benefit.

17. "Despite taking all the usual suggested insulation tactics, we still have a high utility bill so was interested to see if there were any areas for further improvement."

18. "To find out any heat loss and how I can address the problem, I have done as much as I know needs to be done but modern technology will no doubt tell me more."

19. "I was about to undertake some upgrading work and thought an independent appraisal would be useful."

Theme 3: Saving Money

Quote 7 already illustrates the expectation that the thermal images might provide new information that would help to reduce the cost of heating the home.

20. "Hoped I could find where best to spend time & money on economically reducing my heating bills."

21. "To better understand what could be done to improve heat losses from the house and thus potentially reduce energy bills."

22. "Keen to minimize the amount of money spent on heating my house."

Theme 4: Confirm the efficacy of previous actions

Participants hoped that the thermal images would illuminate the efficacy of previous actions taken to conserve energy; and the narrative here suggests measures taken, but with uncertain or disappointing consequences for the householder. The earlier quote 14 hints at an expectation not met and 18 a mistrust of the level of workmanship involved in providing the efficiency measures.

23. "Wanted to check to see if the cavity insulation had been done properly as the bungalow still feels cold."

24. "The energy survey provided by the estate agent stated that there was no cavity wall insulation. The engineer said the walls did have cavity insulation and so I could not have it done. I would like to know who was correct."

25. "I have tried many insulation and draught proof measures and wanted to see if and how well they have worked."
26. "I have installed all the obvious energy savers at my property and would have liked to monitor how/if they perform in practise."
27. "To show the heat loss of our type of house. To prove the insulation already partly in place is making a difference."
28. "I have already used lots of ways to try and insulate my home, but still find it hard to keep warm. Any advice is therefore appreciated."

Theme 5: Curiosity

There were householders who expressed simply a curiosity in seeing the thermal images, although often this was qualified with a statement which refers back to theme 1 to 4.

29. "Morbid curiosity."
30. "For the purposes of energy research and out of interest in what our house 'looks like."
31. "Curious following purchasing (sic) new double glazing."

OVERALL DISCUSSION

Taken together, 5 themes provide the main reasons why 231 householders were interested in seeing thermal images of their own homes. Their responses provide an insight in to the context of domestic energy efficiency, into householder expectations of visualisations using the thermal imaging technology and so in to the role that visualisations can play. We argue that these householder responses suggest an interesting narrative around the context of energy efficiency in buildings. Firstly, heat is regarded as an elusive entity, not totally understood. Secondly, there is a narrative of householders running up against the limit of the actions they can take to stay warm but save energy. Thirdly, there is a narrative of uncertainty (or even disappointment) in the efficacy of previously taken energy efficiency measures.

The main theme (where heat is lost) suggests that householders in the cohort wanted to see thermal images because energy efficiency is set within a context of quite mysterious building physics. Heat, in relation to the fabric of the building, behaves in an elusive and mysterious way, heat loss is known about but hard to detect and find. In this sense energy conservation seems beyond the control of the householder. This is not in any way to suggest that our householders were lacking in knowledge, neither is this to suggest that a deficit should be filled with lots of information on buildings and heat; our householders were looking for something different and new in the images. The thermal image was expected to be able to detect heat escaping out of the home, to locate the source of leakage for the householder such that the repair or cure could be considered and possibly applied.

Householders wanted situation specific information and this focus on how to deal with specific and different building materials suggests the tension between achieving energy efficiency in a building whilst also meeting other needs (the period features of a home for example). Making retrofits to achieve optimum energy efficiency requires quite extensive practical knowledge or know how (Gram-Hanssen, 2010) and buildings are widely idiosyncratic in the UK in terms of their construction type, materials, location and age. Householders are aware of these idiosyncrasies and don't always feel confident that they have that know how specific to their own home. 'Not knowing what to do' is a recognised barrier to action in the environmental domain (Gifford, 2010).

Thirty-nine of the householders (17 %) wanted the thermal images in order to further improve their home. This is not the narrative of householder inertia (as described by the UK governments Energy review report, in 2006). Rather this is a segment of householders motivated to do more to save energy and stay warm, but at the limit of either their knowledge or the available actions; 'I have done as much as I know'. In other words, these householders were turning to visual technologies to open up new actions that would save energy and keep them warm. This is an interesting pattern, in that householders can go through the available' menu' of actions to save energy (insulate, draught proof and so on, until they have exhausted the 'to do' list available to them and then where do they go? Householders look to the visual thermal imaging technology for guidance as to further energy efficiency actions, but they are beginning to reach the limits of the actions available to them. Hargreaves documented that householders, in using the technology of smart meters, run up against and therefore become aware of the limits of the steps they can take to save energy (Hargreaves, 2013).

Related to know how and confidence is uncertainty. The householders had some uncertainty about external advice. This segment of householders wanted to do more but questioned the independence of available advice and thereby questioned whether their needs were paramount. Householders (15 %) wanted to confirm the efficacy of previously taken energy efficiency measures. This tells us that these householders have uncertainty that the energy efficiency actions they have already taken have translated into the more comfortable homes and lower energy use that they expected (Shove, 1997). This raises questions about workmanship and householder expectations around the efficacy of energy efficiency measures.

Can visualisation and specifically thermal imaging meet the needs of these householders and if so, what does it tell about the role that visualisation has to play in energy efficiency. The householders in our study were asking for thermal imaging technology to make visible the relationship between heat and their building, given the context of mysterious and elusive heat. Midden, Kaiser and McCalley (2007) have described technology as having this capacity, to mediate our experience of phenomena. The thermal camera can render heat loss into a more direct, sensory, visual communication format, but importantly, this visualisation provides a new view of the phenomena (Figures 1, 2 and 3), which goes beyond traditional verbal communications and can better reveal the physics of heat and buildings and better represent the cause and effect relationship between the heat/buildings and efforts to conserve energy (Giacomin, et al, 2012; Midden et al, 2007). The householders in this cohort were asking for this type of mediation in order to identify and understand the energy conserving actions available to them. Thermal images can 'tell the viewer more' about heat, they can help with some aspects of know-how and can represent the efficacy of actions to a certain extent. They can be used to provide specific, practical evidence of defects that need fixing when the visual array show draughts and missing insulation for example (provided that there are defects there to see, that the thermal

images are taken as per the recommended protocols, by qualified personnel who understand building construction and that the images are interpreted correctly). This visual is readily understandable. However, householders may be asking for a lot from visuals and technology. Thermal imaging, it is after all a technology which shows the infrared radiation from the surface of the building and the apparent surface temperature of the house. Thermal images cannot provide broader judgements on 'good' or 'bad' homes or assess the overall efficacy of, for example, cavity wall insulation. In this sense, householders might expect too much from such a visual technology.

LIMITATIONS AND FUTURE RESEARCH

One limitation of the paper is that the cohort of responses came from a group of householders already motivated enough to sign up to receive a free thermal image. Care should be taking in generalising these findings to the wider public. However, if an already motivated cohort find heat loss puzzling and elusive, then this is likely to be the same for a less interested sample. Further, it tells us that a motivated sample of householders still do not feel that they have exhausted all of the voluntary ,energy efficiency measures available to them. A second limitation is that the question to householders was asked after the householders received an energy saving intervention. It is possible that their response to the question was clouded by the intervention they received. However, the qualitative responses are from all householders, independent of their intervention type. Similar recurring themes were evident across all householders and were quite specific examples of why they wanted the images, in this way we have no evidence to suggest that responses are anything but householders recall of why they signed up to receive the thermal images. However, future work can revisit this.

These findings touch on other aspects of visualising heat; that of trust in advice and workmanship. There is also the regard that visualisations provide an independent viewpoint. These are topics for further exploration.

Conclusion

In conclusion, thematic analysis of householder responses to the question asking them to explain their interest in receiving a free thermal image of their home, showed a preoccupation in specifically pinning down 'where' their home 'lost heat' as an adjunct to prioritising future improvements, informing investment strategies and to confirming the efficacy of previously taken energy efficiency measures. Thermal images, in visualising heat, can illuminate some of these uncertainties. But these responses suggest another narrative; of building behaviour mysterious to the householder, of elusive heat loss ('how much loss'/'where?') and of uncertainty over the efficacy of energy efficiency measures already taken (the 'act of faith'). In sum, householders appear to see thermal images as powerful tools that can provide answers and help them understand the mystery of home energy.

References

Anglian Home Improvements. Retrieved from https://www.youtube.com/watch?v=hmFh0Wz8VKs.

Boomsma, C., Goodhew, J., Goodhew, S. & Pahl, S. (2014). Improving the visibility of energy use in home heating: Thermal images and the role of tailoring (under review).

Burgess, J. & Nye, M., (2008) Re-materialising energy use through transparent monitoring systems. *Energy policy* 36, p. 4454–4459.

Department of Trade and Industry. (2006) *The energy challenge: energy review report*, Department for Trade and Industry, London.

Energy Savings Trust. Retrieved from http://www.energysavingtrust.org.uk/domestic/ 14th Jan 2015.

Gardner, G.T., Stern, P.C. (1996) *Environmental Problems and Human Behavior*. Boston, MA: Allyn and Bacon.

Giacomin, J. & Bertola, D., Human emotional response to energy visualisations (2012*) International journal of industrial ergonomics* 42, p. 542–552.

Goodhew, J., Pahl, S., Auburn, T., Goodhew, S., (2014) Making heat visible; promoting energy conservation through thermal imaging. *Environment and Behavior*.

Gram-Hanssen, K., (2010) Introducing and developing practice theory – Towards a better understanding of household energy consumption' Proceedings of the Sustaining Everyday Life Conference. Retrieved from http://www.ep.liu.se/ecp/038/006/ecp0938006.pdf.

Hargreaves, T., Nye, M. & Burgess, J. (2010) Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. *Energy policy,* 38, p. 6111–6119.

Hargreaves, T., Nye, M. & Burgess, J. (2013) Keeping energy visible: Exploring how householders interact with feedback from smart energy monitors in the longer term. *Energy policy*, 52, p. 126–134.

Midden, C.J.H., Kaiser, F.G., McCalley, L.T. (2007) Technology's Four Roles in Understanding Individuals' Conservation of Natural Resources. *Journal of Social Issues* 63 (1), 155-174.

MPs really are full of hot air! (2014, Jan). Daily Mail. Retrieved from http://www.dailymail.co.uk/sciencetech/article-2549532/MPs-really-hot-air-Thermal-imaging-reveals-famous-buildings-leaking-heat-Houses-Parliament-WORST-culprits.html.

Parnell, R., & Popovic Larsen, O., (2005) Informing the development of domestic energy efficiency initiatives: An everyday householder-centred framework. *Environment and Behavior*, 37 (6), p 787–807.

Pearson, C. (2011) *Thermal imaging of building fabric*. BSRIA Guide, BG39.

Shove, E. (1997) Energy knowledges. Retrieved from http://www.eceee.org/conference_proceedings/eceee/1997/Panel_4/p4_14.

Shove, E. & Guy, S., (2000). *A sociology of energy, buildings and the environment: Constructing knowledge, designing practice*. London: Routledge.

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