Wales Centre for Public Policy
Canolfan Polisi Cyhoeddus Cymru

How could Wales heat and build low-carbon homes by 2035?

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Contents

Summary

- In this paper we highlight key issues in the decarbonisation of buildings in Wales, focusing on existing and new residential buildings.
- Decarbonising heating in buildings is key to reducing residential emissions. Although some powers relating to building decarbonisation are devolved to Wales, many are reserved to the UK government.
- Reducing emissions from existing residential buildings will involve: improving energy efficiency; other measures to reduce energy demand; and switching from fossil fuels to low carbon heat sources. However, there is debate about the optimum balance between and sequencing of these measures.
- Currently, there are significant behavioural barriers to the adoption of heat pumps which will need to be resolved to increase rollout at the scale required. Without addressing these, climate benefits alone are not sufficient motivation for the majority of homeowners to install a heat pump.
- We need to consider the future impacts of climate change and how buildings can be adapted and made more resilient, especially in relation to flooding and overheating.
- The upfront costs of funding home decarbonisation are currently a significant barrier and there is a need for financial incentives to encourage households to embark on the retrofit journey.
- As operational emissions from the day-to-day use of heating and appliances in homes are reduced, emissions from constructing, maintaining and demolishing buildings will become proportionately more important.
- There is a tension between the need to build more homes to satisfy demand, and the embodied carbon emissions involved in doing so. Across the UK at the current rate of house building, the entire UK 2050 carbon budget for house building will be exhausted by 2036.
- Decarbonising new homes will involve changes to the design and materials involved in their construction.
- Despite the scale of the challenge ahead, there are opportunities to lower household bills, reduce fuel poverty, improve health outcomes and create a significant number of jobs.

Introduction

Reaching net zero in Wales will require drastic reductions in emissions from new and existing buildings. This paper provides an overview of key considerations for decarbonising buildings in Wales, in a policy context where responsibilities are divided between the Welsh and UK governments.

This report forms part of WCPP's work to support the Wales Net Zero 2035 Challenge Group, established as part of the Co-operation Agreement between the Welsh Government and Plaid Cymru to examine potential pathways to net zero by 2035. Specifically, this piece contributes to the Group's third challenge area: *How could Wales heat and build homes and workplaces by 2035?*

This paper presents an overview of emissions trends from buildings in Wales, the building sector's net zero pathway, and the policy competences of the Welsh and UK Governments. It then discusses seven key considerations for the decarbonisation of existing residential buildings, followed by a shorter overview of key issues in the construction of new buildings.

Buildings in Wales

Wales has some of the least energy efficient housing stock in Western Europe (Decarbonisation of Homes in Wales Advisory Group, 2019). 23% of homes in Wales were built before 1919, and only 13% were built after 1990 (Lannon and Green, 2019). Semi-detached homes are the most common housing type, comprising 32% of housing stock, followed by detached houses (29%) and terraced houses and bungalows (27%) (Office for National Statistics, 2023).

The median EPC score for houses in Wales in 2023 was 66 (equivalent to a band D), with homes in urban areas typically having a higher score than in rural areas (Guggisberg and Smith, 2023). EPC ratings have improved considerably over the past two decades, yet the older stock (pre-1919) is still lagging behind (Robinson et al., 2023). Older homes with solid walls are considerably less likely to be insulated. While 68% of dwellings with cavity walls in Wales are insulated, the same is true for just 19% of dwellings with solid walls (reflecting the fact that retrofit upgrades to solid walls tend to be costlier and more complex than the 'low hanging fruit' of cavity wall insulation) (Welsh Government, 2019a; Palmer et al., 2018).

Around two-thirds of occupied homes in Wales are owner-occupied; of these 57% are owned outright and 42% are mortgaged (Office for National Statistics, 2023). The one third of occupied dwellings in Wales that are not owner-occupied are split almost

evenly between socially rented and privately rented (Office for National Statistics, 2023). Social housing in Wales is typically more energy efficient than owner-occupied and privately rented homes (Decarbonisation of Homes in Wales Advisory Group, 2019).

Across the UK, commercial and public (or non-domestic) buildings, tend to be younger than residential buildings, with around 30% of the non-domestic building stock having been constructed since the year 2000 (UK GBC, 2022). Non-domestic buildings are also less likely to be owner-occupied: approximately 61% of non-domestic buildings in England and Wales are rented (Department for Business, Energy and Industrial Strategy, 2021a). There is no specific data on the energy efficiency of commercial and public buildings in Wales.

Buildings emissions trends

Direct emissions from buildings of all types in Wales was 4.4MtCO_2e in 2020 (UK CCC, 2023a). Of this, over 80% came from residential buildings, with around 11% from commercial buildings and 7% from public buildings.

The primary source of these direct emissions is from the burning of fossil fuels for heating. These direct emissions do not include those from electricity use in buildings, mainly from lighting and appliances (indirect emissions) which are considered to be significantly lower (UK CCC, 2023b). Reducing carbon emissions from heating in buildings is considered a key component in reaching the overall net zero aim.

There was a reduction in direct emissions from **residential** buildings in Wales of almost one third between 1990 and 2014, largely due to improvements in energy efficiency; however, there has been little reduction since 2014 (Coles-Riley et al., 2023). While electricity demand from residential buildings fell by around 9% between 2009 and 2019, gas demand remained about the same (UK CCC, 2023a).

Increases in home working due to the COVID-19 pandemic largely contributed to the increase in direct building emissions of 2% between 2019 and 2020 (UK CCC, 2023a).

Direct emissions from **non-residential** buildings in Wales declined by around 60% between 1990 and 2018. Due to both reductions in demand and the decarbonisation of electricity generation, indirect emissions from buildings across the UK have been falling at an average rate of 10% per year since 2009 (UK CCC, 2020a).

Pathway for decarbonising buildings

The UK Climate Change Committee's (CCC's) balanced pathway scenario draws on a range of solutions for reaching net zero, with an emphasis on known and existing technologies and behaviours while also allowing flexibility for solutions to be adapted as more evidence emerges (UK CCC, 2020b). It is intended to be illustrative of what the CCC regards as a broadly sensible path based on moderate assumptions (Coles-Riley et al., 2023).

The scenario set out in the balanced pathway sees residential emissions in Wales fall 45% from the baseline in 2035, and by almost 100% to near zero in 2050 (UK CCC, 2023a). In the balanced pathway, non-residential buildings emissions fall by 52% compared to the baseline by 2035, and by 95% by 2050.

There are three main areas of buildings decarbonisation which are envisaged in the balanced pathway scenario: behaviour change, energy efficiency and low-carbon heating (UK CCC, 2020a).

In the balanced pathway scenario, the switch to low-carbon heating is the predominant source of emissions reductions by 2035, with smaller contributions occurring as a result of behaviour change and increased energy efficiency in homes. The scenario assumes that 60% of all owner-occupied homes meet EPC C standards by 2035 at the latest and 80% of heat installations in Wales are low carbon by 2030 (UK CCC, 2023a).

In contrast, the majority of emissions reductions for public and commercial buildings by 2035 in the balanced pathway are driven by energy efficiency and behaviour change. The scenario assumes a slower uptake of heat switching measures albeit with uptake increasing (both in individual buildings and through district heat networks) between 2035 and 2050. Across the whole of the UK, the balanced pathway envisages that district heat networks serve a significant amount of heat demand from public and commercial buildings, equivalent to around 22% by 2035 and 42% respectively by 2050 (UK CCC, 2020a). District heat networks are most likely to be deployed in high density urban areas, meaning that they are unlikely to be suited to more rural communities in Mid and West Wales; modelling estimates that only around 5% of the UK's total district heat capacity will be deployed in Wales (Element Energy, 2015).

The scenario assumes that gas boilers are replaced at the end of their useful life and are phased out by 2033, with public buildings moving faster and phasing out gas boilers by 2030.

In the CCC's 'tailwinds' emissions scenario, a 'stretch' scenario considered to be at the limits of feasibility, near zero emissions from buildings is achieved in 2044, with substantial behaviour change (including a 6% reduction in heating demand), high uptake of energy efficiency measures, and an increased efficiency and reduced cost of heat pumps over time (UK CCC, 2020a).

Powers and policies

While it is widely acknowledged that the Welsh government has some powers to influence the decarbonisation of buildings, most of the requisite powers are reserved to the UK government, including 'energy efficiency standards for existing buildings, products policies and regulating the financial sector' (UK CCC, 2023a: 57).

The Welsh Government has published its draft heat strategy, showcasing its vision for the path to net zero heating in Wales (Welsh Government, 2023a). It identifies the key actions in which the Welsh Government can make progress but notes that urgent reform is also needed by the UK government. The strategy also highlights the range of positive wellbeing outcomes from delivering clean, affordable and secure heat to people and businesses across Wales and supports a whole building approach to designing low carbon solutions for buildings (Welsh Government, 2023a).

The Welsh Government also has policy competence over housing and fuel poverty and has developed several policy programmes related to decarbonisation of residential properties:

- The Optimised Retrofit Programme is currently in its third phase and aims to retrofit socially owned homes in Wales while also trialling and refining tools which could support the wider decarbonisation of residential properties (Welsh Government, 2023b).
- The Warm Homes Programme has formed a key part of the Welsh Government's efforts to eliminate fuel poverty.
- The former Arbed scheme (2009-2021) took an area-based approach to improving the energy efficiency of the worst performing properties, targeting areas identified as most likely to include people living in fuel poverty (Audit Wales, 2021).
- The Nest scheme (from 2011) provides free advice and support to all households in Wales; as well as funding packages of energy efficiency measures to those on low incomes, or those struggling to meet the costs of their domestic energy bills (Welsh Government, 2023c).

Powers relating to planning and building regulations are also devolved to Wales. Part L of the Building Regulations Act 2010 was amended in 2022 to require a reduction

in carbon emissions from new homes, but it does not prohibit the installation of fossil fuel boilers (UK CCC, 2023a).

For social housing, the Welsh Housing Quality Standard 2023 requires houses to have a pathway to an EPC ‘A’ rating, and to reach the minimum ‘C’ rating by 2030 (Welsh Government, 2023d). Powers to set minimum energy efficiency standards for privately rented properties (residential and non-domestic) are reserved to the UK government, which has announced that proposed changes to raise minimum standards have been scrapped (Prime Minister’s Office, 2023). Powers in relation to the decarbonisation of commercial buildings are limited to incentivising building owners to undertake decarbonisation measures sooner.

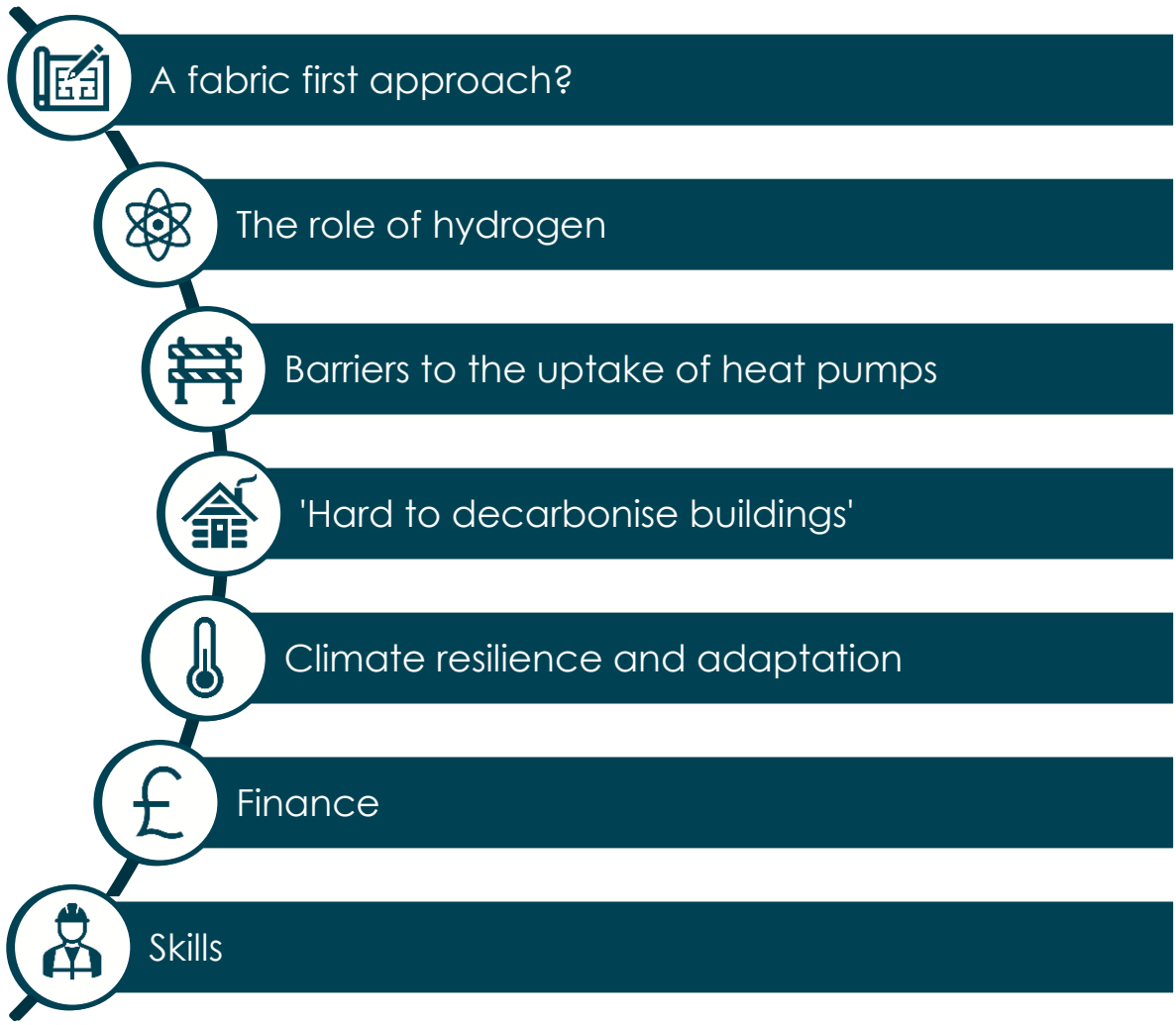
The Welsh Government has also published its route map for reaching net zero in the public sector by 2030 (Welsh Government, 2021). Buildings were highlighted as a priority area within this plan: by 2030 the route map indicates that all public buildings will be supplied with low carbon heat, while new public buildings will also be built to net zero standard. The route map does not, however, detail specific actions, responsibilities or funding requirements; and there is considerable uncertainty where funds will come from, especially given current financial pressures on both local councils and the Welsh Government (Audit Wales, 2022). It is also important to note that some public sector buildings in Wales, such as prisons, are the responsibility of the UK government, whose target date for decarbonisation is 2050, rather than 2030 (Department for Business, Energy and Industrial Strategy, 2021b; UK CCC, 2023a).

Decarbonising existing buildings

Given that emissions from residential buildings comprise around 80% of total buildings emissions in Wales and that 80% of homes that will be inhabited in 2050 already exist, the key considerations presented below relate mostly to the decarbonisation of existing residential buildings (Institute of Engineering and Technology, 2020; UK CCC, 2023a).

Figure 1 shows seven considerations when decarbonising buildings which are discussed in turn below, with a focus on residential buildings. It is also important to consider these when considering the decarbonisation of commercial and public buildings.

Figure 1: Considerations when decarbonising existing buildings



A fabric first approach?

As presented in the CCC's balanced pathway scenario, substantially reducing residential emissions will involve a combination of different measures (UK CCC, 2020a):

1. Fabric measures to improve the energy efficiency of buildings;
2. Fuel switching from fossil fuel to low carbon heat sources; and
3. Other measures to reduce energy demand.

However, there is debate about the optimum balance between and sequencing of these.

The 'fabric first' approach prioritises reducing heat demand through improving the energy efficiency of buildings. Increased energy efficiency has been cited as having multiple benefits, including lower energy bills for occupiers, reduced fuel poverty and improved health and wellbeing (IEA, 2015; Passivhaus Trust, 2021).

Improving a building's energy efficiency helps reduce the demand for heat in buildings, largely through improvements in fabric insulation (predominantly in walls and lofts) (UK CCC, 2020a). Other measures such as pre-heating, smart heating control and zoning (with separate time and temperature controls for separate rooms) can also help reduce the demand for heat. This can reduce emissions from heating buildings, but it cannot remove them entirely while the heating system remains fossil fuelled (Rosenow and Hamels, 2023).

However there is now significant potential for zero carbon electricity to be deployed at scale to heat buildings, using technology which is more efficient than existing fossil fuel boilers (Eyre et al., 2023). It may therefore prove better to only install fabric measures in homes in order to ensure that a heat pump is able to work well (Willis, 2022). Many homes have already installed easier and cheaper fabric measures, meaning that further improvements would likely involve measures which would be more expensive and more disruptive to occupiers (Eyre, et al., 2023). It is estimated that between a quarter and a third of Welsh homes may be ready to have heat pump installed without any fabric retrofit (Regan et al., 2023).

Fabric first may therefore be viable where it is cost effective, however it has been argued that it should be additional to heat switching, and not an alternative (Eyre et al., 2023). Prioritising fabric measures instead of heat switching may also slow the pace of building decarbonisation, as it may not be feasible to conduct over the timescale required (Eyre et al., 2023; Regan et al., 2023).

Solely focusing on heat switching (for example, switching from a gas boiler to a heat pump) can, in principle, reduce direct buildings emissions to zero if the new heat system is zero-emission (Rosenow and Hamels, 2023). Providing there was enough zero-emission energy to satisfy demand, this would remain true even if buildings remained thermally inefficient and with high heat demand. Moreover, even if the electricity supply is 100% carbon intensive, heat pumps reduce indirect emissions as they are significantly more efficient than gas boilers.

However, prioritising heat switching will accelerate the growth of additional demand for electricity. The electrification of heat could add approximately 50% onto the UK's peak electricity demand by 2050, with increased year-to-year variability of demand (Zhang et al., 2022; Peacock et al., 2023). Meeting the demand for electricity will already require an aggressive rate of increasing electricity generation capacity (Price, 2023). Therefore, focusing on fabric measures before adopting a heat pump could reduce the pressure on an energy system which will also face significantly increased demand in other areas; however costs may be prohibitive (Williams and Vigurs, 2023).

It is beyond the scope of this paper to assess in detail where the optimum balance lies between fabric focussed and fuel-switching focussed approaches. Given the pace of and large number of unknowns in the development of low carbon heating technologies, this is an area where existing published evidence can only take us so far. As we acknowledge in our **linked report** on international retrofit programmes, decarbonisation of residential heating at the pace and scale required can be regarded as uncharted territory beyond the available evidence base, meaning that policymakers are faced with the challenge of making key policy decisions on buildings decarbonisation while navigating uncertainty (Carmichael, 2019).

The role of hydrogen

When considering heat switching measures for decarbonisation, hydrogen heating and heat pumps are generally considered the two primary pathways. It is also acknowledged that district heat networks will likely serve an increasing number of homes in mostly urbanised areas (Department for Business, Energy and Industrial Strategy, 2021c). Some also advocate for the use of hybrid heating systems, such as using an electric heat pump alongside a hydrogen boiler (HHIC, 2022).

The Welsh Government's draft heat strategy proposes heat pumps as the optimum solution for most buildings, with hydrogen hub zones for high-temperature industries (Welsh Government, 2023a). The UK National Infrastructure Commission states that 'government should rule out supporting hydrogen heating to enable an exclusive focus on switching to electric heating' (2023a: 37).

The extent to which hydrogen is carbon neutral is dependent on how it was produced; estimates suggest that, at best, enough hydrogen could be produced to heat around 20% of all UK homes by 2030, but only half of this would be carbon neutral (Woollard, 2023). As set out in the draft heat strategy, hydrogen has an important role to play in industrial decarbonisation, which would likely require a significant proportion of the hydrogen available. It may be possible to deliver hydrogen heating in homes where it is also being delivered to industrial hubs, such as in the proposed hydrogen hub zones, though there is currently insufficient evidence on whether this is indeed the case (Rosenow, 2022).

Proponents of hydrogen heating argue that its primary advantage is the ease of the transition, as many gas boilers are already capable of withstanding a 23% hydrogen blend (Citizens Advice, 2020; Rosenow, 2022). However, conversion would likely require property surveys and temporary disconnection (Williams et al., 2018; Energy Systems Catapult, 2022a).

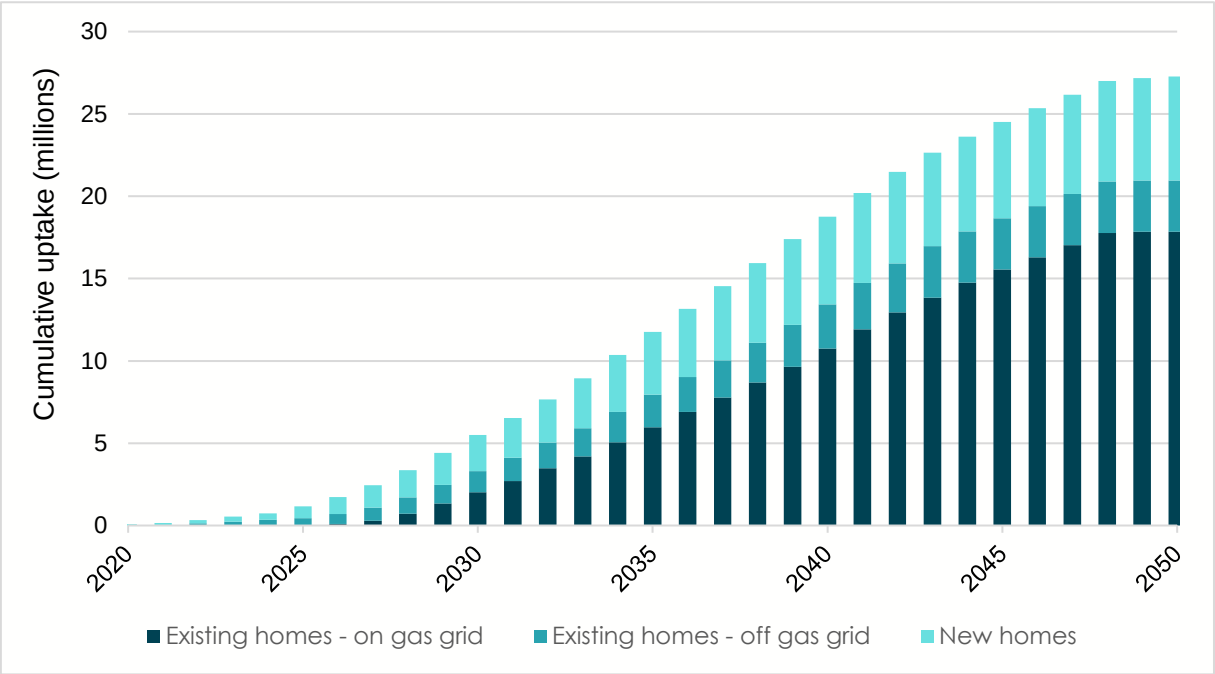
Evidence suggests that hydrogen heating is also likely to be less efficient and more resource intensive (Rosenow 2022; Royal Academy of Engineering, 2022). Modelling suggests that despite the initial installation costs of heat pumps, the ongoing cost of producing hydrogen means that heat pumps, which are an already mature technology, are likely to be more cost-effective in the long-term (Strbac et al., 2018; Baldino et al., 2020; UK National Infrastructure Commission, 2023)

As well as concerns over the costs of both technologies, research suggests that there is limited understanding of both hydrogen and heat pumps amongst consumers and that their lack of acceptability is underpinned by a perceived lack of benefit for consumers (Williams et al., 2018).

Barriers to the uptake of heat pumps

There are now estimated to be nearly 15,000 heat pumps installed across Wales, with the pace of adoption increasing from 600 certified installations in 2016 to 2,000 in 2022-23 (Regan and Gorman, 2023; Welsh Government, 2023e). While this is welcome progress towards an increased rollout of heat pumps, more work is needed to meet the new Welsh Government target of 580,000 installed heat pumps in Wales by 2035 (Welsh Government, 2023f). Currently, there are significant behavioural barriers to the adoption of heat pumps which will need to be resolved in order to increase rollout at the scale required; and meeting retrofit targets will require understanding of how multiple actors influence homeowners' behaviour (Hale et al., 2022). Figure 2 below shows the CCC's modelling of levels of uptake of heat pumps in residential buildings across the UK required to meet net zero targets.

Figure 2: Cumulative uptake of heat pumps in UK residential buildings



Source: UK CCC (2020a)

While many people recognise that decarbonising their home is important and changes will be needed, few have said they have either installed, or plan to install a heat pump (Chapman et al., 2021). This gap between values and actions is partly due to a feeling that individuals should not have to shoulder the responsibility for decarbonising their homes (Ofgem, 2020).

Decarbonisation alone is not a big enough priority for homeowners to install a heat pump. Rather, the potential to save money on energy bills is the largest motivator for installing a heat pump (Ofgem, 2020; Ahmad, 2023). High upfront costs are however a significant barrier. Upfront costs for installing heat pumps and other low carbon heating solutions are considerably higher than carbon-intensive heating options, even when considering existing government support (Ofgem, 2020). Older age groups (who are more likely to own their own home) evaluate high upfront costs as more important than potential future savings (Chapman et al., 2021).

The upfront cost barrier is exacerbated by the fact that cheaper running costs are not guaranteed and depend on heat pump performance: heat pumps which achieve a higher seasonal performance factor (SPF) do have lower annual fuel costs compared to gas boilers, but heat pumps with a lower achieved SPF cost marginally more per year to run than a gas boiler (Barnes and Bhagavathy, 2020). While heat pumps more generally have a 300%+ efficiency benefit over gas boilers, this does not fully translate into cost savings because of the higher retail cost of electricity compared to

gas (Carmichael, 2019), though it should be noted that recent trends have seen retail gas prices rising faster than electricity (Willis, 2022).

The economic competitiveness of heat pumps compared to gas boilers is further weakened by the effects of taxes and levies on electricity; environmental levies account for 23% of electricity bills in the UK while the same charge makes up just 2% of gas bills (Lowes et al., 2022). The UK government has recognised that the current taxes and levies mechanism for electricity may be having unintended consequences for heat pump (and EV) uptake and intends to reduce electricity costs via a rebalancing of energy levies or obligations away from electricity over this decade (BEIS, 2021).

Beyond cost barriers, there are other barriers to the uptake of heat pumps throughout the adoption journey. Research by the Behavioural Insights Team found that alongside high upfront and running costs, barriers of particular importance included reluctance to recommend a heat pump by seemingly sceptical heating engineers who are also new to the technology; and the huge complexity and duration of the process (a particular barrier when needing to replace a gas boiler with any urgency, given that winter is when gas boilers are more likely to fail) (Park et al. 2023) . Getting information about alternative heating solutions and obtaining quotes is perceived to be a laboursome and confusing process as heat pumps operate in a different way from gas boilers (Harrington, 2023). Consumers are reluctant to make significant renovations which may change the appearance of their home or take a long time to install, and it is difficult to find the right tradespeople (Ofgem, 2020; Chapman et al., 2021; Ahmad, 2023). There are also concerns about the visual and noise impacts of heat pumps (Ahmad, 2023).

The experiences of others is a particularly important influencing factor for consumers in making changes to their home. People value personal testimonies, positive or negative, about different products and are likely to trust these more than other types of information (Ofgem, 2020). Negative reports of poor installation leading to worse than expected performance and higher running costs contributes to low confidence in heat pumps; it has been suggested that sharing testimonies from early adopters could help remedy this, as the current media focus is overwhelmingly negative (Harris and Walker, 2023).

The path dependency of heating systems has resulted in the infrastructure, homes and the current regulatory environment being optimised for gas central heating (Gross and Hanna, 2019). Successful uptake of heat pumps in other countries such as Sweden and Finland have taken place when oil and solid fuel, rather than gas, were the established heating systems. In these countries lower costs and increased comfort have been the primary drivers (Williams and Vigurs, 2023).

Policies encouraging the move towards heat pumps need to overcome the embedded path dependency of gas heating systems and encourage an environment where cost and performance advantages stimulate further uptake (Gross and Hanna, 2019).

Hard to decarbonise buildings

Buildings are hard to decarbonise when the measures required to reach net zero are uneconomic, logistically or technically troublesome, or impose disruption on the occupiers (Parity Projects, 2022).

There are three main types of home which can be considered hard to decarbonise, including those not on the gas grid, those with listed status or in a conservation area (heritage properties) and those which are space constrained (Element Energy, 2019).

Up to 20% of UK homes could potentially not have enough space to install electrified heating systems (Element Energy, 2019). Pilot studies suggest that some space constrained homes may lack space for outdoor units, and others are too close to neighbouring properties to comply with current planning regulations (LCP Delta, 2022). A small proportion of properties, largely flats, also lacked the space for thermal stores, and required heat batteries which are more expensive (Burns et al., 2022; LCP Delta, 2022). Some space constrained properties may benefit from communal heat pumps but will still require additional energy efficiency measures (Element Energy, 2019).

Heritage and off grid properties face similar challenges in installing heat switching measures. These properties are typically older and poorly insulated, meaning that taking a whole-building and fabric first approach is likely to be significantly more expensive (Qureshi, 2022). Heritage properties also face the additional barriers of more stringent planning restrictions and associated additional costs (Nair et al., 2022; Parity Projects, 2022). The 30,000 listed buildings in Wales comprise less than 1% of the total Welsh building stock (Cadw, 2018).

Around one in five households in Wales are not connected to the gas grid, a higher proportion than the UK average (Department for Business Energy and Industrial Strategy, 2022). There is significant regional variation, with properties in rural parts of Mid and North Wales less likely to be connected. Off grid properties use a range of fuel sources, and many buildings utilise multiple sources of fuel. Around 8% of dwellings in Wales use oil as their sole fuel source, 2% use tank or bottled gas, and 10% use multiple sources (Office for National Statistics, 2023).

It is estimated that around 15% of off grid homes and 35% of heritage properties across the UK may be suitable for district heating; and the majority that are not suitable likely requiring a heat pump (Element Energy, 2019). Hybrid heat pumps, with a backup boiler running biogas, may be a solution for off grid homes with high heat demands, or which are too expensive or impractical to sufficiently insulate (Sustainable Energy Association, 2020; Qureshi, 2022).

Reaching net zero in hard to decarbonise buildings will require significant upfront investment from their owners, yet despite this there are currently no dedicated schemes to decarbonising off-grid or heritage properties (Qureshi, 2022). Heat switching measures are, however, likely lead to lower energy costs in the long-term, which will benefit owners, especially as those using alternative fuels or living in older buildings are more likely to be classified as being in fuel poverty (Welsh Government, 2022; Stewart and Bolton, 2023).

Climate resilience and adaptation

When making decisions about retrofit, we will also need to consider the future impacts of climate change and how buildings can be adapted and made more resilient. There is currently little reference to climate change adaptation in existing building regulations and there is a shortage of advice and tools to help tackle the impact of future conditions (Hayles, 2022).

Flooding is the greatest risk requiring adaptation and Wales will need to prepare for wetter and more extreme weather patterns (Hayles 2022). There are however currently no policies to help homeowners finance or implement flood resilience measures in individual properties (Town and Country Planning Association, 2021; UK CCC, 2023b).

Another risk is overheating in the summer, already a significant concern. Based on the current climate, it is estimated 55% of homes in the UK currently fail the risk assessment for bedroom nighttime overheating, meaning that the temperature exceeds 26C for more than 1% of annual nighttime hours (Arup, 2022). With a

temperature increase of 2C around 90% of homes in the UK are forecast to overheat and will likely need mitigation (Arup, 2022). Increased levels of homeworking are also likely to increase exposure to daytime overheating, with potential impacts on productivity and health and wellbeing (Town and Country Planning Association, 2021; UK CCC, 2023b).

Flats represent the type of building which are most prone to overheating due to their typically high levels of glazing and limited natural ventilation, and while there are models which estimate the current and future number of homes likely to be affected, there is limited data indicating which properties are actually affected (UK CCC, 2023b).

Many potential measures to mitigate against overheating are common in warmer climates already but are not currently present in the UK. In addition to investment in infrastructure such as shutters, fans and air conditioning; they also require behaviour change, such as using blinds, curtains and opening windows at the coolest time of day (Arup, 2022).

Finance

The upfront costs of funding home decarbonisation are currently a significant barrier to the uptake of retrofit measures and there is a need for financial incentives to encourage households to embark on the retrofit journey (UK Finance, 2022). For the majority of homeowners, decarbonisation will involve large upfront costs and lengthy payback periods.

However, there are some existing schemes which aim to provide financial incentives: for example, the UK government's Boiler Upgrade Scheme provides grants of up to £7,500 towards low carbon heating systems (Ofgem, 2023). Greater Manchester is also currently trialling property linked finance schemes in partnership with the Green Finance Institute, where the financing of home decarbonisation measures is linked to the property rather than the owner (Green Finance Institute, 2022).

Despite some schemes which are government funded, it is expected that private capital will deliver the majority of financing for homeowners who are able to pay (Green Finance Institute, 2022; UK Finance, 2022). This is likely to take the form of long-term low-interest loans, or be linked to mortgages. Several UK banks now offer a green mortgage product, where interest rates are discounted if the property obtains an EPC A or B grade, however, support will also need to be offered for people whose homes cannot viably reach this level of efficiency (Ahern, 2022). Approximately 35% of homes in the UK are also mortgage-free, meaning that people who own their homes outright will have to be targeted in other ways: financial institutions can

provide information and other products to this group (Ahern, 2022; UK Finance, 2022).

However, lenders and providers of financial products will need clarity and leadership from government, providing stable long-term policy signals and fostering collaboration between the private and public sectors (Green Finance Institute, 2020; UK Finance, 2022). Regulation of financial products is a reserved power, requiring further collaboration between the Welsh and UK governments to signal a joined-up response to the net zero challenge for lenders.

Land Transaction Tax (LLT) is devolved to Wales, however, and is one potential mechanism for encouraging homeowners to decarbonise their properties. One proposed policy option is to adjust the LTT that is required to be paid on a property based on its energy efficiency, thereby increasing demand from buyers for energy efficient homes (UK Finance, 2022). There may also be the potential to receive tax rebates if improvements are made to a home's EPC within two years of purchase.

Measuring such energy savings will likely prove a challenge. Currently, savings are largely estimated using models (like the Standard Assessment Procedure used to generate EPCs) which account neither for variations in energy use, nor for the quality of works carried out (Energy Systems Catapult, 2022b). EPCs are also not updated frequently enough to be of use to lenders. Instead, a standardised method which accurately measures energy savings using metered data could help provide confidence to lenders and help build accurate data about homes into their decision making (Energy Systems Catapult, 2022b; 2023; UK Finance, 2022).

Skills

The transition to decarbonised homes and buildings in Wales will require a significant reskilling of the existing workforce alongside a large number of new entrants to the construction sector and associated trades including electricians, plumbers and heating engineers. As well as technical skills relating to the installation of heat pumps and other retrofit measures, there are other skills needs including energy evaluation, surveying, and retrofit design, coordination and assessment (Notman et al., 2023). The sector has also faced persistent skills shortages in past years, with large numbers of older workers retiring without being replaced (Watkins and Hochlaf, 2021).

It is estimated that around 12,000 additional full time equivalent workers in Wales alone are needed by 2028 to deliver the change set out in the CCC's Balanced Pathway, representing an increase to the current workforce of around 11% (CITB, 2021). This includes an additional 2,800 plumbers and heating, ventilation and air

conditioning technicians, as well as over 2,500 project managers (including retrofit coordinators) (CITB, 2021). Apprenticeships are typically the route through which new workers enter the sector, but a range of entry routes will be needed to support additional jobs in new and existing roles, including through further education, which is often underutilised (CITB, 2021).

Demand for reskilling is currently limited by a perceived lack of consumer demand for retrofit measures (James Relly et al., 2022). There is a recognised need for new pathways into the sector and sufficient provision of qualifications (CITB, 2021). However, course provision is determined by uptake and employers are reluctant to devote time for employee reskilling without strong signals from government over the pathway to net zero buildings (including, for example, the role of hydrogen) (James Relly et al., 2022; Notman et al., 2023). There is also a high proportion of self-employed workers, who are reluctant to engage in education and training given potential losses of earnings (James Relly et al., 2022).

The education and training system supporting the construction and buildings sectors is fragmented, with a range of actors accountable for training provision and skills (Watkins and Hochlaf, 2021; James Relly et al., 2022). Coordination and collaboration between actors, including between the Welsh Government and the new Commission for Tertiary Education and Research (CTER) will be key to ensuring that there is adequate provision of skills to decarbonise buildings in Wales.

Decarbonising new buildings

As operational emissions from the day-to-day use of heating and appliances in homes are reduced through electrification and the decarbonisation of the electricity supply, the emissions in constructing, maintaining, and demolishing buildings will become proportionately more important.

Between April 2022 and March 2023, 5,785 new dwellings in Wales were completed, of which 79% were by the private sector (Welsh Government, 2023g). There has been a significant downward trend in the number of new houses completed in Wales over time: around 40% fewer buildings were completed in 2022-23 compared to the 1990s, and around 25% fewer than in the early 2000s.

The number of new homes currently built in Wales is not meeting demand. The Welsh Government previously estimated that between 6,200 and 8,300 new home per year would be required between 2019-20 and 2023-24 (Welsh Government, 2020a). Other models have estimated that this demand could be higher: at least 8,700 homes per year (Holmans, 2015). In order to meet demand, rates of house building will have to return to levels not seen since the early 2000s (Holmans, 2015).

There is a tension between the need to meet the demand for housing while also meeting environmental objectives. Emissions from new buildings largely come from those emitted in the production of materials (especially steel and concrete), as well as those indirectly emitted from fossil fuelled machinery in the construction process. Right across the UK there is a need to increase the number of new homes built to meet demand, but at the current rate of housebuilding, the entire UK 2050 carbon budget for house building will be exhausted by 2036 (Drewniok et al., 2023).

When selecting a site for new developments, consideration needs to be given to the overall flood risk, to avoid the need for future flood defence measures ((Town and Country Planning Association, 2021). More dense and hard-surfaced areas are more likely to suffer from surface water flooding and incorporating blue and green spaces into these developments can mitigate this risk (Town and Country Planning Association, 2021). Incorporating blue and green spaces can also help achieve multiple other benefits, including strengthening biodiversity, improving health and wellbeing and reducing the risk of overheating (Georgiou and Chastin, 2021; UK GBC, 2021). Shading, albedo, air movement and development layout are other factors which may increase the risk of overheating; moreover, as new homes are designed to become increasingly energy efficient, the risk of overheating in these properties increases (Town and County Planning Association, 2021).

Designing new homes to be as energy efficient as possible will mitigate heat loss, reduce household bills and reduce both direct and indirect emissions. However, building regulations tend to enforce minimum standards rather than encouraging optimal levels of energy efficiency for both build cost and carbon emissions. The energy efficiency standards for new homes in Wales were changed in 2022 to require a 37% reduction in emissions compared to the 2014 standard: this is a larger reduction than in England (31%) (Ideal Heating, 2022). However, both the CCC and the National Housing Federation agree that these regulations do not go far enough to deliver net zero, and that significantly increased levels will be needed to avoid having to retrofit new homes in the future (National Housing Federation, 2020; UK CCC, 2020c; 2023a)

The remainder of this section highlights four key considerations for reducing emissions from the construction of new homes.

Carbon intensity of materials

While operational emissions have fallen as buildings have become more efficient and renewable energy has grown, embodied carbon, emitted through the production of materials and in construction itself, has remained relatively flat (Isaac and Hawkshaw, 2020). Steel and cement are commonly used materials in construction and, alone, these materials are responsible for almost half of the UK's industrial emissions (Woodknowledge Wales, 2019).

To decarbonise new buildings, designs need to be optimised to reduce the quantity of carbon intensive materials, manufacturing processes themselves need to be decarbonised, and materials need to be reused and recycled where feasible (Pomponi and Moncaster, 2016; World Economic Forum, 2023). Carbon intensive materials can also be substituted for others: timber (discussed below) is the most prominently discussed, but there is also the potential for innovative materials including vibro stone columns, hemp lining and straw bales (Isaac and Hawkshaw, 2020).

The use of timber

Instead of steel and concreate frames, timber framed homes are a proven low-carbon construction method. Around one in three Welsh houses are timber framed, and they are even more widespread in Scotland, the United States and Scandinavia (Spear et al., 2019; Timber Development UK, 2023). Around 80% of the timber used in construction is currently imported. While Welsh timber could be used to satisfy demand, this would require a further 45,000 hectares of forest, unless a proportion of

the timber harvest is diverted from other markets, such as fencing and packaging (Woodknowledge Wales, 2019). It is estimated that in a scenario of high timber usage, with around 270,000 homes built using timber in the UK each year, around 3 $MtCO_2e$ is sequestered in 2050, only around 4% of current UK emissions from residential buildings (Spear et al., 2019).

The main downside to using timber occurs at the end of its life. The three primary options are re-use, burning or landfill, of which the latter two will return CO_2 to the atmosphere (Ramage et al., 2017). Therefore, the production of energy through biomass (with carbon capture and storage) or other innovative sequestration approaches will be required to mitigate emissions (Arup, 2019a). Moreover, the use of timber in construction is often perceived to be a fire risk (Gildings, 2022). Indeed, the use of timber cladding is prohibited on residential buildings and hospitals over 18m in height, after changes in legislation following the Grenfell Tower fire (Welsh Government, 2019b).

Modern methods of construction

Modern methods of constructions (MMC) refers to a wide variety of construction techniques using technological advancements to replace or complement traditional construction methods (Welsh Government, 2020b). This can include the prefabrication of building elements including wall and ceiling panels, frames, and full

modular apartments. The primary benefit of MMC is its speed: it can reduce construction time by more than half while increasing build quality (Arup, 2019b). While the upfront cost of buildings can be higher with MMC, longer-term savings can be realised over the whole life of the house, from construction, occupation, demolition to disposal (Town and Country Planning Association, 2020). Prefabrication can also minimise waste in factories and allow for higher environmental standards compared to traditional construction.

However, the durability of MMC buildings, and associated impacts on cost, are currently unknown compared to traditional properties (Town and Country Planning Association, 2020). Consumers are increasingly concerned with the homogeneity of modern homes, preferring a traditional style which is less intrusive to the local environment, hence the modular approach of MMC buildings is typically not popular with consumers (Ali, 2019). Lenders are also cautious about investment in projects using MMC, meaning there is currently a need for developers to raise a significant amount of upfront capital before a project can begin (Town and Country Planning Association, 2020).

Demolition or conversion?

By demolishing an existing building to replace it with a new one, the emissions involved in building the original property are wasted and new emissions are created (Penman, 2021). There are few incentives in the planning process to encourage the retention and conversion of existing buildings and there is often a lack of information on the old building itself, leading to extensive and time-consuming surveys (Penman, 2021). Non-residential buildings have a higher rate of replacement than residential buildings, but there have been recent suggestions that unused office space could be converted at scale into homes (Clifford, 2021; Abbey et al., 2022).

The evidence supporting either demolition and replacement or refurbishment is still uncertain due to methodological differences in carbon accounting (Schwartz et al., 2018). Based only on operational emissions, replacing the building would likely have a lower environmental impact than converting it, however, converted buildings tend to have a lower whole-life carbon impact due to the emissions involved in demolition and reconstruction (Schwartz et al., 2018; Abbey et al., 2022). The quality of any retrofit is a key concern, as some poorly retrofitted converted buildings perform worse over their life cycle compared to new buildings due to their high heat demand (Schwartz et al., 2018). Investors are now encouraging developers to refurbish buildings instead of demolishing and replacing, however there is still a need for improved knowledge and understanding within the sector on the benefits and challenges of both approaches (Penman, 2021)

Conclusion

Decarbonising buildings in Wales is an incredibly complex task, especially when considering the older Welsh building stock compared to the rest of the UK and the large number of buildings which are hard to decarbonise. The pace of decarbonisation is increasing but not fast enough to meet the Welsh Government's targets.

There is hope that progress in the social housing sector will encourage the decarbonisation of private rented and owner-occupied homes by both developing a skilled workforce and increasing consumer confidence through a demonstration effect; though it is yet to be seen whether this will be enough to accelerate progress at the pace required.

There remain large gaps in data on the uptake of heat decarbonisation measures and on the energy saved as a result of their deployment, which presents a challenge. This lack of data is one reason why there are few financial products or incentives geared towards helping owner-occupiers decarbonise their homes – something that will be critical if the barrier of high up-front costs is to be overcome. Although many areas of policy competence are reserved to the UK government, the Welsh Government's draft heat strategy is a significant step towards identifying areas in which it can make a difference (UK CCC, 2023a). In developing these policies, Wales could apply learning from efforts elsewhere, as highlighted in our other work **in this area.**

While residential retrofit is undoubtedly key to achieving the decarbonisation of buildings in Wales, commercial and public buildings face many of the same challenges. Financing the retrofit of public buildings in particular is likely to be a significant obstacle for the Welsh Government, especially in the current economic climate. All buildings will also undoubtedly have to adapt to Wales' changing climate, particularly in relation to flooding and overheating, yet there is currently insufficient property-level data to fully understand the scale of this problem (UK CCC, 2023b).

As we make progress in reducing operational emissions from the day-to-day running of buildings, the full emissions lifecycle will become more significant. This may lead to potential changes in the design of buildings, the materials used, and decisions about demolition. The Welsh Government does have policy autonomy in this area, but any decisions will need to be carefully considered to ensure they are coordinated with changes across the rest of the UK.

While greater attention will need to be paid to the emissions involved in building the number of new homes needed to meet demand, retrofitting residential properties at the scale required to reach net zero in 2035 or 2050 will require significant change to be made at a rapid pace, and will require targeted policies to enable this to happen. Both the Welsh and UK governments need to consider how change of this magnitude can best be facilitated and coordinated.

Despite the scale and number of significant challenges outlined above, decarbonising buildings also presents opportunities. As the Future Generations Commissioner for Wales noted in 2021, the introduction of cleaner and cheaper heating for homes has the potential to reduce fuel poverty and improve health, as well as supporting local supply chains and providing many jobs in the construction sector, especially in home renovation and maintenance.

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