Implementing net zero affordable housing — towards a human-centred approach

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Abstract: This paper reviews the UK Net Zero Strategy in conjunction with the decarbonisation of the affordable housing sector, with a focus on the key stakeholders involved in the decarbonisation process. Viewing it from a socio-technical perspective, this paper discusses three overarching groups of people in delivering low-carbon affordable housing — affordable housing providers, the supply chain and residents — highlights the range of issues and factors that policymakers should be considering; provides sign-posts to evidence; and discusses some critical gaps, barriers and transition risk factors in delivering net zero policies and potential mitigating strategies that can be learned from exemplary projects. The conclusion of this paper proposes a preliminary structure for a five-step place-based, human-centred framework to implement net zero in the affordable housing sector, emphasising the importance of long-term legislative certainty and funding, localised decision-making with stakeholder engagement, including approaches such as communities of practice, a soft landings framework, and developing monitoring and evaluation matrices.

Keywords: Net Zero Strategy, affordable housing, human-centred, place-based, decarbonisation, socio-technical, low-carbon, communities of practice, soft landings, evaluation matrices.

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Introduction

Buildings are the UK's second-largest source of emissions. The household sector in particular, contributes more than a quarter of overall energy consumption and GHG emission, with space heating contributing 62 per cent of household energy consumption.[1] To date, there are over 24.7 million dwellings in England,[2] with a steady growth of 140,000 dwellings built per year over the past ten years. Based on this, the total number of dwellings in the UK is projected to reach 32 million by 2050. This will further increase total household energy consumption by a third of the current consumption levels. Meanwhile, the UK is experiencing an unprecedented housing crisis. Affordable housing (AH) is a key element of the government's plan to end this crisis, tackle homelessness and provide support for people whose housing needs cannot be met in the commercial market. AH providers and residents represent very specific social groups that face particular challenges in UK's decarbonisation transition. Understanding those challenges and providing relevant policy support are key to decarbonising the AH sector, delivering net zero goals and, most importantly, ensuring a just transition.

The definition of AH has been heavily contested. Housing affordability and criteria to apply for AH funding vary across different regions in the UK. AH does not have a statutory definition; instead it is defined primarily through policy and practice. Historically, the term 'affordable housing' tended to be interchangeable with references to social housing.[3] However, the sub-categories of AH have grown over past decades. The most commonly used definition of AH in recent years is taken from the National Planning Policy Framework (NPPF), which defined AH as 'housing for sale or rent, for those whose needs are not met by the market (including housing that provides a subsidised route to home ownership and/or is for essential local workers) […]'. Under this definition, AH includes social rent (with rents at around 50–60 per cent of market rents), affordable rent (with rents of up to 80 per cent of market rents), as well as a range of intermediate rent and for-sale products.[4] However, many of the above categories are concluded by the Affordable Housing Commission to be 'clearly unaffordable to those on mid to lower incomes'.[5] For the purpose of this paper and statistical discussion, the definition of AH follows the NPPF definition, whilst recognising criticisms of it.

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[1] Department for Energy Security and Net Zero and Department for Business, Energy and Industrial Strategy (2022)
[2] Department for Levelling Up, Housing and Communities (2020)
[3] Wilson, W. & Barton, C. (2022)
[4] Ministry of Housing, Communities and Local Government (2021a: 64)
[5] Kell, M. *et al.* (2020)

Up to 2011–12, the largest tenure in the AH sector was social rent. 2010 saw an increase in affordable rent and shared ownership schemes, and a rapid decline in social rent following the withdrawal of funding for new social rented housing in 2010, meaning the proportion of properties in the lowest rent bracket was decreasing. However, social and affordable rent still make up the majority of the AH tenure — nearly 60 per cent of AH built in 2022 were social or affordable rent, and a third of them were homeowners with shared ownership.[6] There were about four million homes in the social and affordable rent sector across the UK in 2022,[7] representing about a sixth (17 per cent) of all UK housing stock. The overall trend of AH construction sees big fluctuations over past decades. The number of AH built each year is smaller than it was in the 1990s, but recent years have seen a trend towards a slight increase in numbers with the growth of affordable rent and shared ownership housing. There is also an uneven spread of AH built in urban areas and in rural areas. The overall amount of AH delivered in urban areas is higher, even though the proportion of rural AH has seen a steady increase (from 30 per cent in 2014–15 to 44 per cent in 2019–20).[8] The proportion of new-build AH has been increasing dramatically since 2003–4 to nearly 20 per cent in 2020,[9] accompanying the decline in the number of AH acquisitions. The current AH supply is around a quarter of all new houses being built each year. In the year 2021–2, amongst 239,840 homes built in England, over 24 per cent (59,175 homes) were built as affordable homes. However, the quantity of AH and the speed of delivery are far from sufficient. In England, more than 10 per cent of the households are on council waiting lists for five years or more waiting for AH.[10]

AH is often offered to people on a low income (usually at or below the median as rated by a recognised housing affordability index) or who need extra support. As has been explored by the Affordable Housing Commission focus group, housing payments of 25 per cent to 33 per cent net household income are seen as affordable.[11] It has been recorded that nearly half (49 per cent) of social or affordable tenants are either retired, in full-time education or belong to an 'inactive' group that includes those who have a long-term illness or disability and those who are looking after the family or home.[12] The most prevalent group in the social or affordable rented sector were households with a householder aged 65 or over (28 per cent).

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[6] Department for Levelling Up, Housing and Communities (2022a)
[7] Department for Levelling Up, Housing and Communities (2022b)
[8] Department for Levelling Up, Housing and Communities (2021b)
[9] Department for Levelling Up, Housing and Communities (2021b)
[10] Leckie, C. *et al.* (2020)
[11] Kell, M. *et al.* (2020)
[12] Department for Levelling Up, Housing and Communities (2022b)

Tenants also formed the highest proportion of the population that has an income within the lowest two quintiles (nearly 80 per cent). Over half (54 per cent) of households in the sector had one or more household members with a long-term illness or disability, much higher than private renter or owner-occupier groups. Social or affordable renters were also the least likely to have internet access at home. 1 per cent of owner-occupiers were in overcrowded accommodation compared with 8 per cent of social renters. They also had the lowest score for life satisfaction, thinking life is worthwhile, and happiness.[13]

Meanwhile, a staggering 13 per cent of social dwellings failed to meet the Decent Homes Standard.[14] Low-quality homes with poor indoor air quality, and insufficient heating and ventilation are detrimental to residents' health. The illness caused by such poor-quality housing with high energy demand is estimated to cost £1.4 billion a year to the NHS.[15] Low-quality social dwellings also contribute directly to fuel poverty in the UK. Amongst the UK housing stock, over 13 per cent of households (3.16 million) suffered from fuel poverty, of which 23.8 per cent were social tenants. For those dwellings that are newer and more compact with higher average EPC (Energy Performance Certificate) ratings, they also face a higher potential to overheat in summer, affecting vulnerable households more than others, creating an increasing trend in summertime fuel poverty. The inactive social profile of the tenants also restricted the median increase in household income for those tenants. With the recent sharp rise in fuel prices, the fuel poverty gap is expected to widen further.

Given the above background, there are great and specific socio-technical challenges in the AH sector decarbonisation transition that need to be understood and addressed. First of all, the need to deliver AH in quantity often competes with the quality at which AH needs to be delivered in order to provide significant carbon reduction and a healthy living environment. In delivering low-carbon affordable housing (LCAH), AH providers are often restricted by funding when specifying low-carbon measures (including higher air tightness levels, triple-glazed windows and electric-based heating and ventilation systems). The lack of experience and precedents creates an uncertain tender market and higher risk premiums during procurement. Furthermore, improving the current energy efficiency of homes requires not only the availability and affordability of low-carbon technology (such as heat pumps and photo-voltaic (PV) panels) and subsidy funding to ensure the uptake of such technology, but also skills training and supply-chain scale-up to

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[13] Department for Levelling Up, Housing and Communities (2022b)
[14] Department for Levelling Up, Housing and Communities (2022b)
[15] BRE (2021)

specify, install and maintain the technology. The limited funding and policy guidance in implementing training and skills sharing, and a lack of consideration of a fair and just transition for those jobs at risk are important factors in the slow uptake of low-carbon technology. These factors combined make the decarbonisation of affordable housing extremely difficult.

More critically, because of their specific social profile, AH residents are in need of consistent and systemic support in this transition to ensure that they are empowered to control their home environment and can fully benefit from the installation of new heating networks and technology, rather than be further disadvantaged by the change. For instance, social or affordable tenants, older people, low-income households and ethnic minority groups are more likely to be connected to heat networks,[16] where electrification of the heating grid exposes them to potentially higher energy tariffs and further deprivation.[17] Furthermore, reducing energy demand remains a critical measure in facilitating the low-carbon transition of the UK's affordable housing stock. The residents' knowledge of using low-carbon housing and technology, as well as the amount of information and support they receive, could all influence their energy behaviour and demand. AH residents of different economic status, ethnic background and age experience different levels of difficulties and require a tailored engagement plan in order for them to be effectively supported. In addition, as has been pointed out by the Climate Change Committee (CCC) progress report, unintended consequences of energy-efficiency improvement giving rise to issues such as damp/mould, summertime overheating or reduced indoor air quality, are detrimental to the health of vulnerable AH residents, affecting especially older people, those with a disability or a long-term illness and those living in compact or crowded dwellings. Without policy support and guidance, these problems will hinder the progress of the transition, pushing vulnerable AH residents further into economic deprivation and widening the inequality gap.[18] However, there has been no overarching plan for public engagement, or advice for local authorities to support AH residents to mitigate negative impacts on different social groups, reduce energy demand, make behavioural changes or adapt to electrified low-carbon living. The lack of a coherent public engagement plan and evaluation strategy greatly hinders the implementation of the Net Zero Strategy (NZS).

People play a vital role in the net zero transition. In order to deliver the emission goals set by the government, the current framework of implementation that has a technical focus on heat pumps and renewables is not enough to address the complex

[16] BEIS (2023)
[17] Miller, C. *et al.* (2019)
[18] Morey, J. *et al.* (2020)

socio-technical challenges. A human-centred approach is needed to effectively engage people in this transition, ensuring equity and effectiveness. The human-centred approach originated from the field of design, but has been developed across a variety of fields as an approach to creative problem-solving that focuses on human elements. A human-centred, place-based approach proposed here, as opposed to a 'resource-centred' or 'technology-based' approach to net zero, puts the emphasis on the challenges, barriers and conflicting interests faced by stakeholder groups within a specific social, cultural and institutional context, and focuses on involving the stakeholders in decision-making, problem-solving and policy-implementation processes, to ensure the outcomes are feasible, viable and desirable.[19]

Policy context

The 2008 Climate Change Act[20] has propelled the setting out of the carbon budget. Each carbon budget, set 12 years in advance, provides a five-year, statutory cap on total greenhouse gas emissions. The CCC has reported that the first and second carbon budgets were met and the UK is on track to meet the third, but is not on track to meet the fourth or fifth budgets.[21] In alignment with setting the sixth carbon target, the government published the Net Zero Strategy (NZS) in 2021, aiming to reach net zero emissions by 2050.[22] As one of the strategies set out to reduce emissions, the government's Heat and Buildings Strategy specified a range of policy mechanisms to decarbonise the sector mainly through a rapid scale-up of low-carbon heat supply chains and an upgrade of measures to improve home energy efficiency rating EPCs.

Following the publication of the NZS, its feasibility and lawfulness were called into question in July 2022. It was determined by the High Court that the NZS lacked proper explanation or quantification of how the UK government's plans would achieve the sixth carbon budget. The High Court further noted that a carbon shortfall in the NZS was unaccounted for in the report itself.[23] The progress report of the Net Zero Strategy document by the Climate Change Committee (CCC) clearly stated that important policy gaps remain in delivering the NZS, in which the energy efficiency of buildings is an outstanding item. The independent review by the Rt. Hon. Chris Skidmore MP further emphasised the importance of decarbonising

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[19] IDEO.org (2015)
[20] UK Government (2008)
[21] CCC (no date)
[22] BEIS (2021: 10)
[23] Markowitz, K. *et al.* (2022)

homes by reducing energy demand,[24] for which the UK is currently lacking policy support.

At the same time, the Heat and Buildings Strategy (HBS), as part of the NZS, has been criticised for overlooking the impact on legally protected groups under the Equality Act 2010,[25] where people in these groups can be unfairly and disproportionately impacted by a badly planned transition to low-carbon living. The CCC progress report has also criticised the lack of cross-cutting enablers for a just transition in the NZS.[26] The newly published 'Equality impact assessment for the Heat and Buildings Strategy' has recognised some negative impacts affecting groups of people with protected characteristics,[27] but has not provided a clear plan to mitigate such impacts.

On the other hand, the building regulations have also been trying to reflect the sector's transition to net zero over the past two decades. But the effort has been greatly affected by the shifting policy landscape, resulting in slow progress. This has been illustrated in the past decade, by the withdrawal of the Code for Sustainable Homes standard (introduced in 2006), despite the advice given by the House of Commons Environmental Audit Committee,[28] leaving local authorities and home builders with limited guidance on expected standards for low-carbon housing. The Zero Carbon Homes target, introduced in the same year, aiming to challenge the construction industry to produce zero-carbon housing by 2016 through a gradual tightening of building regulations and a series of sustainability requirements, was scrapped one year before the target was supposed to be met (in 2016), resulting in subsequent slow uptake of low-carbon heating systems and projections of a very costly future retrofit.[29]

Since then, there has been a vacuum in government-backed low-carbon building standards. A minority of affordable housing providers sought alternative sustainable building standards, such as the *Passivhaus* standard developed in Germany,[30] as guidance to achieve better energy efficiency. But without relevant support from the government to recognise its value, the barriers to delivering such low-carbon housing are hard to overcome.[31] In 2020, changes were made to Building Regulations Part L (Conservation of Fuel and Power), F (Ventilation) and O (Overheating) in

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[24] Skidmore, C., Rt. Hon. (2022: 238)

[25] UK Government (2010)

[26] CCC (2022)

[27] BEIS (2023)

[28] Environmental Audit Committee (2013)

[29] Currie & Brown, (2019)

[30] See definition of *Passivhaus* standard at https://www.passivhaustrust.org.uk/what_is_passivhaus.php#2

[31] Zhao, J. (2023)

line with the Net Zero Strategy that has only come into effect in 2022.[32] The recently announced Future Homes Standard, which will deliver 'zero-carbon ready' new build is scheduled to come into effect in 2025. However, this has already delayed the progress of low-carbon housing by a decade. Given this context, this paper explores the policy gaps, barriers and transition risks facing AH providers, supply chain and residents in the process of decarbonisation of AH, emphasising a human-centred policy framework to effectively implement NZS.

Research overview— people at the centre of the transition

This section considers the role of people in the transition. Specifically, perspectives are taken from three overarching stakeholder groups: AH providers, the supply-chain and AH residents.

AH providers in net zero transition

The section discusses the policy gap in supporting AH providers, some of the critical barriers AH providers experienced in this transition and examples where those challenges have been overcome by effective mitigation strategies. In 2021–2, 81 per cent of all affordable homes was delivered by private registered providers, with local authorities delivering 13 per cent and non-registered providers 3 per cent.[33] Those AH providers, whether a housing association, a city council or a private business, are often the start of the 'chain reaction' to decarbonise the sector. Studies across different countries have shown that they are key decision-makers in determining the extent to which low-carbon designs and technologies are implemented.[34] As the main providers of affordable housing, each local council and housing association has different levels of funding commitment, experience and capabilities for delivering low-carbon affordable housing.

A critical policy gap in this area is the lack of legislative certainty and consistency on the expected standard for homes. There has been a decade of absence of clear ambition and targets in place of the Code for Sustainable Homes and Zero Carbon Homes that residential buildings should achieve in order to reduce carbon emission. The widely used Standard Assessment Procedure (SAP) and EPC ratings have long been questioned for their ability to reflect real energy costs, and their use

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[32] Department for Levelling Up, Housing and Communities (updated 2022c)
[33] Ministry of Housing, Communities and Local Government (2021a: 64)
[34] Diyana, N. & Abidin, Z. (2013), Elias, E.M. & Lin, C.K. (2015), Ahn, Y.H. *et al.* (2013)

has been discouraged in setting a minimum target in the upcoming Future Homes Standard.[35] This creates uncertainty amongst AH providers whether there is a clear target (either an energy use target or lifecycle carbon emission target), and whether the government is committed to long-term funding for the extra costs associated with low-carbon projects.

Evidence from local climate action plans has shown some local authorities adopting higher energy-efficiency standards in building affordable homes than the criteria set in Building Regulations. For instance, Exeter City Council and Norwich City Council have committed to building all new council buildings to achieve the *Passivhaus* standard; the Greater London Authority and Bristol City Council have set an ambition to reduce a minimum of 35 per cent carbon beyond Building Regulations.[36] The Welsh government has proposed that all social homes should achieve the highest Energy Performance Certificate rating (EPC A).[37] But such efforts are isolated and meet with challenges and barriers. The following sections discuss some of the main barriers met by AH providers, in terms of delivering LCAH schemes, and provide examples where positive results have been achieved when the barriers have been sufficiently overcome.

Barriers facing AH providers in delivering net zero AH

For AH providers, the main barriers when pushing the boundaries of Building Regulations to achieve better energy performance and lower carbon emissions are the higher capital costs and the lack of familiarity in procurement.

The higher capital costs, driven by increased material and technology costs, skilled labour inputs as well as certification, is the most critical barrier to delivering AH projects,[38] where economic viability is the biggest challenge in implementing low-carbon choices in design and construction.[39] Most affordable housing developers have a constrained budget. Their decision to build low-carbon housing and to what extent they want to increase energy-efficiency credentials are affected by subsidies and projected increases in rental incomes.[40] Balancing value and affordability becomes key to initiating development. Studies show that the current UK decarbonisation grants can only achieve an emissions reduction of 33.5 per cent

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[35] Ministry of Housing, Communities and Local Government (2021b: 33)
[36] Passivhaus Trust (2019)
[37] Welsh Government (2022: 5)
[38] Outcault, S. *et al.* (2022), Zhao, J. (2023)
[39] Copiello, S. (2015)
[40] Outcault, *et. al.* (2022)

without incurring significant additional investment costs to the local authority.[41] This creates huge pressure on local authorities when planning for low-carbon affordable housing. Under this pressure, during 2021–2, out of 157 surveyed housing associations, a total of 50,000 homes were completed, among which only 1 per cent (607 homes) achieved a high energy performance rating (EPC rating A).[42]

Closely related to the cost implication is the uncertainty AH providers face during the procurement process. The procurement method is designed to strategically identify the best route to achieve the objectives of a project. It defines the relationships of various parties involved in a project and assigns responsibilities and authorities.[43] During the procurement process, choosing the most suitable procurement route for a low-carbon AH project often requires more preliminary planning in comparison with procuring a standard affordable housing project. This is due to a lack of experience from the client. But contractors' and consultants' unfamiliarity with the design and construction of low-carbon housing also creates an uncertain risk premium and uncertain tender market. As a result of unfamiliarity and inexperience, choosing the appropriate procurement route becomes a critical challenge in commissioning a low-carbon affordable housing project.

Examples from the US and the UK below demonstrate that committing to low-carbon projects early on in the development, accessing multiple strands of funding, choosing the appropriate procurement route, as well as being agile in response to the market in development can have positive cost and time implications.

Examples of what can work to overcome these gaps and barriers

A case study in the US comparing three LCAH projects has shown promising results where low-carbon designs and satisfying local needs helped projects secure funding, incentives (rebates for solar PV panels, tax incentives and a deferred developer fee) and increased rental incomes, which alleviated initial concerns about the cost premium.[44] The three studied projects were similar in size and carbon emission ambition, with different specifications of energy supply (all-electric or mixed fuel). The research found that for all three projects, funding was sourced from multiple streams, often associated with specific criteria (local provision for vulnerable groups of people or emission and energy targets). Those targets further motivated developers

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[41] De Mel, I. *et al.* (2023)
[42] McCabe, J. (2022)
[43] BSI (2011: 6)
[44] Outcault, S. *et al.* (2022)

to achieve better design and performance for the projects, in order to access the funding. In these cases, the funding itself motivated low-carbon construction. Furthermore, the developers suggested that committing to a lower-carbon design earlier in the development process (before the design phase) enabled the development team to pursue more ambitious decarbonisation strategies. This echoes studies conducted in the UK context,[45] where research into the delivery of *Passivhaus* social housing in the UK illustrated barriers and mitigating strategies shared by experienced AH providers and supply chains, which were then mapped against the Royal Institute of British Architects (RIBA) Plan of work 2020, confirming the importance of integrating carbon targets from the outset of the project.[46] It has shown that setting a low-carbon ambition early on in the planning stage (RIBA stage 0) with clear energy performance goals, choosing the right procurement route (RIBA stages 0–1), and involving experienced low-carbon designers and contractors early in the design stage (RIBA stages 1–2) will increase the success of the project, reducing additional cost implications associated with low-carbon skills and technologies.[47]

An example of LCAH procurement can be taken from Exeter City Council's *Passivhaus* development. Exeter City Council has a track record of building low-carbon council houses. It adopted the *Passivhaus* standard over a decade ago and committed to building all new council projects to *Passivhaus* standard. According to its experiences in procuring a low-carbon project or a *Passivhaus* project, because of the novelty or uncertainty of the low-carbon building design and technology involved, understanding the risks, the client's appetite for risk and ways to mitigate risks often determine the most suitable procurement route.[48] For instance, when procuring a *Passivhaus* affordable housing project, the traditional single-stage route carries a higher level of risk for the clients. It is believed to be more suitable for smaller scale, simple or one-off projects. It limits contractor involvement in the design, and could potentially be time intensive and incur extra cost. But it gives the client good control over change and the quality of the end product. Choosing this route means that the client needs to be very well informed with a certain appetite for risk to initiate a *Passivhaus* brief. Whereas for larger projects, a design and build procurement route, with early contractor involvement and oversight, is more advantageous than a traditional single-stage tender, where contractors have no involvement in the design process. It is believed that this procurement route transfers risks to the contractor, and effectively uses their expertise

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[45] Zhao, J. (2023)
[46] RIBA (2020)
[47] Zhao, J. (2023)
[48] Zhao J. & Carter K. (2022)

and buildability, as well as the supply chain within the contractor to drive cost benefits.[49]

Another example of successful delivery of affordable housing schemes can be drawn from Norwich City Council. For a series of its development sites, it strategically mixed tenures to ensure affordable housing targets and economic growth. It embarked on joint ventures with local businesses, employed a combination of shared equity, social rent, private sale and rent, and affordable rent. The houses are designed as tenure blind, where dwellings in the different housing tenures are designed to be externally indistinguishable to help with social integration without affecting property prices.[50] Tenure mixing and tenure-blind design have been considered to be a more important factor in enabling the success and integration of communities in mixed-tenure estates than the clustering or dispersal of social housing.[51] The council uses tenure-blind design not just as a social principle, but also as a good business principle, so it could be more agile in responding to market change by adapting specifications throughout the design and delivery stage.

In recognising the policy gap, barriers and learning from exemplary projects, a crucial step towards a human-centred approach is to assess specific local needs, set appropriate carbon emission ambitions, ensure long-term funding commitment with clear LCAH standards and targets, support affordable housing providers and engage local stakeholders in decision-making from the early stage of LCAH delivery.

Supply chain in the net zero transition

Another critical link in delivering net zero AH is the supply chain. Closely connected with AH providers in the delivery of LCAH, the supply chain is also experiencing unprecedented challenges in the net zero transition. The lack of skills and experience has not been sufficiently addressed in policy. There is also a lack of a coherent plan for people currently working in carbon-intensive jobs to transition into a low-carbon skilled market. The Climate Change Committee has noted that current carbon-intensive jobs (steel, cement or glass manufacturers, gas boiler manufacturers and installers), at risk in this transition cannot be ignored. The construction industry, especially home builders who have traditionally had a local focus and apprentice-based skills building, are often restricted by localised construction methods, building materials and technologies. For instance, builders and

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[49] Passivhaus Trust (2016a)
[50] Passivhaus Trust (2016b)
[51] Norris, M. *et al.* (2021)

tradespersons trained for a conventional building type do not necessarily have the skills or opportunities to access the skills and experiences involved in building low-carbon buildings. Unfamiliarity and inexperience could result not only in higher costs and longer time in construction, but could also mean local jobs being commissioned to bigger, national companies that have low-carbon expertise, worsening the local construction job market.

The following sections further discuss the skills challenge facing the supply chain, and provide examples of local supply chains working with AH providers in a successful skills transition.

Barriers facing the supply chain in delivering net zero AH

The skills shortage is reflected in both hardware technologies (such as heat pumps) and software capabilities (such as energy modelling). For instance, when designing a *Passivhaus* project, challenges arise in designing the appropriate building form, orientation and construction details that can satisfy the *Passivhaus* energy performance criteria. This often requires an architect/designer with specific *Passivhaus* certification to carry out the design. The verified design then needs to be implemented appropriately during construction, which often involves a different construction process, additional air tightness tests and experienced contractor on-site monitoring. Unfamiliarity with the construction of *Passivhaus* projects could have time and cost implications.

The uneven geographical spread of low-carbon housing across the country has also restricted the supply chain in accessing the training and practice required. In general, residential buildings that achieve an EPC rating C or above represent a higher proportion of all dwellings in Southern regions (43 per cent and above) than in the North and Wales (37 per cent to 39 per cent). Similar trends apply to *Passivhaus* projects, where the South has a higher concentration of certified *Passivhaus* projects than the North. There is not enough skills-building, experience or learning being generated across different regions.

Examples of what can work to overcome these gaps and barriers

An example of successful skills transition in the local supply chain can be reflected in locally developed specialist frameworks. For example, Norwich City Council has employed a specialist framework of local building professionals — the Fabric First Framework — to deliver LCAH. The Fabric First Framework consists of nine contractors in three lots procured to provide the range of services and works necessary to deliver housing and associated infrastructure. The framework is available

for use by Norwich City Council, any other public authority or Registered Provider (RP).[52] Using this specialist framework has greatly reduced the uncertainty involved in procurement, design and construction, making the project economically viable. The Goldsmith *Passivhaus* social housing scheme, developed by Norwich City Council, comprising 100 per cent social housing units, has won the 2019 RIBA Stirling prize, due to its architectural design, community building and energy performance credentials. It has been regarded by RIBA as an exemplary project marrying reduced energy consumption with mass housing. Norwich City Council had previously delivered smaller scale *Passivhaus* projects, and the success of this project was achieved through a combination of aspiration and commitment to achieve *Passivhaus* from the client side, effective solar design and careful selection of construction method, as well as the employment of the Fabric First Framework to assist with the procurement process, increasing efficiency and significantly reducing costs by pre-qualifying suppliers under set terms and conditions.

A similar specialist framework has been developed by other local authorities, such as Exeter City Council and the EXEseed Framework.[53] The frameworks provide access to a carefully selected list of contractors who have proven their competency in collaboration, culture, value and quality in delivering the low-carbon construction of projects.[54] Fundamental criteria for the selection of contractors are the delivery of housing and public buildings that promote low-energy consumption, create a healthy and comfortable internal environment and buildings that are sufficiently robust to withstand future predicted climatic changes.[55] Furthermore, the framework manager will also provide procurement advice, compilation of employment and skills plans, standard tender and contract management documents, etc. to assist with project procurement.

Moreover, the experiences from the above two city councils are regularly shared nationally amongst a group of AH providers, low-carbon designers and contractors via workshops, training and symposia organised by the Passivhaus Trust. Together with other skilled and experienced professionals in the AH sector, they have formed communities of practice[56] to share knowledge and lessons learned in order to advance the domain of LCAH.

Those examples show that another crucial step towards a human-centred framework in delivering LCAH is to employ a more integrated approach to supply-chain management, engaging local stakeholders and establishing a local

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[52] Hamson Barron Smith & Norwich City Council (2015)
[53] Exeter City Council (2015)
[54] Zhao, J. (2023)
[55] Exeter City Council (2015)
[56] Wenger, E. (1988)

delivery framework. At the same time, supporting local supply-chain transition in skills building where the specialist framework of low-carbon skilled jobs can be secured locally is critical in mitigating risks faced by people in carbon-intensive jobs. It is equally important to encourage communities of practice amongst AH professionals, engaging AH providers and supply chains across regions in conversations where knowledge and experience from experienced LCAH providers such as Exeter and Norwich City Councils can be effectively shared.

AH residents in the net zero transition

This section discusses the policy gap in engaging and supporting affordable housing residents, the systemic disadvantages they face and risks that could lead them into further deprivation and affect their behavioural adaptations in this transition, as well as examples where the residents are sufficiently supported to live in and benefit from low-carbon homes. Decarbonising AH requires a holistic strategy to engage the residents in a just transition, in order to prevent further deprivation of already underprivileged social groups. Currently, there is no clear plan from the government to effectively engage and support AH residents. Local efforts made by councils and housing associations are not supported and guided by national policy. For instance, there is very limited funding for AH providers to engage and support tenants in reducing demand, using low-carbon technology more efficiently and transitioning into low-carbon behaviours. Grants are often available in the form of energy upgrade materials and installation costs, but rarely is any funding made available specifically for engagement workshops, focus groups or R&D activities leading to behavioural adaptations. Moreover, there is also a lack of measurement or indicators of positive behavioural change or community benefits that can inform policymakers about the effectiveness of supporting residents in low-carbon affordable dwellings, making it difficult to evaluate and improve plans for public engagement.

The following sections discuss the barriers faced by AH residents during the net zero transition and examples where sufficient and effective support has been given to the residents to assist them to adapt to low-carbon living.

4.3.1 Barriers facing AH residents in the net zero transition

Overall, there are two main barriers facing AH residents' low-carbon behavioural transition. The first concerns the systemic barrier the AH residents face in managing lives under considerable material and social stress, which influence their power

in planning and adapting to a low-carbon future. The second barrier is the availability, or not, of support given to the residents in transitioning to low-carbon living.[57]

AH residents by definition are on a low income (usually at or below the median) in their region or who need extra support. However, due to the wide range of tenures involved and delivery mechanisms, AH residents include a variety of social groups that require tailored engagement strategies. Social and AH tenants represent some of the most vulnerable groups of people in the UK, facing rising energy bills and the cost-of-living crisis. However, more often than not, they do not have the opportunity to choose a low-carbon home, nor do they have sufficient means or control over what low-carbon technology is to be included in their homes. As a result, they are often in need of more systematic support to fully benefit from a low-carbon home. For those residents living in shared ownership properties, in addition to an effective support mechanism to engage them in planning and transitioning to low-carbon living, policy to assist them financially to opt for low-carbon technologies is also critical in this transition.

Without a specific engagement plan, guidance, energy audits and support mechanisms, the residents are at a loss as to what the decarbonisation transition means and how to plan and adapt to living in a low-carbon house (e.g. switching from gas central heating to heat pumps). For instance, quite often, the behaviour of AH tenants is considered to be unpredictable, and they are seen as incapable and unwilling to change their behaviour,[58] resulting in building professionals 'designing out' the residents' role in operating a low-carbon home,[59] restricting their behaviour, leaving them feeling powerless to control their own home environment[60] and putting them at a higher risk of further deprivation.

Another example can be taken from the electrification of heating grids. For AH residents living in homes with an Energy Performance Certificate (EPC) rating of D or below, the electrification of the heating grid exposes them to potentially higher energy tariffs and further deprivation. If such households do not switch away from gas, their fuel costs may increase as a result of a decline in the number of gas customers, caused by a widespread shift to electric heating. But early electrification of heating for low-income households could also make them vulnerable as the price of electricity greatly exceeds the price of gas.[61] The volatility of energy prices as

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[57] Zhao, J. & Carter, K. (2020)
[58] Cherry, C. *et al.* (2017)
[59] Cherry, C. *et al.* (2017)
[60] Zhao J. & Carter K. (2016)
[61] Miller, C. *et al.* (2019)

experienced in the past year (2021/2), and the possibility of future energy crises has put further strain on the situation. Possible mitigations could include the installation of solar PV panels, if feasible. However, the capital cost of PV again creates a barrier preventing this transition from happening.

An increasingly prominent issue facing AH residents is summertime energy poverty, with the increase in summer temperature and heatwaves. Research on overheating shows that social housing stock, which has a high proportion of flats, newer dwellings and buildings with higher EPC ratings, is more prone to becoming overheated. Rooms inhabited by vulnerable occupants were found to be more likely to overheat due to a lack of ventilation or where the ventilation control is limited by age or mobility.[62] The financial constraints of AH residents also put them at a higher risk of overheating. An appropriate support framework in arranging for vulnerable occupants to live in dwellings less affected by overheating risks, as well as accessible guidance for occupants' behaviour and adaptation play an important role in mitigating summertime overheating.[63]

Furthermore, decarbonisation of affordable housing often involves the introduction of innovative low-carbon technologies, which can bring challenges to residents. Research has revealed that the performance of low-carbon technology, such as heat pump systems, relies on complex socio-technical system interaction. Both residents' behavioural patterns and enabling feedback processes (such as a user-friendly display of energy consumption on a heat pump system or a simple identifiable alert when high-carbon back-up heating is enabled) can affect their energy use.[64] For instance, the optimum performance of a heat pump system was associated with situations in which people better understand the system. As a result, their satisfaction is linked to the amount of technical support they receive in operating the heat pump system.[65] Even though the residents are, to an extent, capable and willing to adapt their behaviours to save energy,[66] their technical know-how, the usability of the control interface as well as the technical support available to them determine a great deal of how much they can adapt their behaviour. In a study conducted in the UK among low-carbon dwellings, even for residents who lead a low-carbon lifestyle, their energy behaviour does not necessarily result in energy savings if not facilitated with relevant information and support.[67]

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[62] Morey, J. *et al.* (2020)
[63] Sameni, S.M.T. *et al.* (2015)
[64] Oikonomou, E. *et al.* (2022)
[65] Caird, S. (2012)
[66] Centre for Climate Change and Social Transformation (2022)
[67] Zhao, J. & Carter, K. (2020)

Research has repeatedly stressed that residents are one of the most important groups in lowering the carbon emissions of buildings: behaviour contributed 46 per cent of the variance between the higher end and lower end of energy consumption among surveyed households.[68] Even in energy-efficient housing, totals of 51 per cent, 37 per cent and 11 per cent of the variation in heat, electricity and water consumption, respectively, can be explained by occupant behaviour (e.g. high thermostat setting, or the use of energy-intensive heating devices when low-carbon technology is available).[69] The 'performance gap', a term used to describe the gap between predicted energy use and actual energy consumption, especially in low-carbon buildings, has been the focus of the energy-efficiency research area. One of the main contributors to the 'performance gap' has been found to be the energy behaviour of residents.[70] It is critical that building professionals and policymakers address the role of residents in the discourse of decarbonising AH, in order to continue the debate surrounding energy demand reduction, encouraging behavioural change, rather than focusing purely on energy efficiency. Failure to do so could lead to an adverse effect of energy reduction, called 'the rebound effect'. The rebound effect is defined as an economic mechanism that drives an increase in energy consumption following a 'below-cost improvement' in energy efficiency.[71] In other words, people's energy consumption can increase as a result of the installation of energy-saving measures in their homes as their behaviour changes to match the lower costs they face. While some research reported an increase in pro-environmental behaviour in users of low-energy buildings,[72] a number of other studies show a lack of occupants' behaviour adaptation in low carbon residents,[73] or their frustration that they had to actively adapt their behaviour to acquire comfort in what they assumed to be a house that provided comfort automatically.[74] Evidence of the rebound effect following increases in energy efficiency were also presented in research.[75] It is unclear how the rebound effect affects AH residents specifically, but an unintended rebound effect could put AH residents into further economic deprivation in an uncertain energy market. Further research is needed to understand the mechanism of the rebound effect in the AH sector.

[68] Sonderegger, R.C. (1978)

[69] Gill, Z.M. *et al.* (2010)

[70] Gupta, R. *et al.* (2019)

[71] Bourrelle, J.S. (2014)

[72] Zhao, J. & Carter, K. (2020)

[73] Monahan & Powell, 2011

[74] Sherriff et al., 2019

[75] Guerra Santin, O. (2013), Haas, R. & Biermayr, P. (2000)

Given those barriers and risks, the following example shows the contrast between two AH *Passivhaus* projects. One was supported by a landlord in terms of knowledge sharing and behavioural adaptation, resulting in behavioural change and eco-community building. In contrast, the other project was not supported, or was even restricted by the housing association controlling their low-carbon home technologies, leading to resident dissatisfaction.

Examples of resident support and behavioural change

A case study of two low-carbon affordable housing projects represents a distinctive contrast as a result of the availability of support to residents during their occupancy. The two projects both belong to the social rent sector, and were developed in Scotland. One was built in 2011 by a private landlord and the other was built in 2015 by a housing association. The two projects have many similarities in terms of floor area, bioclimatic region, construction, household size and service systems. Both have achieved *Passivhaus* standard. They both employ a state-of-the-art mechanical ventilation and heat recovery system (MVHR) as the main heating and ventilation strategy, backed up by a bio-mass burner or electric fire. Domestic hot water was acquired via solar PV or solar thermal, backed up by an immersion heater. The main technical challenge to controlling the environment of this type of house is to learn to use the MVHR, solar PV and thermal heating effectively so not to incur extra energy use with an immersion heater or electric fire. The study has revealed that in the first project, the occupants showed a high level of satisfaction with their home environment and demonstrated increased knowledge and skill throughout their occupancy in operating the low-carbon system (MVHR, solar thermal and bio-mass burner). The landlord initiated a soft landing[76] procedure to provide technical support and troubleshooting where the residents and the landlord have established a community that supports each other in minimising energy use and maximising the benefits of the low-carbon technology. Positive low-carbon behavioural changes were recorded as a result of landlord support and community learning. The landlord also monitored and audited the energy use of each household, evaluating the variance in energy use, uncovering links between energy use and energy behaviour that can be shared within the community. However, the occupants surveyed in the second project showed the opposite experience. Their knowledge of their low-carbon houses was very limited. The residents expressed frustration about how little the low-carbon technologies installed in their houses were effectively communicated to them and said 'if we understood this place better

[76] Way, M. & Bordass, B. (2005)

we'd be a lot happier'. Instead of facilitating the residents in using the features of the house efficiently, the housing association asked them not to change any control settings, or even open windows to ventilate. The residents were given a big instruction manual (with parts of it written in German), without further explanation. The energy use was much higher than they were told or expected at the beginning of the tenancy. The residents were left frustrated without any understanding of the reason for this discrepancy. This study provides evidence of the importance, and the benefits, of effective and continuous guidance and support given by affordable housing providers, which could result in a community that shares low-carbon knowledge and fosters more sustainable behavioural norms.[77]

The example above demonstrated that the support given to residents is as much a top-down low-carbon educational process as a bottom-up eco-community building process. By providing energy advice, low-carbon technology demonstrations and walk-throughs as well as community energy auditing and knowledge sharing, decarbonisation at a larger scale that is centred around the community can be achieved. In addition to energy-efficiency measures, a more comprehensive matrix or set of indicators measuring a wider range of behavioural change and community benefits in relation to low-carbon living would provide a more holistic view of the effectiveness of supporting residents that can inform policy and improve outcomes.

In summary, engaging and supporting AH residents in planning and adapting to the decarbonisation transition by facilitating behavioural change and eco-community building is another important link in building a human-centred framework. Policy could assist this by ensuring resident support through a soft landings process in post-occupancy, as well as establishing frameworks and measuring matrices to involve residents in the discourse of low-carbon living and behavioural change. Support for residents should examine specific local needs and demographic groups to ensure equity during the transition.

Concluding remarks and future research

The above discussion highlights the importance of developing approaches and frameworks that are focused on people and place, where the social challenges are at the centre of the net zero transition. The paper has put forward areas for further examination and research; however, the scope of this paper is not broad enough to provide a comprehensive review of all the factors identified. In identifying the issues concerning AH providers, supply chain and residents in the net zero

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[77] Zhao, J. & Carter, K. (2016)

transition, the following preliminary structure of a five-step human-centred framework towards net zero in the AH sector is proposed, whilst recognising that the framework and accompanying evidence need future research for completion.

Step 1: Ensure long-term certainty in building standards and funding

Certainty and consistency in low-carbon building standards and long-term commitment to funding are critical to ensure that stakeholders are supported in this transition. It is important that the government ensures consistency in setting the ambitions of low-carbon building standards, with funding associated with achieving low-carbon targets. Further review and investigation are needed to devise effective funding strategies associated with energy targets and social benefits. The problem of how to provide funding that specifically engages with stakeholders — AH providers, local supply chain and residents — is also in need of further research.

Step 2: Engage stakeholders early in local net zero AH deliveries

The second step of a human-centred framework is to engage local stakeholders (AH providers, supply chain and residents) in decision-making from the early stage of low-carbon affordable housing delivery, assess specific local needs, set appropriate carbon emission ambitions, and use participatory workshops, focus groups and committees to devise localised strategies, as seen in the examples, to effectively deliver LCAH. More research is needed to set out a strategy to enable specific local needs to be understood, where local groups at higher risk in the transition could be highlighted and supported to enable strategic planning and decision-making for the local context.

Step 3: Enable communities of practice for cross-fertilisation

Skills and experience sharing are important to overcome the uncertainty, unfamiliarity and uplift premium associated with low-carbon affordable housing projects. Successful examples championed by experienced affordable housing providers and supply chains using strategies such as multiple funding streams, tenure blindness, and specialist frameworks in delivering low-carbon affordable housing in a cost-effective way should be shared across regions via communities of practice. More investigation is needed into how to effectively engage stakeholders in communities of practice across regions to connect scattered efforts.

Step 4: Develop a plan for monitoring and support

People's environmental awareness and attitudes are key to facilitating a low-carbon transition in the affordable housing sector. As has been shown in the examples, energy advice, continuous monitoring and resident support in the soft landings process for new-build low-carbon affordable housing are crucial in supporting residents in the net zero transition and are in need of policy support. More research is needed to effectively support AH residents and engage them in planning for low-carbon living and behavioural change to achieve social and community benefits. This engagement strategy should include all local stakeholders and involve communities of different social profiles, to devise a targeted plan for a just transition.

Step 5: Develop metrics and indicators to improve outcomes

It is important to examine both energy-efficiency and carbon emission goals as well as human elements: behavioural change (an increase in pro-environmental behaviour and a reduction in energy demand) and community benefits (skills transition and local hiring). Research is needed to design and develop a comprehensive metric that can be used to measure the effectiveness of the engagement of key stakeholders involved in this transition, to ensure there is a continuous feedback loop to evaluate the framework to deliver the intended outcomes.

Acknowledgements

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