# THE IMPACT OF THERMAL IMAGING ON USERS' PERCEPTION OF ENERGY CONSUMPTION: THE ROUND HILL PROJECT

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In the UK, a significant proportion of energy consumption is associated with buildings, with the single highest sector being housing. Due to this high proportion of energy consumption, it is important to focus on household energy use in order to meet the national energy reduction targets. Whilst measures such as the Energy Performance Certificates (EPC) have been introduced to help homeowners identify how they can improve energy performance of their properties, there have been criticisms as to their effectiveness. To understand how further improvements could be made on energy consumption, a preliminary study was carried out on 10 households using thermal imaging to highlight energy loss to homeowners and subsequently ascertain the impact it had on their perceptions as opposed to the EPCs alone. The findings of this study were promising indicating that in many cases, the use of thermal imaging alongside EPCs had a much greater impact on user perceptions. This paper presents findings from a larger sample size conducted in the Round Hill residential area of Brighton. The area has approximately 1000 homes and the sample selected is representative of the overall household types of the community. Thermal imaging was conducted and presented to occupiers in addition to interviews to identify user perception of thermal efficiency in their properties. Unlike the preliminary study, financial constraints were found to have little influence on how householders perceived energy use and thermal efficiency. Householders believed in improving their properties but living in a conservation area meant they had many restrictions on how much they could change. As part of community engagement, recommendations from the findings of this study will be disseminated to the Round Hill community and other similar areas in city of Brighton and Hove with similar construction methods in order for residents to make useful improvements to thermal efficiency of their dwellings.

Keywords: thermal imaging, energy loss, Energy Performance Certificates, householder perceptions

## INTRODUCTION

Reduction of energy consumption and energy loss are often used in similar contexts in the UK (Armitage *et al*., 2015). Improving the thermal performance of existing buildings have proved difficult and these are based on numerous factors including energy efficiency uptake trends, financial restrictions and overall public awareness (Dowson *et al*., 2012). Key issues identified with many of the existing housing stock across the nation are poorly performing solid walls, single glazed windows, uninsulated roofs and floors as they

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dissipate most of the heat energy in the households (Ibid.). Remediation of the above issues require a holistic approach. Thus factors such as financial constraints cannot be resolved without incorporating a good understanding of the needs of the building fabric such as traditional listed buildings (see Menconi *et al*., 2016). This research follows an initial study that was conducted to ascertain whether Energy Performance Certificates (EPC) alone were capable of helping householders to reduce energy consumption of households (see Aboagye-Nimo *et al*., 2016). The initial paper concluded that more techniques were needed to be incorporated (e.g. visual aids such as thermal images) in order to help householders understand and manage energy consumption more efficiently. In this paper, the standard EPCs are used alongside thermal images to help householders in a 'conservation area' gain a better understanding of their property's energy loss and which areas to tackle as a means of attaining thermal efficiency.

A literature review on household energy consumption in the UK is presented first. This is followed by a description of the setting of the case study namely the *Round Hill Conservation Area* in Brighton, UK. Following this, the research methods and the findings of the empirical work are presented. The paper is concluded by highlighting the practical implications of the study and recommendations for future research.

## HOUSEHOLD ENERGY CONSUMPTION

The thermal efficiency and energy performance of UK housing are governed by the Energy Performance of Building (Certificates and Inspections) Regulations2007 (Parkinson *et al*., 2013). This follows the European Union Directive 2002/91/EC; Directive on the energy performance of buildings (Official Journal of the European Communities, 2003). EPCs are used as the main means of measurement of energy performance of households in the UK (Davis *et al*., 2014). Thus is has a direct impact on householders' perceptions of thermal efficiency and energy performance (Ibid.).

### Energy Performance Certificates

Energy Performance Certificates (EPC) are certificates issued by certified assessors who examine households based on insulation, heating systems and window types to evaluate a particular property's energy efficiency (Parkinson *et al*., 2013). EPCs show property details such as address, type (e.g. detached house), date of inspection, certificate date and floor area (Department of Energy and Climate Change (DECC), 2013). The DECC set energy consumption targets in a scheme known as 'The Carbon Plan' whereby emissions would be cut by at least 34% by 2020 and 80% 2050. Figure 1 shows a typical Energy Efficiency Rating and Environmental Rating section of the EPCs where property owners and occupiers can see scales from A to G. EPCs offer rating scales from 'A' to 'G'.

Figure 1 shows that the property being used as an example has a current energy efficiency rating of low D (57). The property has the potential to attain a rating of high D (68). Also, the property's carbon emissions have a grade E (50) rating but could be improved to grade D (61). The EPC gives householders a suggestion of how much they could save financially. These ratings are supposed to help occupiers make their properties perform more efficiently. However, there are grave concerns that these depictions are not motivating people as much as they were intended to (see DECC, 2013; Amecke, 2012). Such concerns led to the initial concept of this study.

### Thermal Imaging as a Solution?

In innovative building surveying and defect diagnosis practices, thermal imaging is very helpful in indicating heat loss areas of buildings (Gade and Moeslund, 2014). Thermal

imaging is the technique of using the heat given off by a building or object to produce an image of it or to locate it (Titman, 2001).

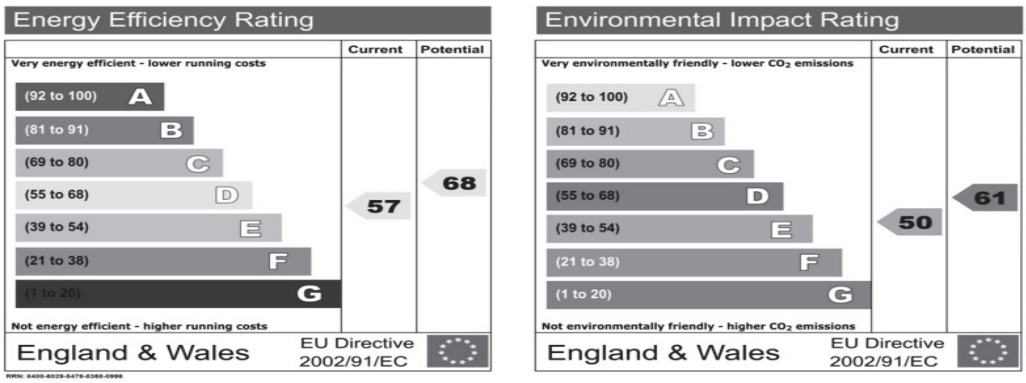


*Figure 1: typical EPC (Source: Oakwood Energy Group, 2016)*

It is a non-invasive method of testing structures (Ibid.). They give more accurate information on heat loss areas and defects such as cold bridging etc. (Gorse *et al*, 2016). Temperature scales are produced alongside thermal images to show users spot temperatures and temperatures of surrounding surfaces (Ibid.). As the EPCs do not show how buildings can make improvements, pairing them with thermal images have been recommended to help better inform occupiers (see Aboagye-Nimo *et al*., 2016).

The location and nature of the Round Hill Conservation Area is presented next.

**Round Hill Conservation Area**

The Round Hill area falls under the purview of Brighton and Hove City Council. The council offers a detailed history of the area on their dedicated webpage (see Brighton and Hove City Council, 2015 for further detail). The Round Hill area was developed in the 1860s. Local materials were used in the 19th century when the development of the area began. Materials such as bricks were not readily available in the region and hence would have been expensive if they had been adopted. The main indigenous materials at the period were flint and bungaroosh but harder cements, replica stone, and made render (for aesthetic value) became more popular with time. Most of the buildings in the area were originally rendered and had timber sash windows. Welsh slate roofs were previously used for most of the buildings but most of these have subsequently been replaced with concrete tiles. Although most of the development was carried out in the late 19th century, there were a few additions in the 1920s.

An area of 12.05 Hectares (i.e. the Round Hill area) was designated as a conservation area on 6th January 1977. The left hand section of Figure 2 shows a general map of a section of the city of Brighton and Hove. The right hand section of the image (which can also be traced to the larger map) shows an outline of the Round Hill Conservation Area.

The scope of this research project is specifically targeted at the Round Hill area described above. The data collection methods are presented in the following section.

## RESEARCH METHODOLOGY

This research utilises case study research methodology with a single case and multiple units of analysis. A case study is a phenomenon is intensively investigated in its natural or conventional setting, where a variety of data sources are used (Benbasat *et al*., 1987). It is popular in social sciences and has a long history in many other disciplines (Creswell, 2007) building upon a constructivist paradigm (Stake, 1995).


*Figure 2: Round Hill Area (Google, 2017 and Brighton and Hove City Council, 2017)*

The robustness of case study as a methodology is argued for by highlighting that " a fatal flaw in doing case studies is to conceive of statistical generalization as the method of generalising the results of the case study" Yin (2009:38) because cases are not sampling units and should be treated as experiments (Tsang 2013). Furthermore to elaborate on the single-case (and multiple-units) studies, Yin (2014) suggests that thinking in such confusing terms as “small sample size of cases” - as if a case were equivalent to a respondent in a survey - should be avoided, to aim towards analytic generalisation. A mainly qualitative approach was adopted for this study hence the views and opinions of the respondents were sought over numerical and statistical outcomes (Fellows and Liu, 2015).

In collaboration with the Round Hill Society (see The Round Hill Society, 2017), this research project has an overall aim of establishing a continuous long-term working relationship with local communities in Brighton and Hove under the University of Brighton's Community University Partnership Programme (CUPP). Thus a longitudinal study into occupants' behaviours and social trends has commenced.

Data collection for this research was carried out in three different chronological phases. The initial phase was a structured interview of householders followed by collection of thermal image data in the second phase during heating season in 2016. The final phase comprised semi-structured interviews with householders using information collected from the initial phases.

In order to carry out a study with findings that are valid and reliable, it was important that robust and ethical measures were taken into consideration during the data collection stages (Fellows and Liu, 2015).Since the data being collected was specific to a relatively small locality, ethical measures were critical to the overall integrity of the study. Participants were informed of the confidentiality and anonymity that would be used while handling their information especially personal opinions and household choices.

**Phase One: Structured Interviews**

Building upon the advantages of structured interviews, where an interviewer can administer questionnaires based on standardised and predetermined questions (Fellows and Liu, 2015). and where the standardised schedule of this approach helps with the specific themes or topics being explored (Saunders *et al*., 2009), in this phase, the questions sought to gain insight into the states of households such as recent improvements or alterations in relation to thermal energy loss and sustainable measures that had been adopted. The time householders had owned/occupied their properties was also asked in

order to gain an overview of the common practices available at the time of moving in. Furthermore, participants were asked to give their views on their EPCs and whether they believed they could further make changes based on the certificates.

Having gained an overview of the physical states and layouts of the various properties, a selection of participants/properties were selected for thermal imaging. A purposive sampling method was used in order to gain a generalizable outcome of the Round Hill area. The selection criteria included number of bedrooms, number of floors, types of windows, and occupants' views on EPCs. That is, so that the research team was ensured that every type of house in the area was represented in the study. More importantly, because the Round Hill area was developed in phases, it was imperative that every street was also represented in the research.

**Phase Two: Thermal Images**

Thermal images of chosen households were captured on a winter night to ensure that the heat loss of households would be captured more accurately. In order to ensure that the various properties would fall under similar/controlled conditions, the chosen properties were asked to turn on their heating systems prior to and during the period of data collection.

The original photos and thermal images were taken from consistent locations/angles in order to give the research participants (householders) a contextualized view of their properties' heat loss patterns. Figure 3 shows a thermal image of a bay window of one of the households used in the study.

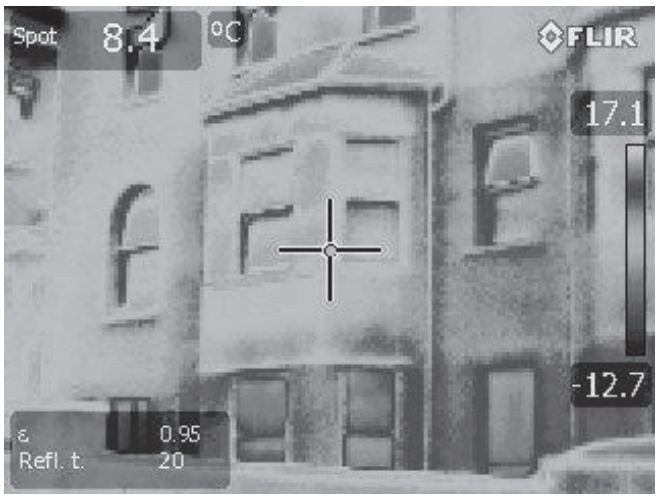


*Figure 3: Thermal image of a bay window in the Round Hill Conservation Area*

In the image, it can be observed that the basement is radiating more heat in comparison to ground floor. A total of 40 properties were included in the thermal imaging phase.

**Phase Three: Semi-Structured Interviews**

Semi-structured interviews were subsequently conducted with the householders included in the thermal imaging phase. The participants of the semi-structured interviews were solely or partly responsible for making decisions in the household with regards to energy consumption. Open-ended questions were used to encourage participants to share their views and opinions on the various topics presented. The questions and topics ranged from general issues (e.g. climate change/global warming) to very specific issues (e.g. how they had attempted to reduce energy consumption and improve thermal efficiency in their various properties). The interviews were recorded (with participants' permission) and

transcribed verbatim. Views presented in the findings and analysis section of this paper are attributed to pseudonyms and not the real names of the respondents for ethical reasons.

## FINDINGS AND ANALYSIS

In this section, findings and analysis presented include the current state of the housing stock. Furthermore, the thermal efficiency of these properties according to householders will be discussed. The general awareness of participants with regards to the technical aspects of the properties and the participants' views on adopting innovative measures will be explored.

### Round Hill Housing Stock and Participants' Awareness

To a large extent, many householders were aware of technical components of their properties. It was revealed that during the processes of improving thermal efficiency and carrying out routine maintenance works, occupants had conducted personal research on the technical components of their buildings and subsequently contacted tradesmen to work on their properties.

Many of the participants of the study had altered their properties by some means. The main areas that had been altered included sash windows, loft space insulation, chimney breasts and draught proofing.

Efforts had evidently been made to improve the thermal efficiency of the properties. Many of the properties were also considered as work in progress. Anthony stated that he and his partner were looking forward to making further improvements:

> I am planning on renovating the area by the basement front door as a lot of heat is lost. A new door was fitted in 2009 but draught still comes from that area as the door had to be eased because it did not open during prolonged periods of wet weather. - Anthony

Similar to Anthony, other householders implied they wanted to make improvements to their properties in order to save energy and cost. Most participants had some form of idea about how they wanted to improve their properties' energy efficiency.

Brian, who works as a professional in construction, indicated that many of his neighbours had made *'supposed improvements'* to their properties but were ill-advised and hence had inherited residual issues or defects including condensation and damp. Although he explained that he was happy to share his wealth of knowledge with other householders, he admitted that he had not had the opportunity and time to do so.

### Thermal Efficiency and EPCs

EPCs were shown to not have influenced participants' views. Particularly, many participants could not find their EPCs or had not received new ones after making improvements. When asked about the thermal efficiency of their properties, the participants all agreed that thermal efficiency was a problem in the area. The responses regarding this thermal efficiency included the following:

> Not efficient, like many loosely constructed Victorian properties. Sanded floor boards in hallway and two reception rooms on ground floor have no insulation beneath and, just 18 inches above bare earth, will suck in cold air. - Hannah

> [We are] Looking to replace the bathroom window and improve draught proofing in front bays when I next overhaul them. This is a conservation area so strictly I should not install UPVC replacement windows, and would not in any case change the front sliding sash bays as they are part of the way the house should look. - Matthew

There was a general opinion amongst the participants that there were inherent thermal efficiency issues with the type of housing in the Round Hill area. The above views were expressed before the introduction of thermal images. Most participants believed the main way they were losing heat in their properties was because of the windows and doors, and this was yet to be confirmed or debunked using thermal images.

Following the collection of thermal images, participants were then introduced to the collected data. Figure 4 shows one of the properties used in the study.

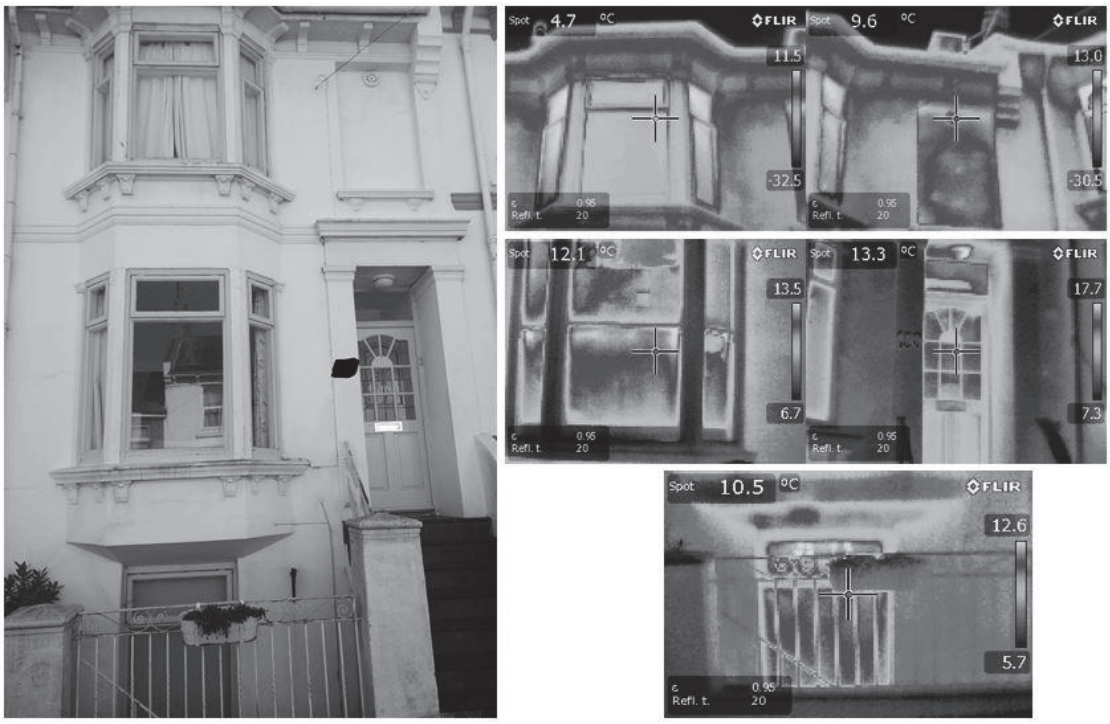


*Figure 4: Typical photo of house and corresponding thermal images*

Although Jerry (the owner of property in figure 4) thought he could not make much improvements as indicated by his EPC, the thermal image gave him a completely different opinion. He confessed that he knew he could not do much about the windows but he was *'surprised'* that he was losing heat through the solid walls. His bedroom walls upstairs were giving off more heat than his windows and this was of some concern to him. As far as he was concerned, this should have never been the case.

Some participants had also noticed that they had to heat up the basements much more than other parts of their houses and the thermal images revealed that their solid walls coupled with single glazed windows were the main reason for this loss.

**Issues with 'Hard-To-Treat' Homes**

'Hard-to-treat' homes are defined as dwellings which usually contain solid walls, no loft space to insulate, no connection to the gas network or are high-rise (Dowson *et al*., 2012). Dwellings that fall under this category cannot be upgraded easily or cost effectively using conventional measures such as cavity wall insulation, loft insulation and modern gas central heating (Ibid.). The Round Hill properties fall under this category and the participants' stories on how difficult it was to prevent draught and heat loss puts the name 'hard-to-treat' into perspective. One of the main problems with such properties is the resultant issues that arise following attempts to manage heat loss such as damp and condensation issues.

*Damp and condensation*
Damp, condensation and mould conditions were common with many of the properties according to the occupants. Although many householders had *'plastered and damp-proofed their walls'*, they were not certain that their solutions were *'100% efficient'*. An expert in restoration, David (not a Round Hill Society member) was consulted for his views and he explained that buildings of that era needed to be *'dried out for months'* in order to be certain that the damp is completely eradicated. Many of the participants believed there were simple solutions to eliminating damp issues, for example: *"We've blamed it on the windows" - Mark*

Mark had ordered new windows at the time of the study. However, David recommended a holistic approach that involved the following:

- Changing lifestyle and producing less moisture
- Better ventilation to remove moisture, whether natural or mechanical
- Improving insulation and draught proofing
- Introducing damp proof courses
- Avoiding intermittent heating

Insulation and draught proofing seemed to be the main method adopted by most of the participants. The other practices recommended in the above list had not been considered by householders.

**Barriers to Uptake of Innovative Trends**

Householders are happy to take on innovative ideas to improve their thermal efficiency and improve their overall energy consumption. In a pragmatic manner, they were all weary of the limitations. A participant stated the following:

> I think we knew it was an old house which needed a lot of help - Jerry

Due to conservation, some households are not able to place solar panels on specific faces of their buildings.

> The barrier of maintaining the conservation value of the building and therefore, you're limited in what you can do… I like living here because I love the look of the buildings Sarah

Sarah was particularly interested in *'clever ways'* to help improve energy efficiency especially with her floors. John also stressed that he was happy to take up new and innovative ideas that would help the thermal efficiency of their property as long as it was environmentally friendly. He added that he would not mind saving up enough money for such improvements giving a typical example of a £14,000 bill for recent window replacement. Unlike findings from Aboagye-Nimo *et al* (2016) and Power (2008), costs did not seem to deter the occupants of the Round Hill area as far as practical improvements were concerned.

## Conclusions and Practical Implications

This paper has presented findings from a study on the Round Hill Conservation Area in Brighton. It has been identified that property owners and occupiers in this area are keen on improving thermal efficiency and wanted to use innovative approaches to manage the hard-to-treat properties. Unlike previous studies (especially the initial research upon which the current study was based), the participants in this situation did not consider financial constraints as the main barrier to improving thermal efficiency. EPCs had not made any difference to the participants because they had accepted that conservation areas meant they would have to accept the poor thermal efficiency that came with it.

Furthermore, shortage in housing in the city of Brighton and Hove means occupants are compelled to accept their properties as they are.

Findings from this study are firstly being disseminated to members of the Round Hill Society. A community engagement meeting will be organised whereby David (the conservation expert) will discuss innovative ways of improving thermal efficiency based on the research data. The findings will be further extended to designers, housing associations, tenant associations and local councils. Also similar local communities such as Kemp Town in Brighton will be informed on how they can improve their energy performance without having to solely rely on EPCs.

As part of the ongoing project, data loggers will be placed in selected homes to assess indoor air quality of properties in the Round Hill area in the near future to shed further light on other aspects pertaining to energy refurbishment of hard-to-treat dwellings.

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