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EDITORIAL

The design and value of "early adopter" low-energy houses

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Abstract

Purpose – The purpose of this paper is to outline an early adopter "low energy" domestic dwelling, one of the social houses built by a collaboration between a university, the local council. The origins of this project are from the early days of interest in sustainable housing, the 1970s. The dwellings were innovative and built to what became known as "the Salford design" which performed to unusual specifications, using approximately 75 per cent less energy than the UK average for space heating and over 40 per cent less than for houses built to what were then the standard building regulations.

Design/methodology/approach – A qualitative and interpretative stance was deemed to be the most appropriate. Within that lens, interviews were chosen as the primary research instrument.

Findings – A marked feature of the results is the variation in energy consumption by different households. A Salford-designed house could be habitable throughout the year without any space heating at all, comfortable at 10 per cent and very comfortable at 25 per cent of normal consumption.

Originality/value – As there continues to be interest and commitment to reducing energy – not just from the United Kingdom but also on a worldwide scale – the United Nations Conference of the Parties known as COP 22 (2016) met in Morocco to take forward many of the initiatives outlined in the Paris Agreement 2015. It is of interest, then, that the latest set of interviews showed that the houses built to the innovative and original 1970s' Salford design principles, protected by highly insulated well-sealed envelopes, are even presently functioning at a relatively low energy threshold.

Keywords Climate change movement, DECC, Energy & Industrial strategy

Paper type Back matter

Introduction

During recent times, there have been major changes to the approaches to what has become commonly known as the "Climate Change Movement". The importance of this issue has continued to increase. For example, the United Kingdom altered the structure of the relevant government departments as the Department of Energy & Climate Change (DECC) became part of the newly organised Department for Business, Energy & Industrial Strategy (BEIS) in July 2016.

This project was fully funded by the award of the Vice Chancellors Iconic Project Fund (when I also worked at the University of Salford), and the author would like to thank the entire Salford team (Phil Brown, and myself, who acted as Joint Principal Investigators; the sterling work undertaken by Gareth Morris, Peter Webster and Will Swann). One of the major outputs of the funding was the opportunity to write up the full technical report which included diagrams, photos and many more design details. This was published internally by the University of Salford. Following on from this work, a conference paper was also presented to the European Council for an Energy Efficient Economy. Details of both these items are listed in the References section below.

Finally, in a project such as this, which is inevitably "on-going", thanks and acknowledgement are due to all the project team and the people who contributed, in whatever way, to the success of the work.

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In addition, the new Energy Innovation Board, which replaces the work of the Low Carbon Innovation Coordination Group, was announced by the Government in November 2016 with a focus on the ever-increasing need to reduce energy demand which has become a part of our everyday conversation. To contribute to a more sustainable society, many are becoming more thoughtful in the use of energy resources and the Energy Innovation Boards will take on the critically important role of "providing strategic oversight of public programmes on energy innovation" and of "identify[ing] opportunities for enhanced collaboration on both UK and international energy innovation priorities" (BEIS, 2016a, 2016b).

These changes are reflections of the more global changes taking place as what has become known as the Paris Agreement (when agreement to limit climate change to "within 2 (and even 1.5) degrees was reached by 195 countries" and endorsed by the United Kingdom at the 2016 Conference of the Parties known as COP 22 in Morocco. Several initiatives agreed at the meeting in Morocco included improving national carbon-reduction strategies, advancing innovation to drive forward clean energy on a global scale, increasing transparency of actions and scaling up ambitious climate finance from a range of public and private sources to avoid the most devastating effects of global warming" (BEIS, 2016a, 2016b).

In addition to the industry, business and public sector, the government is also very interested in the domestic market and the shift of the providers towards energy saving devices such as smart meters and mobile remote control, indeed, any new ways of saving energy that are likely to be of interest to both consumers and suppliers.

If we consider our usage of kettles, irons, TVs, ovens and washing machines over, for example, a New Year or similar celebration season, we can begin to get a picture of how our total energy usage builds up over a relatively short time. Although 1 per cent (total) increase may not seem very high, if we increase our usage by 1 per cent year on year, then we could potentially quickly reach alarming levels. However, the concept of sustainability, of recycling, of using less, of using more prudently our energy resources is becoming much more a part of our everyday life, and this is reflected in our increased usage of low-carbon and low-energy products.

The research outlined in this paper is based on an early adopter of low energy usage, one of the social houses that were built through an unusual collaboration between a university, a local council and new residents during the days of orange lampshades, brown carpets and swivel chairs – the 1970s. The residents are then revisited in more recent times and the results are discussed. This project is undertaken in the North of England, in the expanding city of Salford where, like in many other areas of this time, housing provision was one of the priorities of the local council.

The aim of this editorial paper is to give an overview of that project – a project to build and deliver houses of a new design with improved thermal capacity. The paper is organised in the following way. First, the background of the project is presented along with relevant literature. Next, an outline of the key design principles of the houses, details of the heating system and the performance are outlined with a narrative and analysis of what has happened to the houses 30 years on and how they fare today. The paper closes with a consideration of the implications, questions and observations regarding future developments in the area.

Salford in 1970s

In the mid-1970s, Salford City Council owned, and managed, somewhere in region of 40,000 socially rented houses. Many of these dwellings were of different designs and styles, with the vast majority of them suffering from a variety of problems including condensation, mould growth and poor thermal comfort. The energy crisis of the 1970s only added to the finding that the housing stock was becoming expensive to heat; this had significant impact on the tenants, many of whom were on low incomes and who would today be classed as "fuel poor".

To ensure that the houses could become the standard of the City's social housing stock and not "peculiarities", the new house design had to meet the following specifications:

- the capital cost of the dwelling should be no more than that of a standard dwelling of a similar size;
- it must be built using standard construction methods and materials;
- the houses must place no limitations on the normal living patterns of the tenants;
- energy consumption should be substantially lower than that of existing housing;
- maintenance costs should be no higher than those of existing housing; and
- the dwelling should be flexible concerning the type of fuel and heating appliances used.

The architects and associated designers arrived at a basic design philosophy of a high thermal capacity, highly insulated, low-energy dwelling. Two experimental houses were designed, and in 1978, these houses were built as a semi-detached pair adjacent to the University of Salford. A set of six dwellings were also built to the same specifications which became known as the Strawberry Hill properties.

Literature

At the time of construction of the Strawberry Hill properties, the United Kingdom was in the midst of an energy crisis because of the supply and price of oil. The UK Government established the first Department of Energy to address this issue, although this mainly focused on supply-side issues of developing gas fields in the North Sea (Jenne and Cattell, 1983). It was in the context of this "landscape driver" of rising energy prices that the energy-efficient houses were developed. These large-scale issues, such as the oil crises, have been identified as key drivers in developing niche innovations by Geels (2005) as a response to new realities. Energy policy has changed over the last 40 years, with the energy "trilemma" of climate change, fuel poverty and energy security forming the backbone of the current energy policy (Gunningham, 2013). But in many cases, the responses of low-energy homes has been similar to those developed by Salford City Council, with similar examples being undertaken in Milton Keynes in the 1980s (Summerfield *et al.*, 2010) and the United States of America (Parker, 2009).

While the drivers between Strawberry Hill and later examples of low-energy homes may have changed, the impact of homes on our energy consumption remains important. While energy efficiency standards have increased, particularly through the introduction of Part L recommendations (Lowe and Oreszczyn, 2008), the demands for internal comfort and the level of warmth have increased over the period. Energy consumption in our homes has fallen over time, in many cases driven by energy programmes such as the Carbon Emissions Reduction Target (CERT) (Jenkins, 2010), currently replaced by the Energy Company Obligation (ECO), the Communities Energy Saving Programme (Reeves *et al.*, 2010) and Warm Front (Critchley *et al.*, 2007, Gilbertson *et al.*, 2006), but these were mainly focused on existing buildings. The current standards for newly built properties are far more stringent than they were in the 1970s where energy consumption, despite the energy crisis, was not widely engaged with as a policy issue. While regulation is a driver for improved performance and has been seen to drive innovation to some extent (Gann *et al.*, 1998), the Strawberry Hill properties share more in common with the performance-led PassivHaus principles, a "physics led" building standard for low-energy homes (Schiano-Phan *et al.*, 2008).

From a physics perspective, buildings are designed to protect the internal environment from the external environment or boundary conditions. It does this through fabric and internal heating systems (Hens, 2010). The more efficient the fabric is, generally through the use of insulation or materials, the less power will be required to make the internal conditions comfortable. It should also be noted that buildings are dynamic and that the thermal mass of the building can make a difference to how energy is released and change the performance of the building over time (Zhu *et al.*, 2009). These underlying physics principles were applied in the design of the buildings at Strawberry Hill, driving a physics-led design innovation far before this issue became normalised as a demand-side energy solution. It is clear that the mass-construction housing industry in the United Kingdom still has problems dealing with thermal efficiency (De Wilde, 2014).

It should also be noted that buildings are a socio-technical system (Brown and Vergragt, 2008), and while the design of a building is developed through sound science, the occupants can have a significant impact on the use of the building (Gill *et al.*, 2010), i.e. it may be used in a different way to buildings they may have previously occupied, as identified in retrofit properties by Brown *et al.* (2014). The Strawberry Hill story does play out interestingly in this area, where the design and use principles did not change, but the understanding and demands of the occupants did.

Key system design principles

The systems of the houses were carefully designed to take advantage of just two main drivers: increased insulation and reduced unintended ventilation.

Insulation. It was well known at the time that the principal cause of domestic heat loss was by conduction through the external fabric and ventilation (approximately half a dwelling's heat can be lost in this way). This can be significantly reduced by increasing the level of insulation and decreasing unnecessary ventilation by improving the air tightness of the houses. As such the design utilised 200 mm glass fibre roof insulation, 173 mm external cavity wall insulation and 200-300 mm of ground floor insulation.

Thermal capacity. The amount of heat stored in a building is determined by its thermal capacity and by the temperature. Thermal stability is a characteristic of high mass dwellings of heavy construction, producing a slow-response heating system, as opposed to light-weight (e.g. timber-framed) constructions that have a quick response system which, unless controlled, results in large temperature fluctuations. As such the design included three particular important aspects. First, each house had a concrete construction of the inner leaf of external walls, principal internal walls and floors which provided a total mass of approximately 40 tonnes inside the insulation envelope, which was unusual at the time. Second, the internal walls were built using 100mm blocks. Third, the floors were constructed from suspended concrete beams with a top layer of 75 mm sand and cement screed.

Other key features included the installation of double glazing and draft-stripped external doors which opened into a hallway. The final feature was the implementation of continuous ventilation in the kitchen, bathroom and WC to control moisture and odour levels.

The heating system and performance. During the experimental stages, a variety of heating systems were tested. These included emerging heat-pump technologies which tended to be expensive, complex and prone to maintenance issues. However, it emerged that the performance of these heating systems was in line with expectations, with a steady rate of heat loss of approximately 2.25 kW (a 0.1 K per hour heat loss) under experimental winter conditions of 4°C. Under these conditions, it was possible to maintain an internal temperature of 21.5°C with a 2.5 kW heating system. In line with the specifications, a variety of heating systems were deployed, including a standard gas room heater and a standard solid fuel fire. All were found to heat the dwellings satisfactorily.

Strawberry Hill houses. Following the success of the two experimental houses, Salford City Council took the decision to build a terrace of six, mixed dwellings adjacent to the experimental pair at a location known as Strawberry Hill. Following the same design principles and incorporating a number of "lessons learned" from the design and build of the original dwellings, this next set of houses was completed in 1979/1980. Different heating systems were continuously tested in the houses, including under-floor heating provided by PVC pipe coils, storage heat pumps and gas convection heaters.

The houses were monitored over a period of approximately two years by the University of Salford. This showed that the average energy use for space heating during the early 1980s' heating season was 9.5 GJ in 1980, 10.6 GJ in 1981 and 10.6 GJ in 1982. These measurements were approximately 25 per cent of the calculated requirements of "standard" equivalent dwellings built to 1976 and 1985 building standards.

Once the houses were completed, the residents moved in to the very exciting modern new homes. The houses were deemed comfortable by the new residents, and the average cost of the energy consumed per dwelling for space heating, using January 1988 gas prices (38 per therm, excluding standing charges), was £54, the equivalent of £1 per week, compared to £4 per week spent on heating other similar properties.

Upon successful completion of the design and monitoring partnership between the Salford City Council and the university, the council adopted the low-energy model as the norm and proceeded to build a further 200 dwellings. Unfortunately, the radical changes to the housing policy in the 1980s brought the number of homes built to this design and standard by the local authority to an effective standstill. However, it was reported that a small number of private developers adopted the design for a range of dwellings – from flats to detached houses – with Irwell Valley Housing Association adopting the design for sheltered housing developments.

Thirty years later

In 2009/2010, funding was granted by the University of Salford's Iconic City Award programme to revisit this work.

Aside from the monitoring activity performed in the early 1980s, little attention had been paid to the houses in the intervening period. Indeed, residents of the original houses on Strawberry Hill at the time were assured no further inconvenience and disruption.

The houses and their occupants, though, pose a unique opportunity to better understand – over a long term – whether the houses continue to be energy efficient, how the residents use them, what they think about them and whether lessons could be taken from this experience for the development of the Energy Hub within the University of Salford. More specifically, the objectives of the study were as follows:

- assess how the materials used in the building of the Salford design houses conform to the current building standards;
- analyse the current energy consumption of the Salford houses; and
- determine the various views, experiences and everyday behaviours of the residents of a Salford design house.

In particular, the project team wished to explore whether the system had stood the test of time and to identify any problems that may have arisen.

Rediscovering the houses
It remains unclear exactly how many properties were developed to the Salford low-energy standard. However, it was found that the houses, and flats, at Strawberry Hill remained very much as they were when they were developed. These were easily identifiable as a result of their location on the university campus. One of the main problems in tracking down similar properties in other locations was the lack of awareness about their existence among the current officers within Salford City Council. Officers and councillors that were contacted tended to know of the existence of the houses but were unsure how many were developed and where these might be. However, via a combination of conversations with the city council staff and the publication of a press release about the study on the website, a number of people came forward who had direct knowledge of the houses that were of interest to the study.

Research methodology

As the project dealt with people and their behaviour, a qualitative and interpretative stance was deemed to be the most appropriate. Within that lens, interviews were chosen as the primary research instrument and were organised with as many people as possible that had experience of the properties. A total of 17 households were interviewed. Most of the interviews lasted for approximately 30 minutes and covered the following questions:

- their awareness as to the background of the development of the house design;
- length of habitation and reasons for moving to that location;
- views on how the house compared to other properties the residents had experienced;
- views on comfort;
- installation of any energy-efficiency-related modifications;
- the heating season of the house;
- duration of heating usage;
- how they used the property;
- overall satisfaction with the house; and
- their actual or approximate energy use.

Research results

The occupants
Four of the people interviewed were the original tenants of the houses when they were built in the early 1980s. The others had lived there for various periods of time from just a few months to many years. All the houses were now privately rented or owner-occupied and, in the case of two properties, had been demolished.

Reflections on the use of the heating system
In most cases, the original heating system was no longer on the properties. For these properties, central heating was the main heating system (installed since the original design). A number of residents had organised the installation themselves, whilst others reported that the central heating had been installed when they moved into the property. Three of the respondents reported that they had not needed to replace the heating system – all three were original occupants of the houses.

In those that had experienced the houses' original heating sources, there was a distinct divide in how these were viewed. A couple of people reported that those who complained about the lack of heating in the property did not understand how to use the house. Similarly, one long-term resident reported that people who often moved into these houses "complained" as they expected central heating and saw the houses as somehow inferior to other properties. Although the houses did not require the level of heating that central heating systems would emit, the desirability of modern central heating appeared to outweigh this. This was also an anecdotal finding from the private developers at the time as the Salford design house concept was viewed as difficult to sell to potential buyers who were concerned with ensuring their purchases had the necessary "mod cons".

It was reported by a number of people that the original heating system was more than adequate as they found the properties warm in the winter and cool in the summer. There was some suggestion that the people who favoured the original system tended to be the ones who lived in the properties from the beginning and who were taught to use the heating correctly. It appears that the people who did not favour the original system were those who were later occupiers or ones who were possibly not using the heating system effectively. Most of the later occupiers had since installed a standard central heating system in order to compensate for the perceived failings of the original heating system. However, there were people who had moved into the houses when built in the early 1980s but did not share the enthusiasm for the properties. One person described the houses as "difficult to heat" before they had installed central heating and also "draughty", resulting in the installation of a secondary front door.

Similarly, other more recent residents thought the properties were expensive to run, difficult to heat and generally cold.

Windows

Without exception, all the people interviewed reported that the original windows that were installed were a problem. These were a double-paned design but were not secure as they could be opened quite easily from the outside. All properties except one had replaced the windows. The remaining property was a first-floor flat.

Comparison to other properties

The two people who had since been moved from the original property to a new dwelling as a result of urban regeneration talked about the Salford design house as being far superior to their new properties, describing the new ones as draughty, noisy, difficult to keep warm and expensive to run when compared to the Salford house.

Heating season

The heating seasons for the residents in the properties seemed to vary greatly with, at one extreme, residents heating the houses between December and January for 2-4 h a day and, at the other extreme, heating used between October and May for 6 h a day.

Other issues

Problems with condensation and mould were relatively common. Most people reported that this had, or continues to be, an issue in the properties. One person also mentioned the problems they had experienced in getting "people" (assistance) back to the house when they experienced problems at the house, "we couldn't get anything done […] they just forgot about us".

Implications of the study

Inevitably, there were observations and questions that arose out of the work, which cannot be easily answered and which may point the way for future studies. For example, there were discrepancies between accounts of heating and keeping warm. The knowledge of the added value of the properties being "energy houses" were lost over time, yet it was assumed that the standard assessment procedure or the energy performance rating of the house would transcend this issue. In addition, consumer desirability was influenced by social norms in that the central heating was "normed". Anything less than this was not desirable, as the occupants did not conform to the norms. The novelty value worked for some of the original occupants, but was not strong enough to engage later occupants. This highlights problems with this sort of design when the houses change hands.

Within the wider context, there are two major challenges for the United Kingdom:

(1) securing an energy supply for the future; and

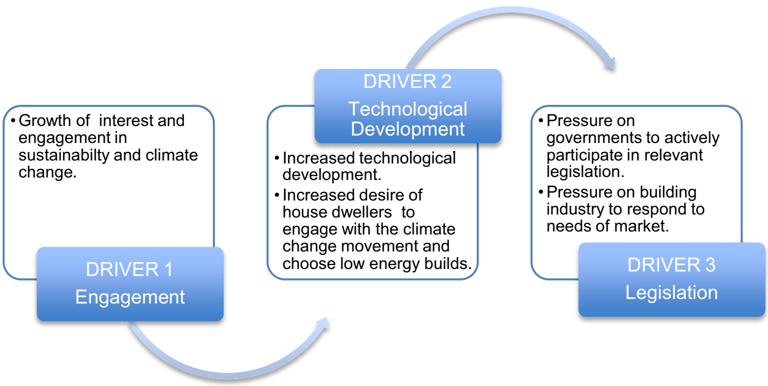
(2) reducing carbon emissions through reduced carbon-energy generation and energy saving.

There is a general recognition that the academic community will have a major role to play in addressing these issues both in the development and optimisation of the technologies needed to meet these challenges and the communication of this knowledge to the local community. In turn, it is likely that academia will play a key role in the social and economic impact of this sector by informing emerging social policies and practices.

Although newly built properties are required to incorporate a number of measures to reduce CO_2 emissions and improve energy efficiency, the vast majority of current housing stock require attention to increase energy efficiency. One way in which this can be achieved is by ensuring that dwellings are retrofitted appropriately.

There is currently a lack of understanding as to the barriers, challenges and opportunities faced by those working in this area and those affected by retrofitting. Such stakeholders include housing providers (local authorities, registered social landlords), developers and constructors, policy makers, technology providers and consumers/residents. At the same time, the University of Salford continues to embark on a number of projects, including the Salford Energy Hub House, that could inform this work which poses opportunities for partnership working.

From a business perspective, the situation can be analysed by identifying the three major drivers, as shown in Figure 1. First is the driver of engagement, i.e. focusing via a continued spotlight on the ecology of the planet and a desire to ensure that the future is safe and secure for all life by striving to use resources carefully and to reduce pollution.



Source: Burke (2017)

Figure 1.
The three business drivers of low-energy house builds

Second is the driver of increased technological knowledge about climate change that continues to develop, leading to an increase in both new and established house dwellers who wish to "play a part" in helping to preserve the resources of the planet.

The third driver is that of pressure, i.e. an acknowledgement of the intense pressure on governments to act in a positive manner by providing relevant modern legislation. This legislation in turn affects many aspects of the built environment, such as the house builders, social provision, landlord regulations and so on, throughout the industry.

Each of these drivers' affects the others, so for example the levels of engagement can be seen to push the development of technology and this impacts the need for further legislation. All the areas are continually evolving and will, no doubt, continue to adapt and change. The three drivers identified in this paper form a starting point for further analysis in the future. For example, new drivers may also be developed and added to this model as new agreements are enforced and new, innovative, low-energy products are developed and available to all sectors of the construction industry. Other ways forward may include development of an advanced model, for example a merger with other relevant value models such as Walker's (2016) "Knowledge Management/Organisational Learning/Complex Adaptive System" model which takes account of the interest and challenges presented by Big Data within the sustainable and built environment context.

Conclusion

This study has added to the body of knowledge which suggests that, although people may live in houses which are designed to exactly the same levels of thermal capacity and insulation, each property can vary widely in the energy used within. The variation is due in large, if not all, to the behaviour and actions of the occupants who ultimately determine the energy efficiency of the dwelling. The next most significant task facing us is trying to develop a better understanding of how people use houses and buildings to ensure that there is a sustainable symbiotic link between the house, the technology and the end user.

There continues to be interest and commitment to reducing energy, as COP 22 has set a timeframe for completion of initiatives by 2018 and parties are committing to reducing greenhouse gases by reducing energy usage together with other appropriate measures.

Within this context of interest, of concern, of the overwhelming need and desire to take action, studies such as the one reported in this paper will, it is hoped, continue to be of value. With the building of the houses, studies of the way they have operated, the partnership between the university and the local council united in the desire to protect the climate, we all continue to work together to ensure that future generations are able to live in protected and sustainable dwellings.

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