Chapter Sixteen: An Evidence Based Pathway to Net Zero Ready Homes

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Abstract

In the UK, the Future Homes Standard (FHS) will be used to achieve reductions in greenhouse gas emissions by 75-80% in newly constructed houses as part of the effort to achieve net zero by 2050. This chapter explains what this means in practice through design and building of houses by a housing association and speculative housebuilder. Research carried out by the Centre for Future Homes at Birmingham City University (BCU), has enabled a deeper understanding to emerge in how technology and collaborative approaches to production by all participants engaged in the supply chain can ensure attainment of carbon emissions. Crucially, the research has incorporated analysis of the experiences of occupants of innovative houses in altering behaviour and interaction with technology including heat pumps and ventilation systems. Findings from the research will be widely disseminated to assist others in appreciating the potential for housing, built with traditional locally available labour materials to be part of the effort to arrest climate change through proactive carbon reduction.

Keywords

Future Homes Standard, innovation, Emissions, Carbon Reduction, Resilience, Collaboration, Occupants

Introduction

The built environment faces significant challenges in achieving climate change that will ensure, critically, safer buildings we live in. The contribution of the housing market to carbon emissions is significant. The global building stock accounts for over 40% of total global greenhouse gas emissions (IEA & OECD, 2015; UNEP, 2023). In 2019, 17% of heating emissions emanating from buildings originated in homes (HM Government, 2021). Recognising this, improving energy efficiency in buildings is essential to reduce energy consumption and greenhouse gas emissions.

To address this problem, the UK has set a target to reduce greenhouse gas emissions to net zero by 2050. Though buildings account for 37% of total energy consumption, heating them in the UK accounts for almost one third of the UK's annual carbon footprint. The UK set an emission reduction target of 34% by 2020 and 80% by 2050, below the 1990 baseline

(Climate Change Act, 2008). In order to achieve these targets, in 2019, the UK government announced the development of a Future Homes Standard (FHS) with the aim that all new homes built from 2025 will produce 75-80% less carbon emissions than homes built under 2013 regulations. To achieve these carbon reductions, Future Homes Standard aims to incorporate more energy efficient fabric, with higher levels of insulation, higher-specification windows, increased levels of airtightness, to reduce heat loss, and low-carbon heating systems. The government introduced an interim enhancement in 2021 requiring new homes to produce 31% less emissions, as a stepping stone to the implementation of FHS in 2025.

As new building standards focus on energy conservation, increasing the thermal insulation and the air tightness, therefore reducing the air exchange from the exterior, further analysis is needed to avoid any unintended consequences before implementation of the regulation in the journey to net zero ready homes that provide comfortable and healthy spaces for its occupants. Achievement of change requires a major shift in design, construction, and operation of buildings, as well as the need to engender cultural and behavioral change. A vital part of the process of change is the education of those who occupy buildings as well as all who work in the construction sector. Accordingly, this chapter examines work being undertaken by a team of researchers at the BCU Centre for Future Homes to explore the impact of designing and building net zero homes as well as lessons learnt for future implementation.

Background to research

The existing housing crisis has made newly built construction a priority in the UK. This is predicted to produce momentum that will translate into aligned input to cope with the even greater challenge of reducing carbon in existing buildings. The government's response to new build homes has been the proposed introduction of the 'Future Homes Standard' supported by the 'Home Energy Model', which will involve the use of electricity instead of gas for home heating and cooking as well as improvements to the building fabric and ventilation to improve energy efficiency and prevent overheating. The Home Energy Model is intended to replace the Standard Assessment Procedure (SAP), which is the methodology currently used in the UK to assess the energy performance of homes.

Crucially, construction, an industry that is highly varied and includes huge diversity and complexity in the way it carries out processes, must play a key role in delivering net zero-ready homes. However, given the scale of the issues, there is worrying paucity of data (as well as critical insights), a key requirement enabling policy makers, informed by the industry, in making evidence-based decisions and avoiding the danger of unintended consequences. To help address this evidence gap Birmingham City University has established the Centre for Future Homes. This centre aims to carry out primary research underpinning highly relevant and critical change in development of net zero ready homes, addressing the challenge of climate change combined with the need of increased building safety for housing resilience. In order to address these challenges, BCU's research team is involved in applied research into areas such as: impact of new building regulations (Future Homes Standard) in the energy performance of houses; improvement of indoor air quality and overheating mitigation; low carbon heat performance (heat pumps); embodied and operational carbon; single life plastics in the construction sector; fire safety for resilient homes; and the retrofit of existing homes and buildings. This experience has led the Centre for Future homes to establish a 'Home Energy Model Task Group' to act a 'critical friend' and support government to make sure that energy performance assessment tools for compliance are fit for purpose before the new regulation comes into force, avoiding unintended consequences.

Developing a strong industry collaborative network has been critical to success of the centre, as has the focus on putting the occupier/consumer, at the heart of research. The main goal is to understand and analyse performance of real houses lived by real people in real time, delivering real impact and producing information and data explicitly intended to change behaviours and enable policymakers to arrive at evidence-based decisions. As part of evidence gathering, researchers at the Centre for Future Homes have partnered with home developers and housing associations providing net zero ready homes meeting "Future Homes Standard".

One of those projects is Eco Drive, developed by social housing provider Midland Heart on what's known as Project 80. This project has built 12 dwellings in Handsworth in Birmingham in compliance with the Future Homes Standard. Another project covered in this chapter is Gedling Green, developed by the home builder Keepmoat who, supported by Homes England, Lloyds Bank and Leeds Building Society, have delivered houses for sale built to the Future Homes Standard. Both projects provide insights from real performance of net zero ready homes as well as occupant behaviour. Some of the tasks undertaken include: advise and monitoring on cost, design, construction, commissioning, sales and handover of properties, followed by two-year post-occupancy evaluation of the homes. The post occupancy evaluation intends to better understand the customer 'journey', including operation and maintenance of these new homes, inherently more complex. This has been achieved by the use of sensors coupled with interviews carried out regularly to ascertain the lived experience of occupiers.

The objective is to elicit data that will accurately inform, create influence and lead to policy and implementation adhering to the principle of net zero whilst making people's lives better. This includes the team working closely with UK government departments engaged in the home development process, hosting site visits and sharing data and lessons learnt with policy makers and industry. Subsequent to publication of an interim report of findings from Project 80 (Mateo-Garcia et al, 2023), in the Spring of 2024, the team presented the current findings at eight NHBC *Building for Tomorrow* conferences across the UK attended by over 2000 construction industry professionals.

Project 80 Eco Drive, Handsworth

In 2019, Midland Heart Housing Association declared its intention to build Eco Drive development in Handsworth, Birmingham. Originally designed to attain the 2013 building regulations, the decision was taken to enhance the design and construction to comply with regulations that would be introduced in 2025. To this purpose, three alternative designs were proposed to test the impact. This demonstrator project provided an opportunity to consider how traditional architectural design, using traditional masonry materials and methods, can achieve the Future Homes Standard and actively respond to dramatic challenges posed by climate change.

The Eco Drive research project sought to understand the impact of designing, building and living in new homes compliant with the new standard for housing. Importantly, the programme included three different buildable and affordable high-specification designs to provide homes that are 'future-proofed' and enhanced experience for occupiers. This adaptive approach would, it was believed, ensure the demonstrator project to provide data and have a greater opportunity for learning including how a traditional architectural design in masonry can be adapted to meet the climate change challenges. The research examined the decision-making process around the design to ensure conventional masonry houses are fully compliant with the projected standard and analysed the success of the construction and operation phases since completion in 2022. It also analysed how the building specification influenced wall construction to reduce air permeability, occupant experience of controls, heat pumps, thermal comfort and ventilation.

The main findings from the research were that Future Homes Standard can be cost effectively delivered and the carbon reduction target exceeded using locally produced masonry materials and a range of heating and ventilation options. There remains a challenge in scaling-up installation of electric heating systems, as well as ensuring building UK manufacturing achieves capacity and ability to commission. Effective commissioning that ensures full understanding by home occupiers of how the systems operate will potentially influence behaviour to underpin the most efficient use of the technology in homes built to the FHS. Key lessons from this demonstrator project are included in the interim report. These have been shared with policy makers and industry to drive impact and facilitate a smooth transition to net zero ready homes and optimum occupier engagement and satisfaction.

Design specification

House types one and two were designed to go beyond the indicative 2025 standard with lower air permeability and MVHR ventilation. Type one was designed with a Baxi heat pump for space and water heating. Type two was a two-bed house in which 'the 'space load' was considered minimal and designed with Glen Dimplex electric panel radiators for space heating and a water only heat pump. Type three included Vaillant heat pumps for space and water heating heating. The ventilation in Type three included filterless extract fans in wet rooms with a low background rate. All 12 houses had a PV array of 2.2KW, beyond the standard, to help reduce energy costs.

One of the key requirements of new regulation is the use of thicker walls to accommodate extra levels of insulation. In the Eco Drive project, due to site's arrangement of plots, this extra thickness could not be implemented without reducing site density or house space, so a 352mm wall with a fully filled cavity with high performance PIR insulation was selected. The fire aspects of this specification were fully considered with the inclusion of brick and block non-combustible elements and fire cavity barriers. Junction details were carefully designed to reduce thermal bridging and heat loss. Polymer wall spray was used in Type one and Type two houses to increase airtightness. As well as thicker walls, internal space for the hot water cylinder needs to be considered as the new standards do not allow the use of gas boilers.

Regarding the window specification, enhanced double glazing was selected instead of triple glazing, due to a number of practical considerations including availability, replacement, weight, cost, ease of maintenance, frame size and light transmission. High specification double glazing was considered the simpler solution with the losses in energy performance balanced out by tighter criteria on other elements including the walls and roof.

The most significant change was the move to electric heating resulting in several key decisions, including where to position a heat pump and a hot water cylinder, the length of the pipe run and security as the air source heat pumps were placed outside of the properties. The PV panels were considered a useful addition to help occupants with their electricity costs, although they were not at the time a requirement of the FHS. The controls and inverter for the PV panels were installed in the roof space, ensuring access for maintenance. Table 1 shows the specification of each housing type and the design energy performance. Passivhaus values have been included only for comparison as these houses were built to meet Future Homes Standard indicative specification.

Table 1: Design performance of each house type

Element/Specifications	Indicative FHS specification	Type 1	Type 2	Type 3	Passivhaus
Floor U-value (W/m^2.k)	0.11	0.11	0.11	0.11	0.15
External wall U-value	0.15	0.13	0.13	0.13	0.15
Roof U-value	0.11	0.1	0.1	0.1	0.15
Window U-value	0.8	1.2	1.2	1.2	0.8
Door U-value	1.0	1.2	1.2	1.2	0.8
Air permeability (m^3/h/m^2)	5.0	1.5	1.5	5	0.6
Heating	Low-carbon heating	ASHP	Panel heater, HWHP	ASHP	-
Ventilation	Natural (with extract fans)	MVHR	MVHR	Natural (with extract fans)	MVHR
PV	None	Yes	Yes	Yes	-
Wastewater heat recovery	No	Yes	Yes	Yes	-
Y-value	0.05	0.028	0.0274	0.028	0.01
CO_2 reduction		**85%**	**80%**	**90%**	

Supply chain collaboration

A unique feature of the project was the extensive collaboration between all the stakeholders involved in the project, despite being a typical ‘design and build’ project. Intensive discussions and negotiations occurred to shape the final specification, which included: two different fabric solutions with low U-values and different levels of air tightness, three low-carbon heating systems and two ventilation solutions, adding extra complexity to the construction. All the project team, including those engaged in building control, collaborated in a spirit of openness and cooperation. Project review meetings were organised monthly with the aim of delivering a trailblazer development, and share lessons learnt. Suppliers’ knowledge and experience was extremely useful to ensure the best use of materials and systems as well as calculating the thermal bridging junction details required to meet the FHS. BCU academic team´s role in these meetings was to examine background material, provide expert advice and develop an in-depth monitoring strategy throughout all the process.

The project identified and recognised the key role of subcontractors in meeting the new standard. In this case, the main contractor subcontracted some of the main work packages but collaborated with them to ensure a model delivery due to the demonstrator nature of the project. This required subcontractors to work with new materials and to greater accuracy in more complex details, disturbing workflows.

User Experience

User experience and satisfaction was monitored for one year after occupants moved into the houses. To achieve this, occupants filled out activity diaries and were interviewed to provide feedback on their experience of living in low carbon homes, particularly around thermal comfort and indoor environment, daily patterns and behaviours and usability of low carbon systems. All occupants expressed satisfaction with their homes and the performance of the homes, particularly around thermal comfort. In addition, they were excited about playing their part in tackling climate change by living in net-zero ready homes built to future standards.

Although occupants identified that their homes required minimal effort to achieve acceptable levels of comfort, these could come from high electricity consumption as some occupants were living at high temperatures. They admitted not having modified their lifestyles to take advantage of the maximum efficiencies of their low carbon heating systems. Some households also disclosed not having experienced any respiratory health conditions, including asthma, since moving into the new homes, highlighting the health benefits of net zero ready homes, as better insulation and ventilation have the potential to create healthier indoor spaces.

Cooking was identified as a source of air pollutants in kitchens. Most households reported using not just cookers, but also other appliances such as microwave, air fryers and toasters. Culturally influenced cooking patterns and ingredients used seem to influence the level of air pollutants, including particulate matter and volatile organic compounds. Although data from air quality sensors showed high spikes in these pollutants during cooking, this pattern was followed by a quick decay, possibly due to occupants opening windows to increase ventilation.

Residents were not confident with heating controls, preventing them from using them in the most efficient way. Research showed that occupants need assistance in understanding the way new homes should 'operate' so they can take greater responsibility in adapting their behaviours to achieve anticipated efficiencies Future Homes Standard should allow.

Keepmoat Gedling Green, Nottingham

Gedling Green is a 33-home development, featuring zero carbon ready, two, three and four-bedroom homes and offers the first new homes in the UK built to the anticipated FHS. These houses were launched for open market sale in 2023. The BCU team research aim is to understand occupants' experience of the homes of the future by assessing energy usage in the new properties over a two-year period. The study will examine how Keepmoat's properties will enable homeowners to use an estimated 51% less energy compared to the 2013 building regulation standards, reducing significantly their energy bills, maximising the benefits of their new homes. There is also a desire to encourage behaviour change and educate the homeowners on the optimum way of interacting with their home.

As well as working with BCU, Keepmoat has partnerships with a number of organisations engaged in development including Homes England, Gedling Borough Council and Arcadis, Lloyds Banking Group and Leeds Building Society. This will allow Keepmoat to be confident of 'lending capacity' by finance through mortgage for green home that are energy efficient home and affordable. Maintenance of confidence by potential purchasers is essential for speculative housebuilders.

Design specification

Built using locally produced brick and block and designed to last at least 150 years, Keepmoat's homes built in accordance with the 2025 Future Homes Standard, will deliver a 91% reduction in carbon emissions when compared to 2013 regulations.

The building envelope is formed of non-combustible brick and block and concrete roof tile construction with mineral wool insulation. The inclusion of high performing double-glazed windows and doors ensures that heat loss is reduced to the minimum. All the new homes at the development feature air source heat pumps, solar PV panels, increased levels of insulation, EV charging points and smart hot water cylinders with AI technology to understand how much hot water people living in the home use on average in order to identify ways to reduce waste.

The ground floor benefits from underfloor heating which adds to the comfort and maximises space. The inclusion of an effective ventilation system ensures the air quality providing a comfortable and healthy indoor environment.

Conclusion

The Future Homes Standard provides a blueprint to other jurisdictions who are looking to progress to net zero ready be homes. Research conducted in the two case studies into the behaviour patterns of occupation of the homes will assist designers in considering and incorporating future trends. Most particularly, it will allow developers to showcase how sustainable technologies and renewable energy solutions can be utilised to inform how homes in years to come can be powered more efficiently whilst, critically, contributing to reduction of emissions as part of the UK's net zero pledge.

The research will assist organisations within the UK housebuilding sector to identify robust, scalable and sustainable solutions to modern house building challenges. This will ensure the sector can both contribute to the economic development, reduce inputs and improve outputs. The research will provide data and insights enabling policy makers to base future decisions on evidence and avoid unintended consequences through learnt lessons from collaboration with practice. Further, research will examine the design, construction, commissioning, sales, financing, occupation, and maintenance of housing to achieve zero ready homes by putting occupiers at the heart of this critical transition.

The research undertaken by Birmingham City University has and will continue to identify key issues that need to be addressed to ensure a smooth transition supported by a skilled workforce. Its critically important to avoid unintended consequences, drive quality and understand that. As Albert Einstein famously claimed, *"The only mistake in life is the lesson not learned"*.

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