Homes

of today for tomorrow

Decarbonising Welsh Housing between 2020 and 2050

Stage 3: Decarbonising social housing

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Homes of Today for Tomorrow

Stage 3: Decarbonising social housing

Welsh School of Architecture

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This work was funded by Welsh Government's Homes and Places division. Previous Stage 2 and Stage 2 reports can be downloaded at http://orca.cf.ac.uk/115442/

The authors would like to acknowledge the many contributors to this piece of work, and the improvements that they made to its relevance and accuracy - in particular, collaborators based within Carmarthenshire County Council, North Wales Housing and Tai Tarian.

To cite the report: Green, E. and Lannon, S. (2020). *Homes of Today for Tomorrow Stage 3: Decarbonising Social Housing*. Cardiff: Cardiff University.

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1. EXECUTIVE SUMMARY

In July 2019, the Independent Steering Group report: Better Homes, Better Wales, Better World recommended that:

> "Action 2.1 – By 2050 the housing stock must be retrofitted to beyond SAP90 to achieve an EPC Band A rating, recognising that not all homes will be able to achieve this…
>
> Action 2.3 – The Welsh Government should urgently commence a 10- year programme to prioritise the retrofit of certain homes…"
>
> (Welsh Government, 2019a)

This study was commissioned to understand the implications of these recommendations, by developing, testing, costing and analysing retrofit strategies for the existing Welsh social housing stock. Key aims were:

1. To test the assumptions and statistical modelling that underpinned the recommendations of the independent steering group report.

2. To learn as much as possible from Social Housing Landlords in Wales about:
- the nature of their stock
- their aspirations for the future and decision-making processes
- the cost and feasibility of retrofit (including learning from WHQS).

3. To identify challenges and benefits related to retrofit for decarbonisation.

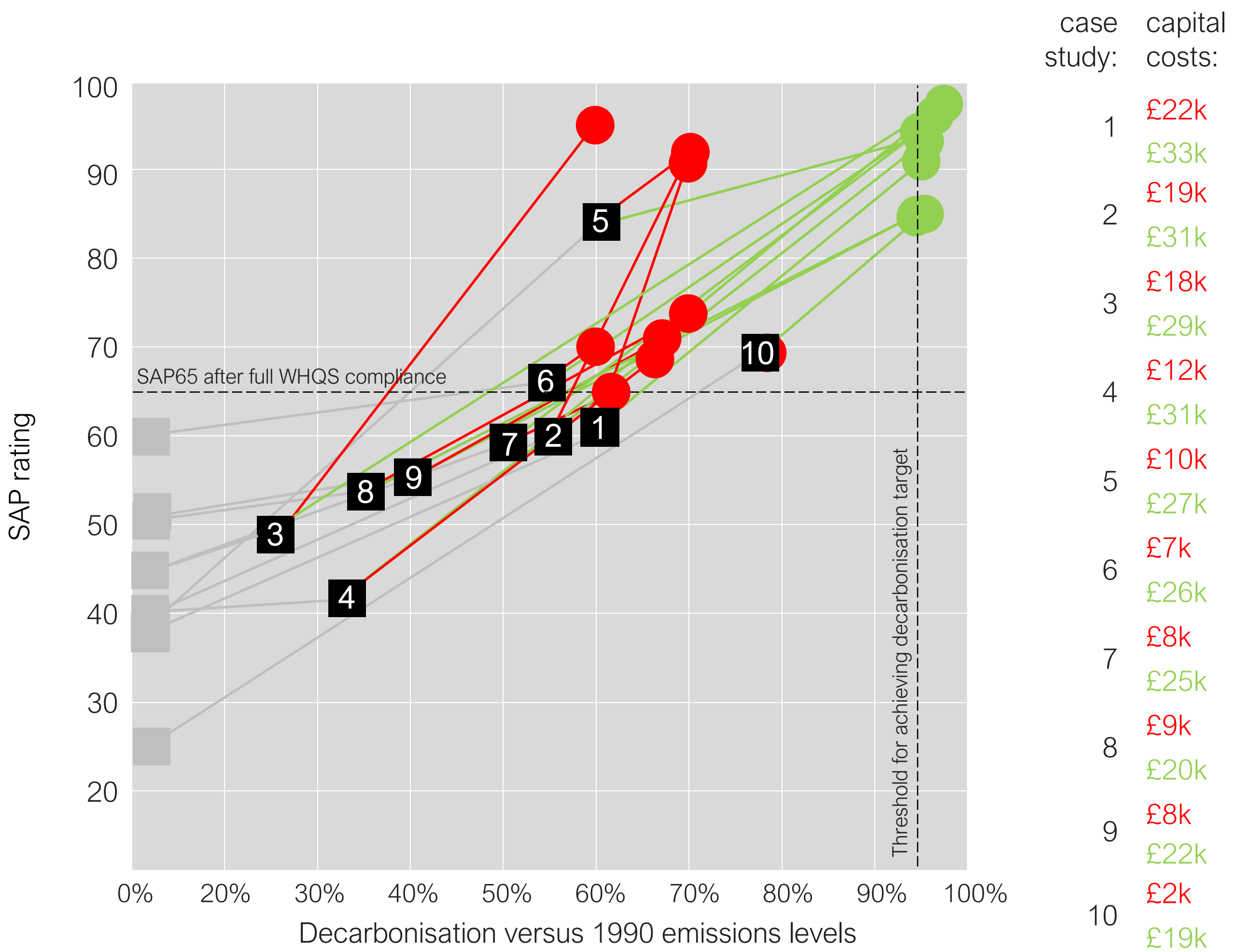
4. To develop tools that help Social Housing Landlords with retrofit decision making.

The project learnt about retrofit that has previously been undertaken (particularly activity related to the Welsh Housing Quality Standard (WHQS) programme between 2002 and 2020), to develop guidance that helps Social Housing Landlords make decisions about when and how to retrofit, and decarbonise, their housing stock. During the course of the research, the focus moved from case studies as the primary output of the work (see Section 6: case studies), to a position where case studies, while still relevant, provide a vehicle for developing a discussion of *tools* that will be useful to Social Housing Landlords (SHLs) in the future (see Section 8: tools).

10 case studies were selected from the participating landlords' housing stock. Dwellings were chosen to represent the wider social housing stock. Discussion with each SHL identified the current condition of each case study, and the extents of any planned repair, maintenance and improvement (RMI) activities. The study compares the impact of anticipated RMI with a retrofit strategy that decarbonises the case studies to achieve the Welsh decarbonisation target of 95% (versus 1990 emissions levels) by 2050.

The diagram below (figure 1.1) combines all ten case studies to describe the results of the project as a whole. Black squares represent the ten (numbered) case studies as existing, and illustrate a considerable range in energy efficiency (SAP 42, EPC 'E' to SAP84, EPC 'B'). The case studies are scattered either side of the threshold for energy efficiency after full compliance with the Welsh Housing Quality Standard (WHQS), which is SAP65, or EPC 'D'. Existing levels of decarbonisation are also very varied (26% to 77%). This range in performance is a combination of a significant range of dwelling ages (pre-1919 to post 1990) but also considerable differences in the retrofit that has already been undertaken.

Most, but not all, of the case studies have been improved through WHQS-related work. (Nationally, 90% of dwellings were WHQS compliant in 2018 – see WG 2019c.) Some case studies have been improved through energy efficiency grants (Warm Wales, ARBED). Others have had energy efficiency failures, such as cavity wall insulation. The case studies' energy efficiency in 1990 (grey squares) was equally varied (SAP 25 to SAP 67), but worse overall by nearly 20 SAP points, reflecting the improvement resulting from WHQS works (2002-2020).



Key:
- case study in 1990
- case study as existing
- case study after anticipated RMI
- case study after decarbonisation retrofit

Figure 1.1: A summary of the results drawn from ten case study dwellings

The red dots describe the predicted impact of anticipated RMI on the case studies. The impact on each case study is varied, reflecting the different approaches being adopted by different landlords, and the differing condition of each case study as existing (some require considerable work to be considered fit for inhabitation, others do not). The cost of anticipated RMI is equally varied, between £2k (recently built flat) and £22k (pre-1919 house that does not yet meet WHQS). However, overall, anticipated RMI leaves the case studies more consistent in terms of both energy efficiency and decarbonisation.

After RMI, the case studies all have energy efficiency between SAP 65 (EPC 'D') and SAP 95 (EPC 'A'). While this is still a considerable range, all dwellings are predicted to achieve the energy efficiency required for compliance with WHQS (SAP 65 or greater). After RMI, the case studies are all predicted to be between 60% and 71% decarbonised (compared with 1990 levels), failing to meet national targets. Decarbonisation is consistently limited by current anticipated RMI, which focuses on renewing existing heating systems with gas-fired wet central heating (or oil-fired boilers in off-grid situations) to maintain affordable fuel bills for tenants.

The green dots describe the predicted impact of a decarbonisation retrofit on the case studies. A consistent approach is adopted to decarbonisation. Fabric is improved to an 'enhanced standard' (to minimise negative impact on fuel bills for tenants when heating systems are decarbonised). Existing heating systems are replaced with air source heat pumps (a lower carbon heat source). Renewables are provided (to achieve decarbonisation targets and make retrofit desirable for tenants). The cost of decarbonisation retrofit is relatively consistent – between £19k and £25k for flats, and between £27k and £33k for houses. The decarbonisation retrofit adopted should not be assumed to be the best practice approach – see Section 4 Method for an explanation of the retrofit specification, capital cost assumptions and limitations of the study.

As modelled, the decarbonisation retrofit typically results in much more consistent energy efficiency and decarbonisation levels. After decarbonisation retrofit, the case studies' energy efficiency is between SAP 84 and SAP 97 (EPC 'B' and EPC 'A'). Energy efficiency of houses (i.e. excluding flats) is between SAP 92 and SAP 97 (all houses achieve EPC 'A'). This distinction reflects the fact that it is easier to improve the energy efficiency of houses than flats, which are constrained by a smaller amount of external fabric and complications arising from party walls and shared ownership. After decarbonisation retrofit, the dwellings are all between 94% and 97% decarbonised. As such, the case studies reflect the amount of work currently needed to meet national (Welsh) decarbonisation targets. (The modelling is based on currently available energy supply predictions for 2023 - source: NationalgridESO, 2019).

Summary of findings:

Decarbonisation of the Welsh housing stock is a more complex challenge than the WHQS programme (2002 to 2020). A component-led approach is embedded in the organisational operations of many Social Housing Landlords. Successful decarbonisation requires a more holistic understanding of stock, and more carefully coordinated retrofit actions.

Learning from the delivery of WHQS suggests that some Social Housing Landlords will struggle with decarbonisation targets. Without in-house skills and expertise alongside coordinated advice and guidance at a national level, it will be difficult for SHLs to develop and evolve successful decarbonisation strategies.

SAP ratings can be used to predict energy efficiency and fuel costs, but cannot be used as the sole basis to judge whether retrofit will meet decarbonisation targets. A low carbon heat source must also form part of the decarbonisation retrofit.

If the dwelling fabric is improved to an enhanced standard, retrofit of low carbon heating systems can be cost effective for tenants (meaning that, at current fuel costs, annual fuel bills remain approximately the same), and the transition to low carbon heat sources could take the place of existing boiler replacement programmes.*

Flats are more difficult to treat successfully than houses, and successful decarbonisation of flats may necessitate more creative solutions. However, flats represent a considerable fraction of the social housing stock in particular, and cannot simply be 'left behind'.

Renewables are currently needed to meet international decarbonisation targets, but may not be needed to meet these targets in the future, if energy continues to become cleaner at point of supply. However, renewables such as roof mounted PV are also highly effective in reducing fuel bills for tenants, making decarbonisation retrofit desirable for tenants. Renewables reduce energy demand, in turn reducing pressure on the energy supply network. This could be an increasingly important consideration in the future.

Unengaged tenants can significantly reduce the effectiveness of retrofit. Tenants should receive training to understand why retrofit is needed, and how to run their home afterwards. Accurate modelling, holistic retrofit that benefits the tenant, and tenant engagement are critical if decarbonisation is to be perceived positively, and be as effective as possible.

Further considerations for future WHQS:

The case studies, and underpinning Stage 2 modelling (ref. Green et.al., 2019), can be used to draw conclusions about the potential to decarbonise the Welsh housing stock (meeting international targets), while giving due consideration to affordable warmth and fuel poverty.

The studies demonstrate that by retrofitting dwelling fabric to an 'enhanced standard', replacing a new mains-gas heating system with a lower carbon heat source such as ASHP results in only minor differences in fuel bills for tenants (see above). The best-fit 'enhanced standard' specification will vary from project to project, and is best understood through accurate modelling.*

* Retrofit strategies should always be modelled as accurately as possible prior to retrofit taking place. In situations where the dwelling fabric is difficult to improve, the fabric is already performing to a high standard, or renewables are already in-situ, replacement of the existing heating systems with low carbon heating systems is currently more likely to result in increased fuel bills for tenants. This relationship needs to be explored, and understood, to avoid causing negative perceptions around retrofit for decarbonisation.

2. CONTEXT

The challenge of decarbonisation

Welsh Government was legally bound via the Environment (Wales) Act 2016 to reduce carbon emissions in Wales by at least 80% by 2050 (versus 1990 baseline levels). However, widespread acknowledgement of a climate emergency has undoubtedly escalated the profile and challenge of decarbonisation. In 2019, the UK Committee for Climate Change (an independent public body formed under the Climate Change Act (2008) to advise UK parliaments on preparing for climate change) stated that Welsh Government should target no less than a 95% reduction in carbon emissions by 2050 (CCC, 2019). In 2016, UK emissions were 41% below 1990 levels, but much of this improvement is attributed to improvements in national energy supply (CCC, 2018).

Previous work has established key considerations related to the challenge of decarbonising the Welsh housing stock, including:

- Cleaner electricity generation is a clear achievement of the last decade. However, progress in the energy sector masks a failure to decarbonise other sectors, including housing. The UK is not on course to meet the legally binding fourth and fifth UK carbon budgets (BEIS, 2017), and will not do so unless barriers compromising the delivery of existing policies are diminished and new policies drive an increased rate of decarbonisation.

- Housing is responsible for 29% of UK carbon emissions. The Welsh housing stock produces 21% of Welsh carbon emissions (BEIS 2018), reflecting the relatively high level of emissions from industry in Wales, and increasing the importance of effective decarbonisation of the housing sector.

- The Welsh housing stock was estimated at 1.4 million dwellings in 2017 (StatsWales, 2018). The only significant change to the stock in recent years is an increase in the private rented sector (StatsWales, 2019). As a result, each year in Wales, less than half the new homes needed are constructed. Meanwhile, very low levels of demolition keep the rate of replacement below 0.1% per year. Low rates of replacement and an underperforming housebuilding sector mean that more than 90% of existing homes are predicted to remain in use by 2050. (PPIW, updated 2015)

- The Welsh housing stock is, as a whole, among the oldest and least efficient in Europe. One third of homes were built before 1919. Just 6% were built in the last 30 years (Re-energising Wales, 2016). As a consequence, the energy demand for heating and reducing comfort is increased. Despite energy efficiency initiatives, it is reported that almost a quarter of households experience fuel poverty (NEA 2017).

- Welsh housing is varied in terms of type, age, physical form and construction, with a relatively even distribution of dwelling types across the housing stock (Re-energising Wales

WP1). Dwellings have been modified over time to create a diverse stock of varying quality and condition. There is no single 'solution' to decarbonise such a varied stock. However, prior analysis of the potential to retrofit the more commonly occurring dwelling 'archetypes' (Stage 2) establishes a baseline level of retrofit needed to achieve decarbonisation targets, and enabled a discussion of the significance of cleaner energy, and the likely impact on fuel bills.

These conclusions and the underpinning research informed the recent Independent Steering Group report: Better Homes, Better Wales, Better World. The report's recommendations were accepted on behalf of Welsh Government by the Minster for Housing on 24 September 2019, and include the following key actions:

> "Action 2.1 – By 2050 the housing stock must be retrofitted to beyond SAP90 to achieve an EPC Band A rating, recognising that not all homes will be able to achieve this.
>
> Action 2.2 – Lobby the UK Government to support and encourage the further decarbonisation of the energy supply grids because Wales will not achieve the carbon reduction target without it.
>
> Action 2.3 – The Welsh Government should urgently commence a 10- year programme to prioritise the retrofit of certain homes. (a) The Welsh Government should set a target of EPC Band A for homes in social ownership and homes in fuel poverty. (b) The Welsh Government should incentivise early adopters to retrofit homes to a target of EPC Band A."
>
> (Welsh Government, 2019)

Further research is needed to understand how these recommendations can be delivered. The objective of this research is to understand the implications of actions 2.1 and 2.3, by developing, testing, costing and analysing retrofit strategies for the existing Welsh social housing stock. Following a data collection exercise by Welsh Government's KAS (Knowledge and Analytical Services) to understand the makeup of the Welsh social housing stock, case studies are identified in collaboration with Social Housing Landlords, and explored in relatively fine detail, with the following key aims:

Aim 1 of this work is to understand more about the existing Welsh social housing stock, by talking to Social Housing Landlords about their housing stock, establishing what work has previously been undertaken, discussing what work is currently planned, and exploring any strategies they may have for meeting future energy efficiency targets. Relevant case studies will be identified within each social housing landlord's stock, by relating their stock back to the archetypes describing the Welsh housing stock as a whole.

Aim 2 of the project is to develop retrofit strategies that meet the target of 95%+ reduction in GHG emissions, relative to 1990 levels. Building on previous work, a decarbonistion strategy will be developed for each case study. These retrofit strategies will be modelled in terms of capital cost, impact on energy, emissions and fuel bills. By comparing them with planned RMI works, and through exploration with the Social Housing Landlords, the strategies will be tested and further developed, to arrive at robust, viable retrofit strategies for relevant case studies drawn from the Welsh social housing stock.

Aim 3 is to support the wider retrofit of the Welsh housing stock - for Social Housing Landlords, but also for other tenure groups (e.g. owner occupiers). Analysis of the case studies will enable a discussion of robust retrofit strategies for the housing stock more generally, exploring opportunities for overlap with typical RMI work, and with the Welsh Housing Quality Standard (currently in development). Finally, findings drawn from the case studies will be used to develop a series of tools that map out decision-making related to retrofit, and establish key factors that should be considered for decision making to be successful.

3. INTRODUCTION

Cleaner energy, retrofit and carbon literacy

Previous work (Stage 2: Green et. al., 2019) has identified three key components to the successful decarbonisation of the Welsh housing stock:

- cleaner energy supply
- an improved (better performing) housing stock
- informed occupants.

From the point of view of a social housing landlord, cleaner energy is the responsibility of government and the utilities companies, but there are opportunities around planning, switching homes to different energy sources, and developing a renewable infrastructure. Retrofit is key to improving the existing housing stock. Guidance on the role of decarbonisation, the Carbon Literacy Project (https://carbonliteracy.com/), is currently being developed by a broad range of stakeholders, to inform and educate organisations and tenants, primarily through peer to peer communication.

This piece of work focuses on understanding the opportunities around RETROFIT – see glossary, section 9. The project was conceived to learn from retrofit that has previously been undertaken (in particular retrofit activity related to the Welsh Housing Quality Standard (WHQS) programme, 2002 to 2014), and develop guidance to help Social Housing Landlords make decisions about when and how to retrofit, and decarbonise, their existing housing stock. During the course of this research, we have moved from case studies as the primary output of the work, to a position where case studies, while still relevant, provide a vehicle for developing a discussion of *tools* that will be useful to Social Housing Landlords in the future.

The relevance of each case study selected for this project was established by comparing them to a collection of recurring dwelling archetypes established in previous work (Stage 2). As part of this project, the Stage 2 archetypes were refined to represent the existing Welsh social housing stock.

A particular focus of this project (again, expanding on findings established by Stage 2 work) was the need to explore an apparent tension between decarbonisation, capital cost of retrofit, and impact on fuel bills for tenants. The results of each case study are structured in such a way that this tension can be explored and understood, enabling better decision making.

The success of this work has depended on a network of collaborators. Particular thanks go to the three social landlords who participated in the project (Carmarthenshire County Council, North Wales Housing and Tai Talon), to Bron Afon Community Housing (for providing case study #01 to broaden the results), to the steering group of Social Housing Landlords (who contributed their expertise and helped shape the project), to CHC for dissemination at key stages, and to Chris Jofeh, for his leadership of the independent steering group.

4. METHOD

This work is based on two earlier stages of research. Both were funded by Welsh Government's Homes and Places division. The scope of each is outlined below.

Stage 1: Decarbonising Welsh Housing between 2020 and 2050 – scoping review

Research conducted within Stage 1 began the process of mapping out pathways towards decarbonisation of the Welsh housing stock, by establishing a baseline understanding of retrofit actions, along with an empirical basis for their effectiveness. A review was produced of relevant case studies and literature. The case studies and literature were then used as an evidence base from which to discuss established retrofit actions in terms of their applicability, key issues likely to reduce or prevent their effective implementation, and their effectiveness in terms of capital costs and impact on energy efficiency and carbon emissions (using empirical data where possible). Key Stage 1 outputs included:

- a summary of existing Welsh policy and housing statistics, to understand the distinctiveness of the Welsh context
- a database of 39 'best practice' retrofit case studies, with empirical evidence of effectiveness
- a literature review of 46 publications (academic, policy, industry and advisory sources) and
- a thematically structured evaluation of retrofit, cross-referenced against the case studies and literature review.

Stage 2: Actions to decarbonise existing homes in Wales: Synthesis and Costs Study

Research conducted for Stage 2 developed a suite of models simulating the retrofit of 14 distinct dwelling 'archetypes' that together represent the Welsh housing stock. Each model simulates the impact of four different retrofit strategies, in terms of capital cost, energy use, fuel bills and carbon emissions. Each model also explores the implications of three distinct energy supply scenarios. (To model all these permutations, the 14 retrofit models are underpinned by more than two thousand separate SAP calculations.)

Together, these models were then used to draw conclusions about the potential to decarbonise the Welsh housing stock, and meet international targets for decarbonisation, while also giving due consideration to affordable warmth and fuel poverty. These conclusions informed the Independent Steering Group report: *Better Homes, Better Wales, Better World*, and the report's recommendations have since been adopted by Welsh Government in the ongoing development of a route map for decarbonisation. (See Section 1: Context for an outline of key recommendations.)

Stage 3: aims

The key aims of the Stage 3 work were as follows:

1. To test the assumptions and statistical modelling that underpinned the Stage2 work, and the subsequent recommendations embedded in the independent steering group report.

2. To learn as much as possible from Social Housing Landlords in Wales about:
   - the nature of their stock
   - their aspirations for the future and decision-making processes
   - the cost and feasibility of retrofit (including learning from WHQS).

3. To identify challenges and benefits related to retrofit for decarbonisation.

4. To develop tools that help social landlords with retrofit decision making.

Stage 3: method

At inception of this project, Welsh Government's KAS (Knowledge and Analytical Services) provided access to a dataset describing the makeup of the Welsh social housing sector. These data enabled us to identify a set of dwelling archetypes that collectively represent the Welsh social housing stock. (Within Stage 2, we developed an equivalent set of archetypes describing the Welsh housing stock as a whole.)

To test the modelling undertaken within Stage 2 research, three social landlords were selected by Welsh Government for participation in the project, based on the degree to which their stock was representative of the wider social housing stock, and the availability of data. Staff with responsibility for decarbonisation from the three participating Social Housing Landlords were interviewed (in person) to discuss the following:

- the nature of their stock
- organisational aspirations
- retrofit decision-making processes
- learning obtained from WHQS work
- the cost and feasibility of retrofit
- potential case study dwellings

10 case studies were then selected from their housing stock. Case studies were identified that represent the wider social housing stock, through comparison with the Welsh social housing archetypes. Each social housing landlord provided details describing their case studies, including current Energy Performance Certificate (EPC) results and details of any retrofit or Repair, Maintenance and Improvement (RMI) measures already installed. Further discussion with each landlord identified the current condition of each case study dwelling, and the scope of any planned future RMI activities.

This information was used in conjunction with Stage 2 modelling to produce case study models (see Figure 3.1, below). Data regarding the size and shape of the dwellings was gathered using a desktop survey of Google Streetview and Ordnance Survey maps. The case study models were validated against existing EPCs, and adjusted to produce similar results. Stage 2 data were used to produce a baseline for performance of each case study in 1990.

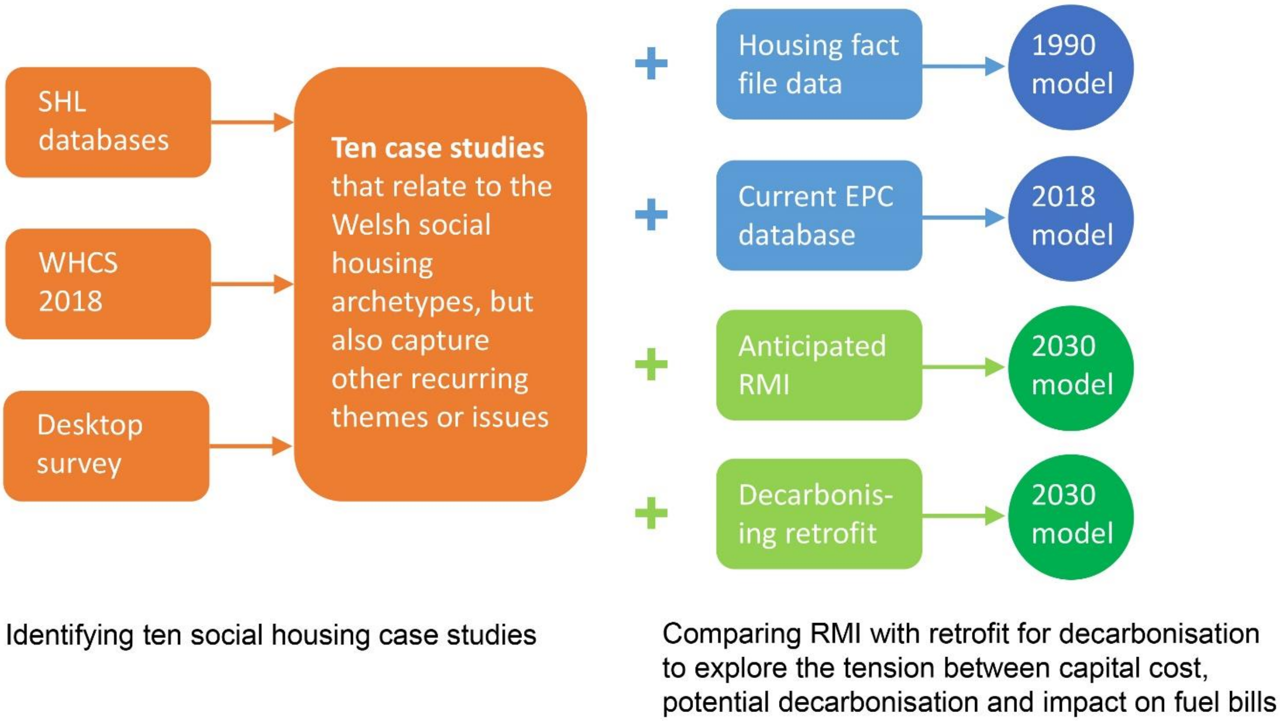


Figure 4.1 – an overview of the modelling methodology

The modelling techniques used in this report are based on the Government's Standard Assessment Procedure for Energy Rating of Dwellings (SAP) 2012 version. The SAP-derived energy requirement (energy required for space heating, water heating, lighting and contributions from renewable technologies) is then used to predict carbon emissions and associated energy costs.

The 'anticipated RMI' model was based on data and conversations with the Social Housing Landlords. Because of this, the specification for RMI is very varied - see Section 6: case studies and Section 7: findings for a discussion of the different anticipated RMI specifications.

The 'decarbonisation retrofit' model was developed from Stage 2 modelling of 'best practice' retrofit strategies for decarbonisation. For comparability, the same specification was used for each case study, so long as it did not conflict with the constraints of the case study (e.g. available roof space for photovoltaics). As modelled, the baseline decarbonisation retrofit specification was as follows:

component:	specification:	reason
walls	Insulation upgraded in a way that is appropriate to the case study, typically 100 to 150mm thickness.	Stage 2 work identified this level of improvement as a good balance between impact and capital cost
roof	Existing levels topped up, typically to 300mm thickness.	Stage 2 work identified this level of improvement as a good balance between impact and capital cost
floor	50mm overfloor insulation typically added to existing floor construction.	To upgrade floor performance while limiting disruption for tenants.
window, door	Triple Glazing composite (timber), to achieve 1.4W/m^2 ^{0}C.	To assess the impact of using newbuild-standard glazing, and the capital cost of using environmentally sound products (ie. timber frames rather than uPVC).
heating and hot water	Air Source Heat Pump (ASHP) with hot water from electric immersion heater.	At the time this work was conducted, ASHPs were considered to be the lower carbon heat source most likely to be financially viable, both from the point of capital costs and impact on residents' fuel bills.
airtightness, ventilation	Best practice without MVHR – draught stripping, good standard of workmanship throughout	In modelling, MVHR was considered to have limited impact on SAP rating / energy use, due to assumed air infiltration rates.
renewables	Photovoltaic (PV) panels, roof mounted, various sizes and orientations	PV was considered to be the most robust renewable source, and the one most likely to be installed by SHLs. Where possible, size was maintained at 4kWp per dwelling (house) and orientation was as close to south as possible. Smaller panels were assumed to be more appropriate for flats.

Table 4.1 – the baseline decarbonisation retrofit specification

Following a first round of modelling, retrofit strategies were sense checked through discussion with the relevant social housing landlord. Where necessary, they were adjusted in line with each landlord's understanding of the appropriateness of different retrofit actions for each of the case study dwellings. After the second round of modelling, the results were reviewed with each social housing landlord, to enable a discussion of the feasibility and implications of retrofit for decarbonisation.

Together, the ten case studies explore the impact of retrofit strategies designed to deliver Welsh Government's 95% decarbonisation target on ten 'real' dwellings - in terms of energy, carbon emissions, fuel bills for tenants, and capital cost (see Section 6: case studies).

Finally, a third round of discussions with the collaborating landlords and Welsh Government's steering group focussed on a review of emerging 'findings' (see Section 7) and development of tools to aid Social Housing Landlords' decision making in the future.

Limitations of the study

The modelling tool

The SAP tool has received criticism regarding accuracy (e.g. Kelly 2012), particularly in its ability to represent specific situations. Criticism focuses on assumptions that are necessarily made during the input stage and the dominant output being cost-based. These issues can be mitigated through the careful selection of input variables and by focusing on carbon emissions. (Prior work has demonstrated that with careful selection of inputs, SAP-based models can deliver stock-level simulation that is close to measured performance). However, it should be noted that the assumptions embedded in the SAP model, for example around hot water demand and occupancy patterns, limit the accuracy of the resulting modelling.

ASHP

At the time this work was conducted, ASHPs were considered to be the lower carbon heat source most likely to be financially viable, both from the point of capital costs and impact on residents' fuel bills. However, other systems continue to be developed, and may offer greater benefit.

Batteries

While renewables (specifically roof-mounted PV panels) formed part of the decarbonisation specification, the impact of batteries was not considered. The reasons for this are twofold. While batteries are beneficial from an infrastructure perspective (reducing demand and potentially increasing capacity) they do not directly improve decarbonisation of the dwellings. Also, the SAP 2012 modelling tool is not sensitive to the inclusion of batteries. Future versions of SAP should include electric batteries, providing the opportunity to explore the impact of batteries in more detail.

Standardised solutions

It should be noted that the decarbonisation retrofits described by the case studies do not necessarily represent 'best practice' retrofit strategies. Our understanding of 'best practice' retrofit is likely to change over the coming years as we learn more about the capacity of the existing housing stock to be improved, the impact of such changes on tenants, and the continually changing nature of predictions around energy supply. Rather, the case studies enable an exploration of the differences (and similarities) between a particular social housing landlord's anticipated RMI and a retrofit strategy designed for that dwelling to meet national decarbonisation targets.

It should also be noted that 'best practice' for one situation (building, geographic location, tenant, landlord, etc.) may well be different from 'best practice' for another – even if the dwellings themselves are very similar. (The SAP model, for example, assumes a 'typical' occupancy pattern – see 'modelling tools', above.) A key lesson that emerged from discussion with Social Housing Landlords was that retrofit strategies should not be fixed / predetermined, but should be sufficiently resilient to adapt to different situations, in order to deliver the greatest impact on efficiency and emissions, the greatest benefit for landlord and tenant, and the most 'liveable' house for tenants in the future. Understanding the existing building and the needs of the tenant are key to successful retrofit for decarbonisation.

Carbon emission factors

During Stage 2, speculative emission factors were assumed for electricity and gas, in order to model the possible outcome of retrofit as late as 2050. For Stage 3, it was agreed that a shorter timescale (looking at 2030 rather than 2050) would enable more certainty in assumptions being made regarding future emissions factors, and greater confidence in the resulting modelling.

Recent work produced by BEIS and the National Grid was analysed (see links below), and their predicted emissions factors for 2023 were incorporated into the modelling (Table 4.2, below). Whilst these figures are not reflective of *further* potential to decarbonise energy supply in the future, they are considered to reflect a reasonable view of emissions by 2030.

Carbon intensity	Electricity supply (kg of CO2 / kWh)	Gas supply (kg of CO2 / kWh)
2018	0.248	0.208
2020	0.103	
2023	0.089	
2035	0.041	

Table 4.2 Carbon emission factors

National Grid System Operator http://fes.nationalgrid.com/fes-document/ and BEIS https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2018

Capital costs

Capital cost predictions for the retrofit of each case study were based on cost data provided by Lee Wakeman cost consultants as part of the previous *Stage 2* work (see Green et. al., 2019). These cost assumptions are outlined in Table 4.3, overleaf. Inevitably, the underpinning assumptions around cost lead to differing levels of accuracy in capital cost predictions.

During the course of the study, a number of organisations described experiences of costs deviating considerably from the capital cost assumptions listed overleaf. These deviations were typically where work related to more complex fabric-based improvements (e.g. wall insulation upgrades), as the baseline cost assumptions do not allow for site set up, preparatory or enabling works, correction of existing fabric defects, making good, profit or overheads. To date, evidence provided suggests that the cost assumptions for more standalone measures are comparable with current real-world costs.

		Application:	Smaller dwelling (62m²):	Larger dwelling (100m²):	Notes:
Fabric	insulation	Roof	£620	£1,000	Rate of £20/sqm ground floor area (GFA)
		Wall internal	£1,230	£1,230	Rate of £30/sqm external wall
		Wall external – B Regs	£1,640	£1,640	Rate of £40/sqm external wall
		Wall external – B regs+	£2,255	£2,255	Rate of £55/sqm external wall
		floor - solid	£1,550	£2,500	Rate of £50/sqm GFA
		floor - suspended	£1,395	£2,250	Rate of £45/sqm GFA
	windows	New - UPVC	£4,500	£4,500	provisional sum of £300/m2 glazing
		New - timber	£6,750	£6,750	provisional sum of £450/m2 glazing
		New – triple, composite	£9,000	£9,000	provisional sum of £600/m2 glazing
		Secondary	£3,000	£3,000	provisional sum of £200/m2 glazing
		Shading	£1,125	£1,125	provisional sum of £75/m2 glazing
		Airtightness (Q_{50})	£620	£1,000	allowance of £10/sqm total floor area (TFA)
Renewables	lower carbon sources	Air source heat pump	£8,180	£11,600	cost at 62sqm dwelling: 5KW ASHP and HWC & immediate controls: £4,650, 7 radiators & valves: £700, Pipes, fittings & all other materials: £650, Labour: £1,400, Electrical works £550
		PV – 2.6 kWp	£5,000	£5,000	£3,500 PV panels and £1,500 builder's work
		PV – 4 kWp	£7,000	£7,000	Pro rata as above
		Electric battery	£5,000	£5,000	Provisional sum
		Solar thermal	£3,000	£3,000	£2,000 for the system, £1,000 for builder's work
		Transpired solar Collect.	£8,000	£8,000	5sqm prototype system - better data in due course.
services	heating	Gas central heating	£3,580	£5,100	provisional sum: £3,000 boiler + £500 builder's work
		Oil central heating	£4,090	£5,800	£3,500 for the boiler and £500 for builder's work
		Biomass	£7,670	£10,900	£5,000 for the boiler and £2,500 for builder's work
		Underfloor	£1,085	£1,085	pipes in insulated GF floor or in screed over slab
		Storage	£1,535	£2,200	£1,000 for the storage and £500 for builder's work
		Warm air	£7,670	£10,900	£5,000 for the system and £2,500 for builder's work
		Hot water	£1,025	£1,500	£2,000 for the system and £1,000 for builder's work
		MVHR	£1,535	£2,200	Base of £1,000 for the MVHR units and ducting and £500 builder's work, pro rata for size of dwelling.
people		Occupants remain in situ	£3,080	£4,600	
		Simple controls	£768	£1,110	£750 for controls+builder's work, pro rata for size
		Smart meters and homes	£768	£1,110	Pro rata as above

Table 4.3 Capital cost assumptions, drawn from Stage2 work

5. THE STOCK

An explanation of the Welsh social housing stock

In December 2019, Welsh Government asked Welsh Social Housing Landlords to report on their stock, by providing information regarding dwelling type and construction age, and condition (based on EPC data). The data for 49 Social Housing Landlords was compiled and made available in an anonymised form to the project team. 231,063 dwellings were listed in the database, of which 94% were provided with EPC/SAP ratings. 2% of the stock were listed in conservation areas and 7.5% were listed as off grid.

Data were compared with equivalent data for the Welsh housing stock as a whole (Table 4.1), which was previously broken down into archetypes (within Stage 2 work). This revealed differences in the composition of the social housing stock compared to stock as a whole:

- Fewer pre-1919 dwellings (5% compared to 23% across the Welsh housing stock)
- Very few detached dwellings (1% compared to 27% across the Welsh housing stock)
- Many more flats (39% compared to 8% across the Welsh housing stock)
- Very little built post-1990 (2% compared to 15% across the Welsh housing stock)

	HOUSE End terrace	HOUSE Mid terrace	HOUSE Semi-detached	HOUSE Detached	FLAT (Purpose built)	Total
pre 1919	0%	2%	1%	0%	2%	5%
1919-1944	2%	3%	5%	0%	1%	11%
1945-1964	3%	5%	12%	0%	8%	29%
1965 - 1990	5%	7%	5%	0%	19%	36%
post 1990	1%	2%	6%	1%	9%	20%
Total	11%	20%	29%	1%	39%	**82%**

Table 5.1 Breakdown of Welsh social housing stock (available data) into archetypes

The 10 case studies represent 68% of the social housing stock, in terms of dwelling type and age, two archetypes were not developed into case studies (semi-detached 1919-1944 and end terrace 1945-1964) as they were closely related to others case studies. As such, they provide insight into the most relevant dwelling types and built ages across the social housing stock, with further relevance for the Welsh housing stock in general. The balance between houses (6no.) and flats (4no.) was driven by the complexity of retrofitting flats due to shared ownership and the coordination of complex delivery plans.

Further review of the social housing stock shows that predicted EPC ratings were mostly ‘C’, with a smaller meaningful proportion scoring a ‘D’ rating, and some dwellings scoring higher (Figure 5.1). This consistency of standard is attributed to the work carried out by Social Housing Landlords while making their stock compliant with WHQS between 2002 and 2020.

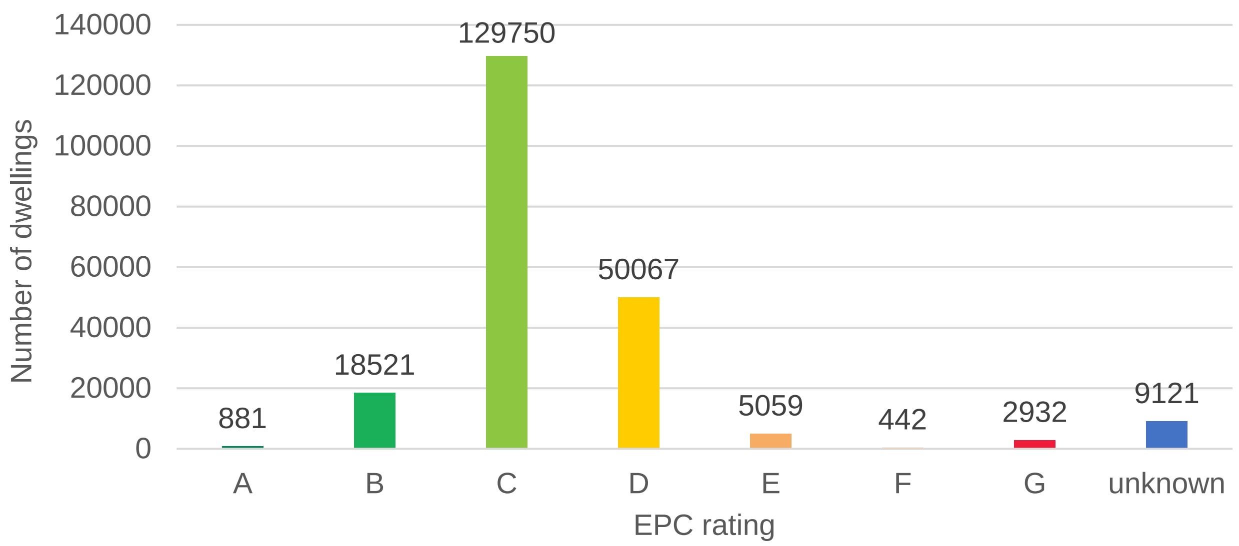


Figure 5.1 Social housing EPC ratings breakdown

Discussion with Social Housing Landlords

This study is the result of a collaboration with three Social Housing Landlords - Carmarthenshire County Council, North Wales Housing and Tai Tarian. The approaches adopted by these SHLs to manage their stock can be described as:

Carmarthenshire County Council are led by financial and technical issues.

North Wales Housing are knowledge, data and component led.

Tai Tarian are knowledge, data and goal led.

Three conversations took place with each social housing landlord over the duration of the study. Notes taken during these discussions can be clustered under the following themes: Components, Data, Financial, People, Targets and Technical issues.

	component	data	financial	knowledge	people	targets	technical	total
CCC	4	2	6	3	4	3	5	27
NWH	8	8	5	9	4	2	2	38
TT	6	7	7	13	3	5	6	47
total	18	17	18	25	11	10	13	112

Table 5.2: Notes taken during discussion with SHLs, broken down by theme

Notes are not included in full in this document, but a summary is provided as follows:

Component

Each SHL was able to supply detailed information about their stock. The data provided by each SHL focused on the components that make up their dwellings:

- walls
- roof
- floor
- window, door
- heating and hot water
- airtightness, ventilation
- renewables

In some cases, SHLs were able to supply costings for component improvements, that were then compared to the baseline costs drawn from the Stage 2 work (see cost assumptions in Section 4: method). Some of these 'real' costs were consistently similar to the assumed costs (roof insulation, windows, heat pump and renewables). Walls, floors, and ventilation costs were often different due to the level of disrepair, enabling works requirements, making good costs and the impact of other, related RMI works.

All of the SHLs involved in the study currently consider their stock from this component-based perspective, and most of the retrofit currently taking place is component-driven. This component-based approach to stock may well be a result of the reporting requirements of recent (2002 – 2020) WHQS work. There is a conflict between a component-based perspective and the need for an holistic approach to successfully decarbonise stock, which needs to be explored further. Any wider work on retrofit strategies or the development of supporting guidance / tools / grant aid should bear this in mind.

Data

All of the Social Housing Landlords are currently developing data collection methods, and building databases that describe their stock more accurately (with fewer assumptions). Data sets are being collected (or will be collected) related to stock, technology, monitoring and social care. Data sets are not currently complete, and the quality of data across different Social Housing Landlords varies considerably. SHLs would benefit from advice around the specific type and quality of data that are needed to enable good decision-making. A coordinated approach to data collection would help with this, and would enable greater collaboration and sharing of lessons between SHLs.

Financial

There are significant issues around writing-off of assets (such as previously completed retrofit) or generating long term debt as a result of further retrofit of previously improved properties. Renewal of components that still have 'life expectancy' is one such issue. These financial issues are obstacles for retrofit, and particularly for holistic decarbonisation, which relies on meeting standards that go beyond the standards embedded in the current WHQS.

Different Social Housing Landlords consider different opportunities to be the right moment for retrofit. These include major works programmes (stock-wide improvements), the void cycle, and 'special' programmes (typically focused on specific communities, or with a particular focus or agenda).

In a typical void cycle, 10% of a SHL's stock may become void and then re-occupied every year. Voids need to be refurbished (if necessary) and reoccupied quickly, as loss of rental income has financial implications. (The SHL's capital access is determined as 10x rental levels.) Because of the implications of extending the period of time for which properties are void, conducting 'deep' retrofit while properties are void can be financially difficult to support.

Provision of broadband is one example of a tangible benefit that can make retrofit more attractive to tenants. Provision of renewables, which can dramatically reduce fuel bills for tenants, is another.

Knowledge

Social Housing Landlords are starting to use EPC ratings as a means of understanding what is possible in terms of the retrofit of their stock. However, EPC ratings do not help them understand the impact of their proposed retrofit on decarbonisation targets, without further analysis of the results.

Retrofit strategies need to be developed with an awareness of each social housing landlord's decarbonisation agenda, business plan and maintenance cycles (2020 to 2030). One social landlord in particular used an external consultant to develop their decarbonisation agenda, which could lead to a wider / consortium approach.

There is currently a lack of clarity around appropriate targets for retrofit: low SAP dwellings, off-gas dwellings, fuel poor households, older properties…

People

Social Housing Landlords already have relevant roles and experienced personnel in-house, for example financial inclusion officers and energy wardens.

Education is key for tenants. A number of SHLs reported finding evidence that lack of occupant involvement can dramatically reduce retrofit effectiveness, or even result in technologies being abandoned entirely and replaced. This corroborates lessons learnt from other energy efficiency programmes (see Stage 2 findings).

Manufacturers such as Mitsubishi (ASHP) offer educational packages which could be offered to tenants. The Carbon Literacy project (https://carbonliteracy.com/) promotes the benefits of peer to peer (tenant to tenant) education.

Targets

Meeting the Welsh Housing Quality Standard (2002 – 2020) is seen as a success (see previous sub-section) and the approaches adopted by SHLs should be explored further, to learn as much as possible about how to develop retrofit strategies that are deliverable and support successful decarbonisation.

WHQS compliance has led to a focused way of hitting targets (and a component-led approach – see 'components', above).

Offsetting provides a mechanism for SHLs to deliver decarbonisation cost effectively (without considerable tenant behaviour change), but exposes them to scrutiny over 'best practice' decision-making.

In addition to developing strategies for decarbonising their domestic stock, SHLs are exploring decarbonisation of their commercial space. They are looking beyond their building stock at ways of working, including reducing car and fleet use (for example by reducing car park capacity and promoting car sharing), facilitating smart / flexible working and expanding renewables networks, including wind as well as solar power.

Technical

The Empty Homes strategy had led to some SHLs accumulating much older properties. These properties have a different set of (sometimes more complex) technical problems, and landlords would benefit from expertise located within the heritage retrofit sector.

There is potential for successful case studies to develop techniques that bring empty (disused) dwellings and commercial space back into beneficial use as decarbonised homes.

Some SHLs have stopped undertaking gas upgrades, but are not yet removing gas from properties (mostly because of negative experiences with lower carbon technologies, and associated concerns over fuel poverty). In the past there has been a focus on converting off-gas properties to on-gas, but this strategy is now under review. Gas safety checks provide an additional incentive for SHLs to remove gas, particularly from flats.

One SHL undertook a programme of 6500 boiler replacements over a 6 years period. Based on current lifecycle expectations, the same properties are likely to need heating systems replacement between 2026 and 2031.

The requirement for improved infrastructure including new substations, grid connections and grid upgrades has historically generated significant costs from utilities companies such as Western Power in the past. This has diminished (or even prevented) renewables uptake and in some cases has prevented projects from taking place. Work is currently being undertaken to reduce or mitigate these costs.

SHLs are keen to explore / understand the implications of installing PV together with battery storage. The circular economy is another issue which SHLs recognise needs to be understood better (for example the implications of embodied carbon on decision making). The SHL knowledge base relating to a number of significant issues is currently in its infancy.

6. CASE STUDIES

Ten case study discussions

Prior work commissioned by Welsh Government (Stages 1 and 2) has been ‘top down’, meaning that it has been strategic, and based on a statistical overview of the Welsh housing stock, provided by low detail, large scale datasets. In contrast, the Stage 3 case studies (see table 6.1) are ‘bottom up’, and use real dwellings as a vehicle to establish reasonable limits to retrofit. Each case study describes two scenarios:

Anticipated RMI describes ‘business as usual’ for the SHL – typically in terms of repair, maintenance and improvement.

Decarbonisation retrofit describes current best practice that targets 95% decarbonisation by:

- Improving fabric such that decarbonising heat does not impact on tenants.
- Replacing the existing heating and hot water system with heat from electricity.
- Installing photovoltaic panels (PV) as a renewable, to assess the benefit to the tenant (reduced fuel bills).

The ten case studies developed in collaboration with Social Housing Landlords are:

#	Social Housing Landlord	Identifier	Type	Age	Page
01	Bron Afon	Torfaen Terrace	End terrace	Pre 1919	25
02	Tai Tarian	Ocean Way	Mid terrace	1945-64	28
03	Carmarthenshire County Council	Ael Y Bryn	Semi-detached	1945-64	31
04	Carmarthenshire County Council	Bryn Hyfryd	Semi-detached	1945-64	34
05	Tai Tarian	Elmwood Road	Semi-detached	1965-90	37
06	North Wales Housing	Cae Bold	Semi-detached	Post 1990	40
07	Tai Tarian	Cove Road	Flats	1945-64	43
08	Carmarthenshire County Council	Y Bwthyn	Flats	1965-90	46
09	North Wales Housing	Cae Clyd	Flats	1965-90	49
10	North Wales Housing	Gerddi Morfa	Flats	Post 1990	52

Table 6.1 Case studies – an overview

Table 6.2 below identifies the percentage of the social and Welsh housing stock represented by each case study (with reference to dwelling type and age – see Table 5.1). However the usefulness of each case study is also derived from other recurring themes or embedded issues such as type of construction or occupant. These factors are identified as 'narratives' in the table below. The narratives should expand the usefulness of each case study, by increasing their relevance for the wider Welsh housing stock.

Case study	Identifier	% of all social housing	% of all Welsh housing	Narratives
01	Torfaen Terrace	<1%	3%	Retrofitting an older, poor quality void Condensation in solid wall construction Smart metering
02	Ocean Way	5%	2%	Non-traditional (no fines) construction Upgrading existing EWI Including a battery in PV installation
03	Ael Y Bryn	12%	10%	A poor quality off-gas house Comparing oil and electric heat A motivated tenant
04	Bryn Hyfryd	above	above	A poor quality mains gas house An holistic retrofit 'Clean slate' for a decarbonisation strategy
05	Elmwood Road	5%	10%	an older home that meets WHQS old cavity walls with EWI Previously installed PV
06	Cae Bold	6%	5%	Reasonable targets, recently built homes Minimising aesthetic impact – IWI Estate-wide equality
07	Cove Road	8%	2%	A retrofit package for the private sector Non traditional construction ('Cornish') Removing gas from flats
08	Y Bwthyn	19%	4%	A poor quality flat needing significant work Cavity failure "most satisfactory course of action"
09	Cae Clyd	above	above	Integrating roof, systems and renewables difficult flats on a desirable estate an estate-wide approach
10	Gerddi Morfa	9%	1%	When do you switch to electric heat? (Recent boiler in 2016) difficult flats – older persons
total		64%	33%	

Table 6.2 Percentage of the social and Welsh housing stock represented by each case study

It is important to note that case studies are not intended to be adopted as the ‘correct’ solution for any particular housing archetype (in terms of dwelling type, age or other factor). The case studies are worked examples, and are as useful for the lessons they offer about how *not* to retrofit, as much as they offer examples about how to retrofit. It is also important to acknowledge that ‘best practice’ retrofit will continue to evolve and develop as more work is undertaken, innovations become mainstream, and lessons continue to be learnt.

Case studies should be read and interpreted, to understand the complexities of working with ‘real’ homes, and in particular to appreciate the tension between retrofit for decarbonisation, capital cost of retrofit, and impact on tenant fuel bills.

Each case study is made up of three pages. The first page provides an outline of the case study, in terms of the type of home, the existing condition, the nature of the proposed work, and the ‘headline’ results. The second page outlines the proposed RMI works and the decarbonistion retrofit, as two different specifications. The third page provides the ‘results’ of each case study, with the impact of the assumed RMI retrofit described in the top half of the page, and the impact of the decarbonisation retrofit described in the bottom half.

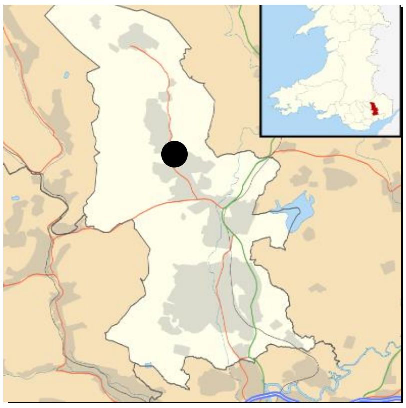
Tabulated numerical results describe the impact of each retrofit on SAP rating (for energy efficiency), decarbonisation (% reduction in emissions versus 1990 baseline), and fuel costs for the tenant. In addition to the numerical results, pie charts describe the relative impact of each retrofit measure in terms of emissions (left hand side pie chart) and capital costs (right hand side pie chart). The size of each pie chart reflects the total emissions reduction (left hand side) or total capital cost (right hand side). To ensure that tenant fuel costs remain a central part of the discussion, comments between the pie charts relate impact on fuel bills to changes in both emissions and cost.

case study 01: **End-of-terrace house, pre 1919**

headlines: Retrofitting an older, poor quality void

Condensation in solid wall construction

Smart metering



Owner:	Bron Afon Community Housing
Location:	15 Torfaen Terrace, Pontnewynydd, Pontypool NP4 8LU
Construction type:	Traditional solid wall construction (stone with brick reveals)
Status of works:	Completed 2018
End user:	social housing tenants

Project summary:

This two storey, four bedroom house was originally built 1900-1929 and extended at a later date. It has a total floor area of 120m^2 floor area, and was a void property which needed significant work to bring it up to lettable standard. The property rear previously had some grant-funded EWI in place. Internally, condensation was giving rise to internal damp and mould growth on cement-based plaster surfaces.

Summary of works:

Two approaches were considered for this retrofit. Both required a full fabric upgrade, Switchee "programmer/moisture monitor" and a 5kWp PV array facing S/E.
The anticipated retrofit describes installation of a replacement mains gas combi boiler.
The decarbonisation retrofit describes replacing the mains gas heating and hot water system with ASHP, via an appropriate heat pump system.

Summary of results:

Anticipated retrofit: RDSAP 62 (EPC ‘D’) to 91 (EPC ‘B’)
Decarbonised 61% to 70% (relative to 1990 levels)
Capital cost £21,762 per dwelling

Decarbonisation retrofit: RDSAP 62 (EPC ‘D’) to 92 (EPC ‘A’)
Decarbonised 61% to 96% (relative to 1990 levels)
Capital cost £33,055 per dwelling

case study 01 - specifications

Specification 1: **anticipated RMI**

The social housing landlord adopted the 'anticipated retrofit' strategy below because the total cost of ASHP was considered too high (additional costs of £12,000 including all remedial work). PV was also included because this project was intended as a case study.

component:	why:	how: (specification)	likely cost
walls	To meet lettable standard	50mm "moisture permeable" IWI and lime plaster to solid stone walls. 100mm EWI to cavity walls.	£4,871
roof	To meet lettable standard	Existing levels topped up to 400mm	£1,200
floor	Nothing planned	No upgrade	
window, door	To meet lettable standard	Standard high performance (upvc)	£3,736
heating and hot water	To meet lettable standard	Mains gas combi boiler	£3,580
airtightness, ventilation	As part of works	Normal practice, extractor fans fitted in kitchen & bathroom	
renewables	Case study	PV 5kWp facing SE	£8,375
Total cost			**£21,762**

Specification 2: **decarbonisation retrofit**

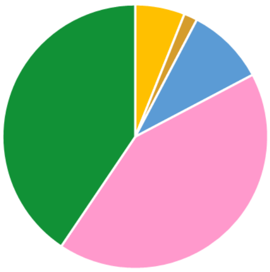
An holistic fabric upgrade of all dwelling fabric is the first step of the decarbonisation retrofit, including over-floor insulation. Heat pumps are installed later and occupants receive training to ensure that the technology is understood and can be supported organisationally. PV reduces fuel bills for the tenant to very low levels.

component:	specification:	likely cost
walls	50mm "moisture permeable" IWI and lime plaster to solid stone walls. 100mm EWI to cavity walls.	£4,871
roof	Existing levels topped up to 400mm	£1,200
floor	Ground floor insulation to 0.13W/m2 0C	£2,958
window, door	Triple Glazing composite (timber)	£7,471
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	Best practice without MVHR (considered to have minimal impact)	
renewables	PV 5kWp facing SE	£8,375
Total cost		**£33,055**

Results 1: **Anticipated retrofit**

Predicted incremental impact of retrofit:

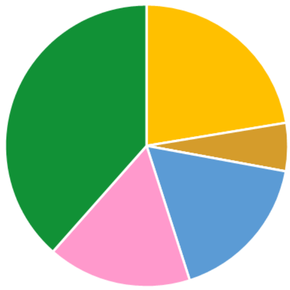
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	37	62	62	62		63	66		91
fuel bills (£)*	£1,786	£1,066	£1,053	£1,049		£1,027	£940		£249
Decarbon**	0%	61%	62%	62%		63%	67%		70%



Modest insulation of walls and upgraded glazing are more expensive than replacing the heating system, and reduce emissions and fuel bills by a modest amount.

Installation of traditional mains gas wet central heating system limits potential to decarbonise (70% overall), and annual fuel costs for tenants remain expensive.

PV is expensive but reduces fuel costs by almost £700 per year.

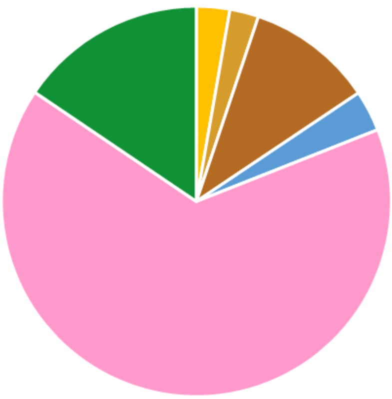


Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

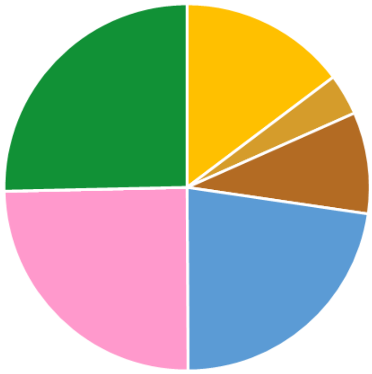
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	37	62	62	62	71	73	67		92
fuel bills (£)*	£1,786	£1,066	£1,053	£1,049	£802	£766	£923		£231
Decarbon**	0%	61%	62%	62%	73%	74%	92%		96%



Full fabric upgrade helps protect tenants from fuel poverty, reducing fuel bills by £300 per year.

The transition to electric heat is key to meeting decarbonisation targets (96% overall, with almost two thirds of the impact from heating).

Renewables make retrofit desirable for tenants, through a dramatic reduction in fuel bills of £650 per year.



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

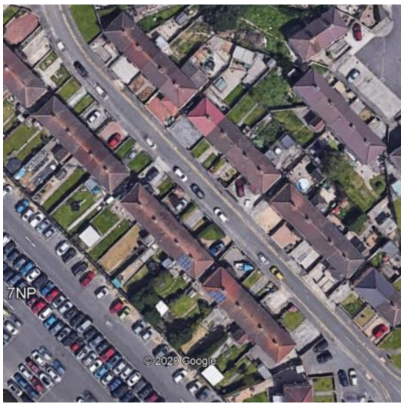
case study 02: **Mid-terraced house, 1945-64**

headlines:

Non-traditional (no fines) construction

Upgrading existing EWI

Including a battery in PV installation



Owner:	Tai Tarian
Location:	Ocean Way, Sandfields Port Talbot, SA12 7NP
Construction type:	Non-Traditional ‘no fines’ concrete construction
Status of works:	planning
End user:	social housing tenants

Project summary:

The Ocean Way terrace was built in the 1950s. The property has been treated with 50mm EWI, which is reaching the end of its anticipated lifespan. WHQS-related works were carried out in 2012. Cavity wall is assumed to be unfilled, with 50mm insulation in the roof and ‘typical’ double glazing. There is currently mains gas wet central heating from a boiler installed in 2012.

Summary of works:

Anticipated retrofit for this non-traditional dwelling type:
window replacement, roof insulation and new gas boiler.

Decarbonisation retrofit:
Upgrading all insulation, replacing mains gas heating and hot water system with electric heating, via an appropriate heat pump system.
PV with battery for storage.

Summary of results:

Anticipated retrofit: RDSAP 60 (EPC ‘D’) to 93 (EPC ‘A’)
Decarbonised 57% to 71% (relative to 1990 levels)
Capital cost £18,686 per dwelling

Decarbonisation retrofit: RDSAP 60 (EPC ‘D’) to 96 (EPC ‘A’)
Decarbonised 57% to 97% (relative to 1990 levels)
Capital cost £30,725 per dwelling

case study 02 - specifications

Specification 1: **anticipated retrofit**

The social housing landlord anticipates upgrading the thermal fabric to improve thermal performance. The property will be re-glazed during a typical RMI cycle, and the existing mains gas boiler will be replaced with a mains gas combi boiler. PV has been considered for all Tai Tarian stock, and the SHL is keen to explore the impact of battery storage on effectiveness. However the battery has not been costed because the battery's impact cannot be modelled with current SAP software.

component:	why:	how: (specification)	likely cost
walls	EWI end of lifespan	Replace with 100mm EWI	£3,197
roof	Whole stock review	Toped up to 300mm insulation	£780
floor	Nothing planned	No upgrade	£0
window, door	RMI cycle	Standard high performance (upvc)	£4,130
heating and hot water	RMI cycle	Mains gas combi boiler	£3,580
airtightness, ventilation	As part of works	Normal practice	£0
renewables	Stock-wide scheme	4 kWp	£7,000
Total cost			**£18,686**

Specification 2: **decarbonisation retrofit**

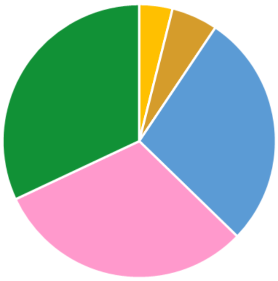
An holistic fabric upgrade is the first step of the decarbonisation retrofit. This includes provision of 50mm floor insulation. Heat pumps are installed later and occupants receive training to ensure that the technology is understood and can be supported organisationally.

component:	specification:	likely cost
walls	Replace with 150mm EWI	£3,756
roof	Topped up to 300mm insulation	£780
floor	50mm over-floor insulation.	£1,950
window, door	Triple Glazing composite (timber)	£8,259
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	Best practice without MVHR (considered to have minimal impact)	£799
renewables	PV 4kWp	£7,000
Total cost		**£30,725**

Results 1: **Anticipated retrofit**

Predicted incremental impact of retrofit:

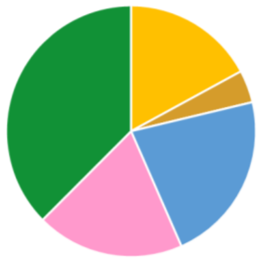
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	40	60	60	61		64	67		93
fuel bills (£)*	£1,275	£844	£836	£823		£759	£695		£141
Decarbon**	0%	57%	58%	59%		63%	67%		71%



The cost of upgrading glazing is considerable, but its impact on emissions is also significant.

Installation of traditional mains gas wet central heating system limits potential to decarbonise (71% overall) but avoids significant increases in fuel costs for tenants.

Renewables make retrofit desirable for tenants by dramatically reducing fuel bills.

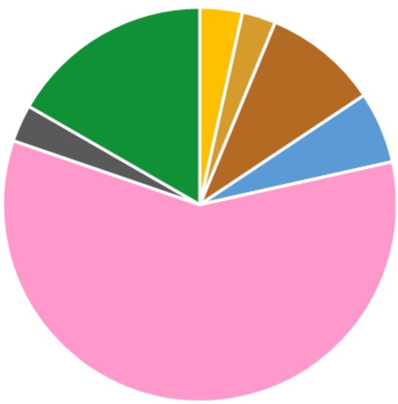


Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

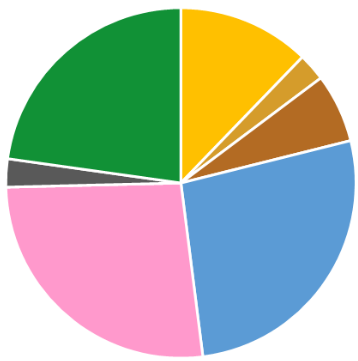
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	40	60	61	62	69	73	68	69	96
fuel bills (£)*	£1,275	£844	£818	£806	£654	£571	£677	£647	£93
Decarbon**	0%	57%	59%	60%	69%	74%	92%	92%	97%



Fabric first helps protect tenants from fuel poverty, reducing fuel bills by £300 per year.

The transition to electric heat is key to meeting decarbonisation targets (97% overall, with more than half the impact from heating).

Renewables make retrofit desirable for tenants, through a dramatic reduction in fuel bills of £550 per year.



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

Case study 03: Semi-detached house, 1945-64

headlines: True cost of decarb, poor quality house

An off-gas dwelling

A motivated tenant

Owner:	Carmarthenshire County Council
Location:	Ael Y Bryn, Penbanc, Llandeilo, Carmarthenshire SA19 7SU
Construction type:	Traditional masonry cavity wall construction
Status of works:	planning
End user:	social housing tenants

Project summary:

The semi-detached houses at Penbanc were built after the second world war. This house has 71m^2 floor area, and is heated via an oil boiler. Little work has been done to improve the energy efficiency of the dwelling. The tenant is eager to engage with a retrofit of the building using “green” principles.

Summary of works:

Anticipated retrofit for this non-traditional dwelling type:
EWI to external walls plus top up of roof insulation, window replacement, new oil-fired boiler, PV.
Decarbonisation retrofit:
Upgrading all insulation, replacing oil-fired central heating and hot water system with electric heating, via an appropriate heat pump system, PV as renewable.

Summary of results:

Anticipated retrofit: RDSAP 48 (EPC ‘E’) to 95 (EPC ‘A’)
Decarbonised 26% to 60% (relative to 1990 levels)
Capital cost £17,915 per dwelling

Decarbonisation retrofit: RDSAP 48 (EPC ‘E’) to 97 (EPC ‘A’)
Decarbonised 26% to 97% (relative to 1990 levels)
Capital cost £29,221 per dwelling

case study 03 – specifications

Specification 1: **anticipated retrofit**

The social housing landlord anticipates upgrading the thermal fabric of the walls to improve thermal performance, but avoiding more invasive work to the ground floor. The property will be re-glazed during a typical RMI cycle, and the existing boiler will be replaced with an up-to-date oil fired boiler. PV is also part of the anticipated retrofit.

component:	why:	how: (specification)	likely cost
walls	Programme of wall insulation	External Wall Insulation 100mm	£2,957
roof	Whole stock review	Existing levels topped up to 300mm	£714
floor	Nothing planned	No upgrade	£0
window, door	RMI cycle	Standard high performance (upvc)	£3,664
heating and hot water	RMI cycle	New oil fired wet central heating	£4,090
airtightness, ventilation	As part of works	Normal practice	£0
renewables	Whole stock review	PV 4kWp	£7,000
Total cost			**£18,425**

Specification 2: **decarbonisation retrofit**

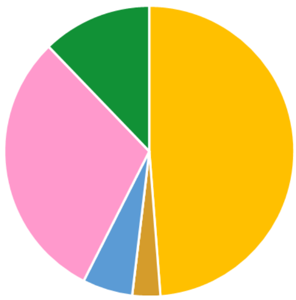
An holistic fabric upgrade of all dwelling fabric is the first step of the decarbonisation retrofit, including 50mm of over-floor insulation. Heat pumps are installed later and occupants receive training to ensure that the technology is understood and can be supported organisationally. PV reduces fuel bills for the tenant to very low levels.

component:	specification:	likely cost
walls	External Wall Insulation 150mm	£3,475
roof	Existing levels topped up to 300mm	£714
floor	50mm over-floor insulation.	£1,785
window, door	Triple Glazing composite (timber)	£7,328
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	Best practice without MVHR (considered to have minimal impact)	£739
renewables	PV 4kWp	£7,000
Total cost		**£29,221**

Results 1: **Anticipated retrofit**

Predicted incremental impact of retrofit:

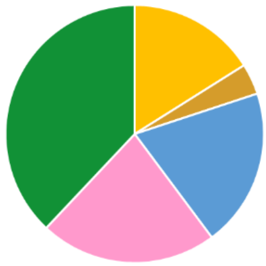
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	46	48	60	61		62	63		91
fuel bills (£)*	£1,062	£1,022	£792	£777		£748	£726		£173
Decarbon**	0%	26%	44%	45%		47%	56%		60%



Upgrading external walls and system are cost effective improvements. Upgrading glazing is more expensive with a limited impact on emissions.

Installation of an oil-fired wet central heating system severely limits potential to decarbonise (60% overall), and annual fuel costs for tenants remain expensive without renewables.

PV is expensive but significantly reduces fuel costs.

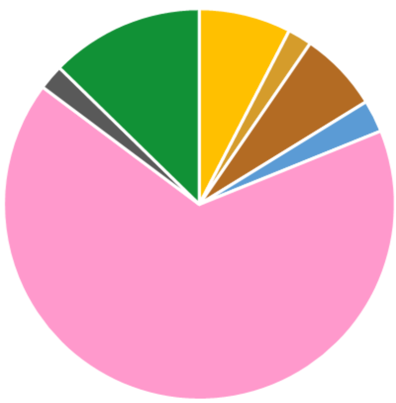


Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

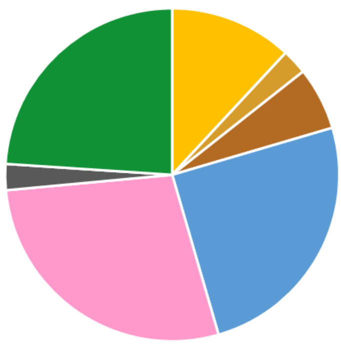
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	46	48	61	62	72	74	68	69	97
fuel bills (£)*	£1,062	£1,022	£770	£754	£557	£512	£639	£616	£62
Decarbon**	0%	26%	46%	47%	62%	66%	93%	94%	97%



Fabric first helps protect tenants from fuel poverty, reducing fuel bills by £500 per year.

The transition to electric heat is key to meeting decarbonisation targets (97% overall, with almost two thirds of the impact from heating).

Renewables make retrofit desirable for tenants, through a dramatic reduction in fuel bills of £550 per year.



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

case study 04: **Semi-detached house, 1945-64**

headlines: A poor quality mains gas house

An holistic retrofit

'Clean slate' for a decarbonisation strategy

Owner:	Carmarthenshire County Council
Location:	Brynhyfryd Road, Llanelli, Carmarthenshire SA15 3RH
Construction type:	Traditional masonry cavity wall construction
Status of works:	planning
End user:	social housing tenants

Project summary: The semi-detached houses on Brynhyfryd Road were built after the second world war. They are 85m^2 floor area, and heated via a gas wet central heating boiler. Minor changes have been made to the properties, but little work has been done to enhance the energy efficiency- this is a 'clean sheet' property requiring considerable attention.

Summary of works: Anticipated retrofit for this non-traditional dwelling type:
EWI to external walls, window replacement, new gas boiler.
Decarbonisation retrofit:
Upgrading all insulation apart from roof, replacing mains gas heating and hot water system with electric heating, via an appropriate heat pump system, PV as renewable.

Summary of results: **Anticipated retrofit: RDSAP 42 (EPC 'E') to 67 (EPC 'D')**
Decarbonised 33% to 67% (relative to 1990 levels)
Capital cost £11,512 per dwelling

Decarbonisation retrofit: RDSAP 42 (EPC 'E') to 93 (EPC 'A')
Decarbonised 33% to 96% (relative to 1990 levels)
Capital cost £30,710 per dwelling

case study 04 – specifications

Specification 1: **anticipated retrofit**

The landlord anticipates upgrading the thermal fabric of the walls to improve thermal performance, but assumes the roof is sufficiently insulated. The ground floor cannot be insulated unless the property is void. With 400 voids last year and 4000 people on a waiting list, it is difficult for them to justify keeping the property void to carry out floor insulation. The property will be re-glazed during a typical RMI cycle, and the existing boiler replaced with a mains gas combi boiler. PV is not considered for cost reasons.

component:	why:	how: (specification)	likely cost
walls	Programme of wall insulation	External Wall insulation 100mm	£3,263
roof	Whole stock review	Assumed to be sufficient 300mm	
floor	Nothing planned	No upgrade	
window, door	RMI cycle	Standard high performance (upvc)	£4,670
heating and hot water	RMI cycle	Mains gas combi boiler	£3,580
airtightness, ventilation	As part of works	Normal practice	
renewables	Nothing planned	No upgrade	
Total cost			**£11,512**

Specification 2: **decarbonisation retrofit**

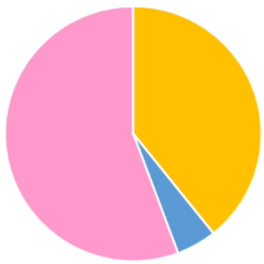
An holistic fabric upgrade of all fabric other than roof (assumed to be sufficient) is the first step of the decarbonisation retrofit. This includes provision of 50mm floor insulation. Heat pumps are installed later and occupants receive training to ensure that the technology is understood and can be supported organisationally. PV is an important part of making fuel bills affordable.

component:	specification:	likely cost
walls	External Wall insulation 100mm	£3,263
roof	Assumed to be sufficient at 300mm	
floor	50mm over-floor insulation.	£2,113
window, door	Triple Glazing composite (timber)	£9,340
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	Best practice without MVHR (considered to have minimal impact)	£816
renewables	PV 4kWp	£7,000
Total cost		**£30,710**

Results 1: **Anticipated retrofit**

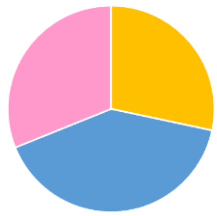
Predicted incremental impact of retrofit:

	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	40	42	54			56	67		
fuel bills (£)*	£1,327	£1,277	£1,018			£983	£726		
Decarbon**	0%	33%	49%			51%	67%		



Upgrading the external walls is cost effective. Upgrading glazing is more expensive, with a limited impact on emissions.

Installation of traditional mains gas wet central heating system limits potential to decarbonise (67% overall), and annual fuel costs for tenants remain expensive.

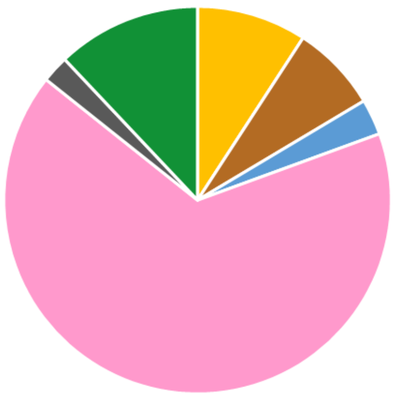


Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

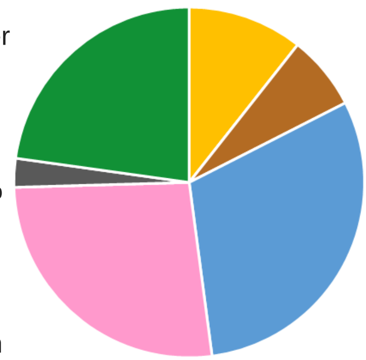
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	40	42	54		64	67	67	68	93
fuel bills (£)*	£1,327	£1,277	£1,018		£794	£739	£729	£701	£148
Decarbon**	0%	33%	49%		62%	66%	92%	92%	96%



Fabric first helps protect tenants from fuel poverty, reducing fuel bills by £300 per year.

The transition to electric heat is key to meeting decarbonisation targets (97% overall, with two thirds of the impact from heating).

Renewables make retrofit desirable for tenants, through a dramatic reduction in fuel bills of £550 per year.



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

case study 05: **Semi-detached house, 1965-90**

headlines: An older home that meets WHQS

Old cavity walls with EWI

Previously installed PV

Owner:	Tai Tarian
Location:	Elmwood Road, Baglan, SA12 8TF
Construction type:	Traditionally built masonry construction with cavity walls
Status of works:	planning
End user:	social housing tenants

Project summary: The Elmwood Road dwellings were built in the 1960s, and have since been retrofitted with external wall insulation. This house ‘type’ represents 10% of the Welsh housing stock as a whole. This particular dwelling already has PV installed.

Summary of works: Both strategies are driven by a focus on improving the performance of farbic, and attendant improvements to airtightness.

The anticipated retrofit includes top up of roof insulation and window replacement.

The decarbonisation retrofit upgrades all insulation to a higher standard, and replaces the existing mains gas wet central heating system with electric heating, via an appropriate heat pump system.

Summary of results: **Anticipated retrofit: RDSAP 84 (EPC ‘B’) to 91 (EPC ‘B’)**
Decarbonised 61% to 71% (relative to 1990 levels)
Capital cost £10,147 per dwelling

Decarbonisation retrofit: RDSAP 84 (EPC ‘B’) to 94 (EPC ‘A’)
Decarbonised 61% to 96% (relative to 1990 levels)
Capital cost £27,338 per dwelling

case study 05 - specifications

Specification 1: **anticipated retrofit**

Social housing landlord anticipates re-roofing the first floor properties, upgrading roof insulation and replacing boilers at the same time. Boilers are kept on mains gas to avoid an increase in fuel bills for occupants, until such time as PV becomes an affordable option.

component:	why:	how: (specification)	likely cost
walls	Programme of wall insulation	None	
roof	Whole stock review	Ensuring 300mm insulation throughout (assumes 100mm as existing)	£873
floor	Nothing planned	Upgrade would be disruptive + costly	
window, door	RMI cycle – whole estate	Standard high performance (upvc) (assumes double glazing as existing)	£5,694
heating and hot water	RMI cycle – whole estate	Mains gas combi boiler	£3,580
airtightness, ventilation	As part of works	-	
renewables	Nothing planned	Already has PV	
Total cost			**£10,147**

Specification 2: **decarbonisation retrofit**

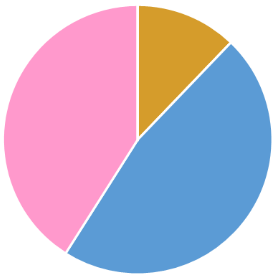
PV is already in situ. Decarbonisation retrofit upgrades fabric, including floor, to ensure tenants aren't pushed into fuel poverty and achieve decarbonisation targets. Heat pumps are installed later and occupants receive training to ensure that the technology is understood and can be supported organisationally. However, the presence of PV means that transition to electric heat increases fuel bills for tenants – a more difficult situation to make desirable.

component:	specification:	likely cost
walls	Replacement External Wall insulation 150mm	£3,886
roof	300mm insulation (assumes 100mm as existing)	£873
floor	50mm over-floor insulation	£2,183
window, door	Triple Glazing composite (timber)	£11,388
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	Best practice ventilation (MVHR discounted as limited benefit)	£827
renewables	Nothing planned - already has PV	
Total cost		**£27,338**

Results 1: **Anticipated retrofit**

Predicted incremental impact of retrofit:

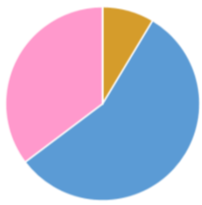
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	38	84		84		88	91		
fuel bills (£)*	£1,404	£373		£351		£263	£194		
Decarbon**	0%	61%		62%		67%	71%		



Replacement glazing represents more than half of capital costs. Costs of roof upgrade are modest.

Annual fuel bills are already low because of existing PV on roof.

Installation of traditional mains gas wet central heating system limits potential to decarbonise (71% overall).

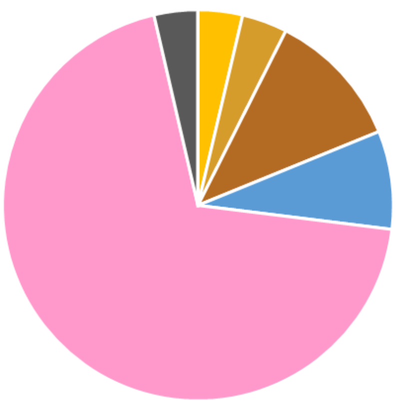


Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

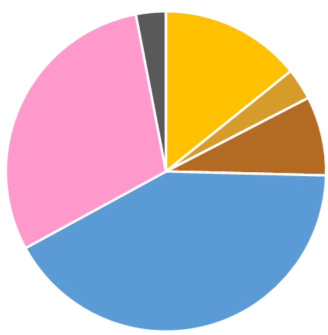
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	38	84	84	85	93	98	93	94	
fuel bills (£)*	£1,404	£373	£352	£330	£164	£51	£167	£135	
Decarbon**	0%	61%	62%	63%	73%	79%	96%	96%	



Capital costs are a little lower than other decarb retrofits because of existing PV.

Fabric first helps protect tenants from fuel poverty, reducing fuel bills from already modest levels by a further £320 per year.

Transition to electric heat is key to meeting decarb. targets (95% overall) but **increases heating bills by £110 per year.**



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

case study 06: Semi-detached house, post 1990

headlines: Reasonable targets, recently built homes

Minimising aesthetic impact – IWI

Estate-wide equality

Owner:	North Wales Housing
Location:	Cae Bold, Ffordd Bethel, Caernarfon, Gwynedd LL55 1EF
Construction type:	Traditional block and render houses
Status of works:	planning
End user:	social housing tenants

Project summary: The Cae Bold houses were built in the 1990s. Their condition is compliant with WHQS (SAP ratings of 66 and 70). They are each 81m^2 floor area, heated via a combi boiler (mains gas supply), and currently have external walls with cavity fill, and over 250mm of loft insulation.

Summary of works: Anticipated retrofit on such recently built dwellings is ‘light touch’, focusing on new glazing and a replacement mains gas combi boiler.

Decarbonisation retrofit upgrades all insulation (including floor), with improved air tightness, replacing the mains gas heating system with electric heating via an appropriate heat pump system, and installation of a 4kWp PV system.

Summary of results:

Anticipated retrofit: RDSAP 67 (EPC ‘D’) to 70 (EPC ‘C’)
Decarbonised 54% to 60% (relative to 1990 levels)
Capital cost £7,292 per dwelling

Decarbonisation retrofit: RDSAP 67 (EPC ‘D’) to 94 (EPC ‘A’)
Decarbonised 54% to 95% (relative to 1990 levels)
Capital cost £27,572 per dwelling

case study 06 - specifications

Specification 1: **anticipated retrofit**

The property will be re-glazed during a typical RMI cycle, and the existing mains gas boiler will be replaced. Boilers are kept on mains gas to avoid an increase in fuel bills for occupants, until such time as PV becomes an affordable option.

component:	why:	how: (specification)	likely cost
walls	Nothing planned	No upgrade	
roof	Whole stock review	No upgrade expected	
floor	Nothing planned	Upgrade would be disruptive + costly	
window, door	RMI cycle	Standard high performance (upvc)	£3,712
heating and hot water	RMI cycle	Mains gas combi boiler	£3,580
airtightness, ventilation	As part of works	Normal practice	
renewables	Nothing planned	No upgrade	
Total cost			**£7,292**

Specification 2: **decarbonisation retrofit**

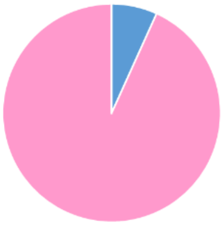
Decarbonisation retrofit upgrades all fabric apart from roof, to ensure tenants aren't pushed into fuel poverty. The social housing landlord would install IWI to improve thermal performance without affecting appearance. Heat pumps are installed and occupants receive training to ensure that the technology is understood. PV is critical to making fuel bills affordable for tenants, but also to ensure equity for residents of the estate, some of whom currently enjoy the benefits of PV and some of whom do not.

component:	specification:	likely cost
walls	Internal Wall insulation 100mm	£2,196
roof	300mm insulation (assumed as existing)	-
floor	50mm overfloor insulation	£2,040
window, door	Triple Glazing composite (timber)	£7,424
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	Best practice without MVHR (minimal impact)	£732
renewables	PV 4kWp	£7,000
Total cost		**£27,572**

Results 1: **Anticipated retrofit**

Predicted incremental impact of retrofit:

	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	60	67				68	70		
fuel bills (£)*	£865	£704				£700	£641		
Decarbon**	0%	54%				55%	60%		



Systems represent almost half of capital costs, which are modest (£7k overall).

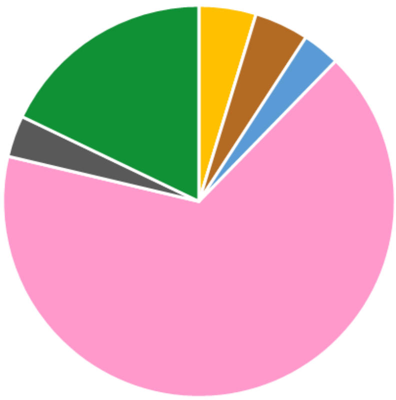
Installation of traditional mains gas wet central heating system limits potential to decarbonise (60% overall) but protects against fuel cost increases for tenants.

Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

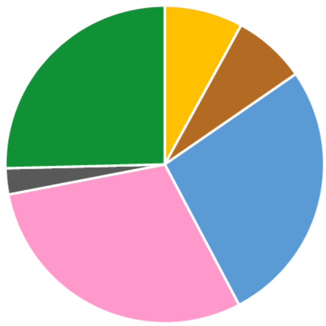
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	60	67	70		72	72	67	69	94
fuel bills (£)*	£865	£704	£657		£613	£599	£712	£681	£127
Decarbon**	0%	54%	59%		63%	64%	89%	89%	95%



Fabric first helps protect tenants from fuel poverty, reducing fuel bills by >£120 per year.

Transition to electric heat is key to meeting decarbonisation targets (95% overall)

Renewables make retrofit desirable for tenants, through a dramatic reduction in fuel bills.



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

case study 07: **Flats, 1945-64**

headlines: A retrofit package for the private sector

Non-traditional construction (‘Cornish’)

Removing gas from flats

Owner:	Tai Tarian
Location:	Cove Road, Sandfields Port Talbot, SA12 6TW
Construction type:	Non-Traditional Cornish flats
Status of works:	planning
End user:	social housing tenants

Project summary: The Cove Road flats were built in the 1950s. These are non-traditional built flats built to the Cornish ‘type’, with cavity wall construction. WHQS-related works were carried out in 2013. Cavity wall is assumed to be unfilled, with 50mm insulation in the roof and ‘typical’ double glazing throughout. There is currently mains gas wet central heating from a recently installed boiler (2013).

Summary of works: Anticipated retrofit on a non-traditional dwelling type:
window replacement, roof insulation and new gas boiler.

Decarbonisation retrofit:
Upgrading all insulation, replacing mains gas heating and hot water system with electric heating, via an appropriate heat pump system.

Summary of results: **Anticipated retrofit: RDSAP 58 (EPC ‘D’) to 65 (EPC ‘D’)**
Decarbonised 51% to 62% (relative to 1990 levels)
Capital cost £8,056 per dwelling

Decarbonisation retrofit: RDSAP 58 (EPC ‘D’) to 96 (EPC ‘A’)
Decarbonised 51% to 96% (relative to 1990 levels)
Capital cost £24,932 per dwelling

case study 07 - specifications

Specification 1: **anticipated retrofit**

The social housing landlord anticipates topping up the roof insulation to improve thermal performance. The property will be re-glazed during a typical RMI cycle, and the existing mains gas boiler will be replaced. Boilers are kept on mains gas to avoid an increase in fuel bills for occupants, until such time as PV becomes an affordable option.

component:	why:	how: (specification)	likely cost
walls	Nothing planned	No upgrade	
roof	Whole stock review	Toped up to 300mm insulation	£1,280
floor	Nothing planned	No upgrade	
window, door	RMI cycle	Standard high performance (upvc)	£3,196
heating and hot water	RMI cycle	Mains gas combi boiler	£3,580
airtightness, ventilation	As part of works	Normal practice	
renewables	Nothing planned	No upgrade	
Total cost			**£8,056**

Specification 2: **decarbonisation retrofit**

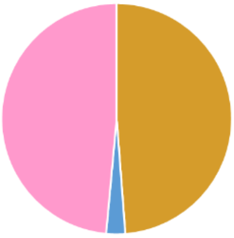
The landlord is keen to remove gas from all flats in their stock, for gas safety reasons. Upgrading the fabric of the first floor flat could take the form of a package improvement. This package could be offered to the private sector, including the owners of adjoining flats. Heat pumps are installed later and occupants receive training to ensure that the technology is understood and can be supported organisationally. PV creates ownership issues where mixed tenure flats have a shared roof.

component:	specification:	likely cost
walls	100mm internal Wall insulation	£1,561
roof	300mm insulation	£1280
floor	No upgrade as party floor	-
window, door	Triple Glazing composite (timber)	£6,391
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	Best practice without MVHR (minimal impact)	£520
renewables	PV 4kWp	£7,000
Total cost		**£24,932**

Results 1: **Anticipated retrofit**

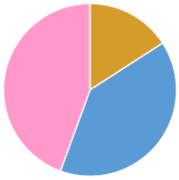
Predicted incremental impact of retrofit:

	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	45	58		62		62	65		
fuel bills (£)*	£1,014	£773		£706		£703	£643		
Decarbon**	0%	51%		57%		57%	62%		



The upgrade of glazing represents almost half of the costs, but with limited impact on emissions.

Installation of traditional mains gas wet central heating system is expensive and limits potential to decarbonise (62% overall), reducing fuel costs for tenants by just £60 per year after fabric improvements.

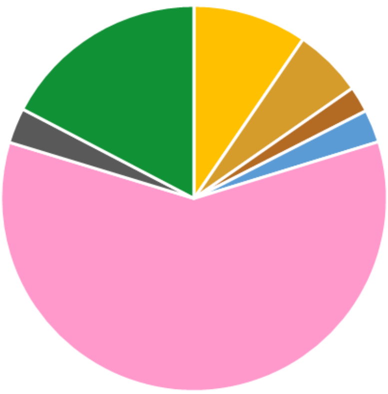


Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

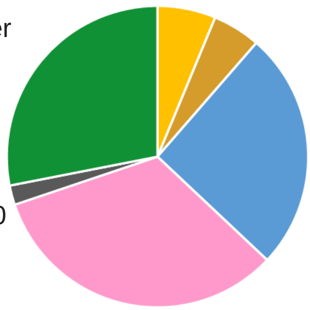
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	45	58	66	70		71	65	67	96
fuel bills (£)*	£1,014	£773	£630	£556		£543	£644	£620	£66
Decarbon**	0%	51%	63%	69%		70%	91%	91%	96%



Fabric first helps protect tenants from fuel poverty, reducing fuel bills by >£130 per year.

Transition to electric heat is key to meeting decarbonisation targets (96% overall), but increases fuel bills by £100 per year.

Renewables make retrofit desirable for tenants, through a huge reduction in fuel bills.



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

case study 08: **Flats, 1965-90**

headlines: Poor quality flats needing significant work

Cavity failure

Most satisfactory course of action

Owner:	Carmarthenshire County Council
Location:	Y Bwthyn, Llanelli, Carmarthenshire SA15 1RS
Construction type:	Traditional masonry cavity wall construction
Status of works:	planning
End user:	social housing tenants

Project summary: Y Bwthyn is a modest estate of block of flats built during the 1960s. Flats are 48m^2 floor area, heated via wet central heating boilers on mains gas. Minor repairs have been carried out over the lifespan on the dwellings, but little work has been done to improve energy efficiency.

Summary of works: Cavity wall insulation has failed and must be removed / replaced. Both strategies are driven by a focus on improving performance – by upgrading external walls, roof insulation and whole-house airtightness.

Anticipated retrofit also provides a new gas combi boiler.

Decarbonisation retrofit upgrading all insulation further, replaces the mains gas heating and hot water system with electric heating, via an appropriate heat pump system and roof mounted PV.

Summary of results: **Anticipated retrofit: RDSAP 53 (EPC 'E') to 73 (EPC 'C')**
Decarbonised 36% to 70% (relative to 1990 levels)
Capital cost £8,718 per dwelling

Decarbonisation retrofit: RDSAP 53 (EPC 'E') to 84 (EPC 'B')
Decarbonised 36% to 94% (relative to 1990 levels)
Capital cost £20,476 per dwelling

case study 08 - specifications

Specification 1: **anticipated retrofit**

The social housing landlord anticipates providing external wall insulation to improve thermal performance. The property will be re-glazed during a typical RMI cycle, and the existing mains gas boiler will be replaced. Boilers would be kept on mains gas to avoid an increase in fuel bills for occupants, until such time as PV becomes an affordable option.

component:	why:	how: (specification)	likely cost
walls	Insulation programme	External Wall insulation 100mm	£2,640
roof	Whole stock review	300mm insulation left as assumed	-
floor	Party floor	No upgrade	
window, door	RMI cycle	Standard high performance (upvc)	£2,498
heating and hot water	RMI cycle	Mains gas combi boiler	£3,580
airtightness, ventilation	As part of works	Normal practice	
renewables	Nothing planned	No upgrade	
Total cost			**£8,718**

Specification 2: **decarbonisation retrofit**

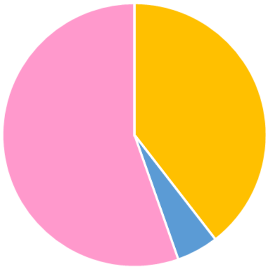
To bring these dwellings up to a lettable standard, other (expensive) work must be carried out. This work combined with the cost of retrofit raises question of the most satisfactory course of action. Suspension of Right To Buy and WG-imposed restrictions on sale mean that the only other option is to demolish and rebuild. However, the SHL also owns a care home in the immediate area, which opens up other possibilities - including district-wide CHP.

component:	specification:	likely cost
walls	100mm external Wall insulation	£2,640
roof	300mm insulation left as assumed	-
floor	No upgrade as party floor	-
window, door	Triple Glazing composite (timber)	£4,996
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	Best practice without MVHR (minimal impact)	£410
renewables	PV 2kWp	£4,250
Total cost		**£20,476**

Results 1: **Anticipated retrofit**

Predicted incremental impact of retrofit:

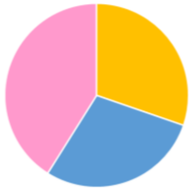
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	51	53	62			64	73		
fuel bills (£)*	£785	£754	£602			£582	£440		
Decarbon**	0%	36%	53%			55%	70%		



The upgrade of glazing represents a third of the costs, but with limited impact on emissions.

Installation of traditional mains gas wet central heating system limits potential to decarbonise (70% overall) but reduces fuel costs for tenants by £140 per year.

The impact of improvement of walls on fuel bills and decarbonisation is significant.

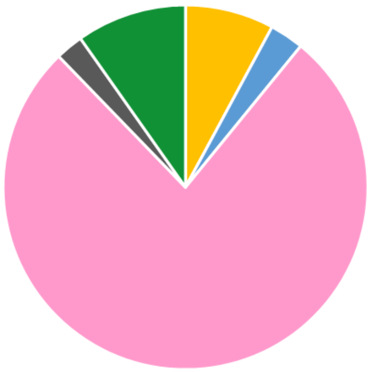


Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

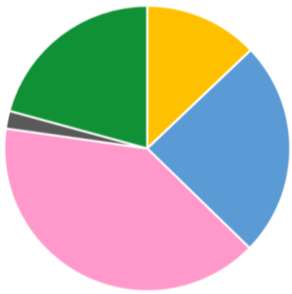
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	51	53	62			64	66	66	84
fuel bills (£)*	£785	£754	£602			£574	£553	£538	£261
Decarbon**	0%	36%	53%			55%	90%	90%	94%



Fabric improvements help protect tenants from fuel poverty, reducing fuel bills by >£150 per year.

Transition to electric heat is key to meeting decarbonisation targets (94% overall).

Modest (2kWp) PV represent a quarter of costs but make retrofit desirable for tenants, by reducing fuel bills.



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

case study 09: **Flats, 1965-90**

headlines: Integrating roof, systems and renewables

Difficult flats on a desirable estate

An estate-wide approach

Owner:	North Wales Housing
Location:	Cae Clyd, Parc Clarence, Llandudno, Conwy LL30 1BL
Construction type:	Masonry construction with cavity and party walls/floors
Status of works:	planning
End user:	social housing tenants

Project summary: North Wales Housing have 8 blocks of flats on this estate, built of mixed materials with flat / mansard roofs. The SAP ratings on these dwellings are low - work is required to the heating systems and NWH plan to upgrade the flat roofs.

Summary of works: Quotes were obtained for reroofing one block. The scope of work was expanded to include all 8 blocks to reduce costs, but will require a competitive tender. Several boilers need to be renewed. However, this has been delayed as scaffolding will be required for work on flues, and is also required for the roof upgrade, so conducting the work at the same time would reduce capital cost.

Summary of results: **Anticipated retrofit: RDSAP 56 (EPC 'D') to 71 (EPC 'C')**
Decarbonised 41% to 67% (relative to 1990 levels)
Capital cost £7,635 per dwelling

Decarbonisation retrofit: RDSAP 56 (EPC 'D') to 84 (EPC 'B')
Decarbonised 41% to 94% (relative to 1990 levels)
Capital cost £22,309 per dwelling

case study 09 – specifications

Specification 1: **anticipated retrofit**

Social housing landlord anticipates re-roofing the first floor properties, upgrading roof insulation and replacing boilers at the same time. Boilers are kept on mains gas to avoid an increase in fuel bills for occupants, until such time as PV becomes an affordable option.

component:	**why:**	**how: (specification)**	**likely cost**
walls	Programme of wall insulation	None	
roof	Whole stock review	Ensuring 300mm insulation throughout (assumes 50mm as existing)	£1,200
floor	Nothing planned	Not considered possible (party floor)	
window, door	RMI cycle – whole estate	Standard high performance (upvc) (assumes double glazing as existing)	£2,855
heating and hot water	RMI cycle – whole estate	Mains gas combi boiler	£3,580
airtightness, ventilation	As part of works	-	
renewables	Cross-estate contract	None	
Total cost			**£7,635**

Specification 2: **decarbonisation retrofit**

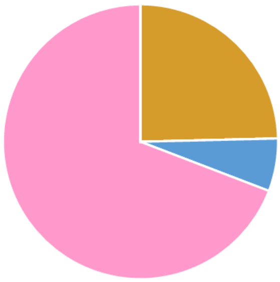
Decarbonisation retrofit upgrades fabric first, excepting party floor, to ensure tenants aren’t pushed into fuel poverty. Heat pumps are installed later and occupants receive training to ensure that the technology is understood and can be supported organisationally. PV dramatically reduces fuel bills.

component:	**specification:**	**likely cost**
walls	External Wall insulation 200mm	£2,513
roof	300mm insulation	£1,200
floor	No Floor	
window, door	Triple Glazing composite (timber)	£5,709
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	Best practice	£457
renewables	PV 2kWp	£4,250
Total cost		**£22,309**

Results 1: **Anticipated retrofit**

Predicted incremental impact of retrofit:

	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	52	56		61		62	71		
fuel bills (£)*	£862	£794		£704		£681	£512		
Decarbon**	0%	41%		50%		52%	67%		



Heating systems replacement represents almost half of capital costs, which are modest (£8k overall).

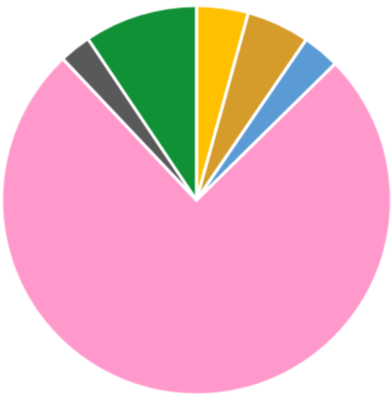
Renewal of traditional mains gas wet central heating system limits potential to decarbonise (67% overall) but reduces fuel bills by a further £170.

Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

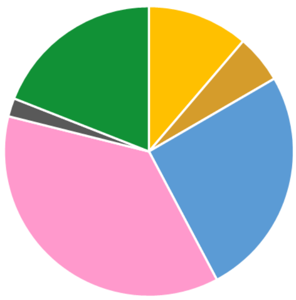
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	52	56	59	64		66	67	69	84
fuel bills (£)*	£862	£794	£730	£637		£604	£583	£561	£284
Decarbon**	0%	41%	47%	56%		59%	90%	91%	94%



Fabric first helps protect tenants from fuel poverty, reducing fuel bills by >£200 per year.

Transition to electric heat is key to meeting decarbon-isation targets (94% overall).

Renewables make retrofit desirable for tenants, reducing heating bills by almost £300 per year.



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

case study 10: Flats, post 1990

headlines: When do you switch to electric heat?

(New boiler in 2016)

Difficult flats, older persons

Owner:	North Wales Housing
Location:	Gerddi Morfa, Morfa, Conwy. LL32 8QL
Construction type:	Traditionally built ‘houses’, each containing two flats
Status of works:	planning
End user:	social housing tenants, older persons accommodation

Project summary: The Gerddi Morfa flats were built in the 1990s. These are brick-built flats, and are of very typical construction. They were converted to mains gas in 2016, when new boilers were installed. Because they are intended for elderly occupants, comfort and affordable warmth are particularly important.

Summary of works: Anticipated retrofit on such recently built dwellings is very ‘light touch’, as the RMI cycle for most components is beyond 2030. The only anticipated improvement is renewal of the windows with high quality uPVC replacements.

Decarbonisation retrofit upgrades all insulation (apart from the floor, which is a party floor) and replaces the mains gas system with electric heating, via an appropriate heat pump system.

Summary of results: **Anticipated retrofit: RDSAP 69 (EPC ‘C’) to 69 (EPC ‘C’)**
Decarbonised 77% to 78% (relative to 1990 levels)
Capital cost £1,698 per dwelling

Decarbonisation retrofit: RDSAP 69 (EPC ‘C’) to 85 (EPC ‘B’)
Decarbonised 77% to 96% (relative to 1990 levels)
Capital cost £18,913 per dwelling

case study 10 - specifications

Specification 1: **anticipated retrofit**

The anticipated retrofit strategy assumes that the property will be re-glazed during a typical RMI cycle, but that the existing mains gas boiler will still be in use in 2030. The boiler is kept on mains gas to avoid an increase in fuel bills for occupants, until such time as PV becomes an affordable option.

component:	**why:**	**how: (specification)**	**likely cost**
walls	Nothing planned	No upgrade	
roof	Nothing planned	No upgrade	
floor	Nothing planned	No upgrade	
window, door	RMI cycle	Standard high performance (upvc)	£1,698
heating and hot water	Nothing planned	No upgrade	
airtightness, ventilation	Nothing planned	No upgrade	
renewables	Nothing planned	No upgrade	
Total cost			**£1,698**

Specification 2: **decarbonisation retrofit**

Decarbonisation retrofit upgrades all fabric components apart from the party floor, to ensure tenants aren't pushed into fuel poverty. IWI will reduce the space available internally. Heat pumps are installed later and occupants receive training to ensure that the technology is understood and can be supported organisationally. PV is modest (2kWp per flat) but makes retrofit more attractive to tenants by reducing fuel bills.

component:	**specification:**	**likely cost**
walls	Internal wall insulation 100mm	£1,126
roof	No upgrade planned	-
floor	50mm overfloor insulation	£1,960
window, door	Triple Glazing composite (timber)	£3,397
heating and hot water	Air Source Heat Pump	£8,180
airtightness, ventilation	No upgrade planned	-
renewables	PV 2kWp	£4,250
Total cost		**£18,913**

Results 1: **Anticipated retrofit**

Predicted incremental impact of retrofit:

	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	25	69				69			
fuel bills (£)*	£1,147	£453				£451			
Decarbon**	0%	77%				78%			

A very modest retrofit generates marginal capital cost and minimal impact on decarbonisation.

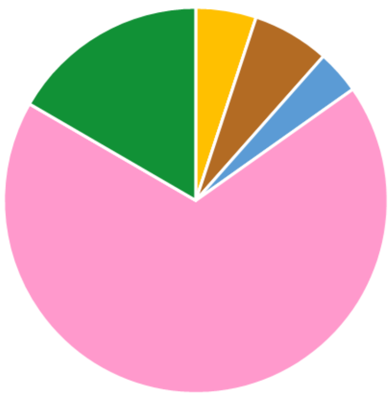
By continuing to utilise the existing traditional mains gas wet central heating system, the potential to decarbonise is limited, at 78% overall.

Comparison of decarbonising impact against capital costs for each component

Results 2: **Decarbonising retrofit**

Predicted incremental impact of retrofit:

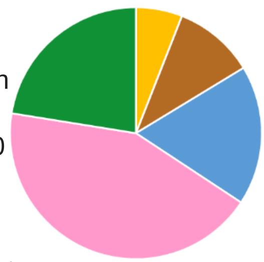
	1990	now	+wall	+roof	+floor	+glazing	+heat.	+vent.	+renew
SAP	25	69	70		72	73	66		85
fuel bills (£)*	£1,147	£453	£433		£397	£391	£491		£214
Decarbon**	0%	77%	79%		82%	82%	94%		96%



Improvements to fabric reduce fuel bills by just £60 per year.

Transition to electric heat is key to meeting decarbonisation targets (92% overall) but increases heating bills by £100 or more per year.

Renewables make retrofit considerably more attractive for tenants, reducing fuel bills by £270 per year.



Comparison of decarbonising impact against capital costs for each component

* energy costs are based on current cost per unit
** emissions relative to 1990, based on energy supply predictions for 2023 (source: NationalgridESO, 2019)

7. FINDINGS

Results and discussion drawn from case studies

The tables below and overleaf summarise the ten case studies. Table 7.1 below explores the impact of anticipated RMI on SAP ratings, decarbonisation (emissions reduction) and fuel bills for tenants. Table 7.2 overleaf explores the impact of the proposed decarbonisation strategy.

Predicted impact of anticipated RMI

Case study	Identifier	Type	Age	SAP rating		Decarbonisation		Fuel bills		Capital cost
				now	after	now	after	now	after	
01	Torfaen Terrace	End terrace	Pre 1919	62	91	61%	70%	£1066	£249	£22k
02	Ocean Way	Mid terrace	1945-1964	60	93	57%	71%	£844	£141	£19k
03	Ael Y Bryn	Semi-detach	1945-1964	48	91	26%	60%	£1022	£173	£18k
04	Bryn Hyfryd	Semi-detach	1945-1964	42	67	33%	67%	£1277	£726	£12k
05	Elmwood Road	Semi-detach	1965-1990	84	91	61%	71%	£373	£194	£10k
06	Cae Bold	Semi-detach	Post 1990	67	70	54%	60%	£704	£641	£7k
07	Cove Road	Flats	1945-1964	58	65	51%	62%	£773	£643	£8k
08	Y Bwthyn	Flats	1965-1990	53	73	36%	70%	£754	£440	£8k
09	Cae Clyd	Flats	1965-1990	56	71	41%	67%	£794	£512	£8k
10	Gerddi Morfa	Flats	Post 1990	69	69	77%	78%	£453	£451	£2k
average				60	79	51%	69%	£802	£410	

Table 7.1: The predicted impact of anticipated RMI

The existing condition of the case studies is very varied, but in terms of SAP, most of the case studies currently fall into EPC ‘C’ or ‘D’ bands. This is partly because of age, and partly because of prior retrofit (typically undertaken for WHQS and/or energy efficiency programmes including ARBED and Warm Wales).

The impact of anticipated RMI on SAP varies considerably because the scope of the proposed works is very varied. However, anticipated RMI consistently achieves the WHQS compliance threshold of SAP65. Anticipated RMI impact on emissions is limited, to between 60% and 78% reduction in emissions.

Costs for RMI works are very varied (from £2k to £22k) because the condition of existing dwellings is very varied, and the proposed works are equally varied.

				Predicted impact of proposed decarbonisation strategy						
				SAP rating		Decarbonisation		Fuel bills		Capital cost
Case study	Identifier	Type	Age	now	after	now	after	now	after	
01	Torfaen Terrace	End terrace	Pre 1919	62	92	61%	96%	£1066	£231	£33k
02	Ocean Way	Mid terrace	1945-1964	60	96	57%	97%	£844	£93	£31k
03	Ael Y Bryn	Semi-detach	1945-1964	48	97	26%	97%	£1022	£62	£29k
04	Bryn Hyfryd	Semi-detach	1945-1964	42	93	33%	96%	£1277	£148	£31k
05	Elmwood Road	Semi-detach	1965-1990	84	94	61%	96%	£373	£135	£27k
06	Cae Bold	Semi-detach	Post 1990	67	94	54%	95%	£704	£127	£28k
07	Cove Road	Flats	1945-1964	58	96	51%	96%	£773	£66	£25k
08	Y Bwthyn	Flats	1965-1990	53	84	36%	94%	£754	£261	£19k
09	Cae Clyd	Flats	1965-1990	56	84	41%	94%	£794	£284	£22k
10	Gerddi Morfa	Flats	Post 1990	69	85	77%	96%	£453	£214	£19k
average				60	90	51%	96%	£802	£189	

Table 7.2: The predicted impact of the proposed decarbonisation strategy

The impact of decarbonisation retrofit on SAP is somewhat consistent (SAP range 84 to 97). Greater consistency is achieved by reviewing houses and flats separately (see below).

The impact on decarbonisation is very consistent (range 94% to 97%). Modelling indicates that the decarbonisation retrofit strategies consistently deliver the desired level of emissions reductions to meet international targets.

Costs vary mostly by dwelling type (due to overall size and constraints on fabric retrofit for flats). More insight is gained by looking separately at houses and flats, below.

Further findings - HOUSES

Fabric retrofit of houses is expensive, particularly for the old / poor quality case studies, but without it decarbonisation could dramatically increase fuel bills.

The impact of upgrading windows varies considerably. Replacing double glazing often contributes significantly to the anticipated RMI impact on emissions, but that is because other fabric improvements are not always anticipated. Installing triple glazing consistently contributes between 3% and 7% of the impact delivered by the decarbonisation strategy, and could be considered 'poor value' when compared to high capital costs (typically 25% of total capital cost). However, much of the increase in capital cost between replacing double glazing and providing triple glazing is associated with the fact that double glazing is assumed to be uPVC, while triple glazing is assumed to be timber. The addition costs therefore relate more to the use of 'sustainable' products than to the improved performance of the triple glazing.

Retaining mains gas central heating constrains the impact of decarbonisation to around 70% emissions reduction (range 60% to 71%). In contrast, switching to heat from electricity dramatically increases decarbonisation levels across all case studies, from 70%+ to 90%+.

Installing renewables (roof mounted PV) has a moderate effect on decarbonisation of the case studies. More critically, it reduces heating bills by more than £500 per year.

The predicted cost of decarbonising houses is consistently around £30k (range £27k to £33k). However, cost assumptions need to be understood (see Section 4: method).

Achieving decarbonisation targets for houses requires SAP>92 AND a transition to low carbon heat. Renewables are currently needed to meet decarbonisation targets, but may not be needed in the future, if energy continues to become cleaner.

Further findings – FLATS

Fabric improvements are typically less expensive than for houses, but also have less impact on decarbonisation. This makes it more difficult to retrofit flats in a way that achieves target levels of decarbonisation.

Flat retrofits are often more complicated to retrofit than houses. Party walls introduce constraints and limit the opportunities for improvement. Shared ownership is also a recurring issue, causing a further complication for both delivering retrofit and making it successful.

The size of smaller flats makes space-consuming measures such as IWI problematic.

Successful retrofit of flats therefore requires greater coordination, and may require a more creative response – e.g. larger scale retrofit programmes, district heating systems. In some cases, Social Housing Landlords are reviewing whether demolition and new build is preferable.

The predicted cost of decarbonising flats is consistently around £22k (range £19k to £25k).

Achieving decarbonisation targets requires fabric retrofit and a transition to low carbon heat. Currently, renewables are also needed to meet decarbonisation targets. Sometimes shared ownership or building form make provision of PV difficult to deliver. However, renewables (typically PV) are essential if tenants are to perceive retrofit as desirable. Benefits for tenants are still typically less than for houses.

7.1 Making retrofit work

For Social Housing Landlords:

There is a presumption among SHLs that a transition from mains gas to low carbon heat sources will be expensive for tenants. This presumption is based on pilots where systems performed poorly or in some cases failed and were replaced. It is also based on word of mouth and anecdotal evidence.

The case studies demonstrate that if dwelling fabric is retrofitted to an 'enhanced standard', comparison of a new mains gas combi boiler with electric heat via an air source heat pump revealed only minor differences in fuel bills. The best-fit 'enhanced standard' will vary from project to project, and is best understood through accurate modelling.

If the dwelling fabric is improved to an enhanced standard, retrofit of electric heating systems can be cost effective for the tenant, and could take the place of boiler replacement programmes.*

This requires an holistic approach to fabric performance, and is more difficult to achieve in flats (less fabric to work with / improve).

Currently photovoltaics (or another source of renewable energy) are a necessary part of meeting decarbonisation targets. As electrical energy supply becomes cleaner, they may cease to be necessary to meet decarbonisation targets. However, as modelled, they consistently and dramatically reduce fuel bills for residents, making retrofit desirable.

For tenants:

There are clear reasons for Welsh Government to drive decarbonisation, and for SHLs to deliver the changes needed. The reasons for tenants to engage with this process are less clear. However, evidence (Stages 1 and 2) shows that unengaged tenants can significantly reduce the effectiveness of housing retrofit.

Case studies indicate that improving fabric to an enhanced standard can mitigate the impact of electric heat on fuel bills (see above). The inclusion of renewables (PV) dramatically offsets fuel bills, making retrofit desirable for tenants. However, as a standalone action, switching from mains gas (typically) to electric heat is currently likely to increase fuel bills. Accurate modelling and holistic retrofit (improving fabric and systems together) are critical to decarbonisation being perceived positively by tenants.

There are potentially additional benefits such as increased space, improved quality. However, it is also possible that retrofit will reduce space and increase the possibility of health risks such as condensation. Tenants should receive training to understand why retrofit is needed, and how to run their home afterwards, in order for retrofit to be perceived positively, and to be as effective as possible.

* Retrofit strategies should always be modelled as accurately as possible prior to retrofit taking place. In situations where the dwelling fabric is difficult to improve, the fabric is already performing to a high standard, or renewables are already in-situ, replacement of the existing heating systems with low carbon heating systems is currently more likely to result in increased fuel bills for tenants. This relationship needs to be explored, and understood, to avoid causing negative perceptions around retrofit for decarbonisation.

7.2 Summary of findings

Decarbonisation of the Welsh housing stock is a more complex challenge than the current WHQS programme (this ran from 2002 – 2014, but in some cases work continued until 2020). A component-led approach is embedded in the organisational operations of many Social Housing Landlords. Successful decarbonisation requires a more holistic understanding of stock, and more carefully coordinated retrofit actions.

Learning from the delivery of WHQS suggests that some Social Housing Landlords will struggle with decarbonisation targets. Without in-house skills and expertise alongside coordinated advice and guidance at a national level, it will be difficult for SHLs to develop and evolve a decarbonisation strategy.

SAP ratings can be used to predict energy efficiency and fuel costs, but cannot be used as the sole basis to judge whether retrofit will meet decarbonisation targets. A low carbon heat source must also form part of the decarbonisation strategy.

If the dwelling fabric is improved to an enhanced standard, retrofit of low carbon heating systems can be cost effective for tenants (meaning that, at current fuel costs, annual fuel bills remain approximately the same), and the transition to low carbon heat sources could take the place of existing boiler replacement programmes.*

Flats are more difficult to treat successfully than houses, and successful decarbonisation of flats may necessitate more creative solutions. However, flats represent a considerable fraction of the social housing stock in particular, and cannot simply be ‘left behind’.

Renewables are currently needed to meet international decarbonisation targets, but may not be needed to meet these targets in the future, if energy continues to become cleaner at point of supply. However, renewables such as roof mounted PV are also highly effective in reducing fuel bills for tenants, making decarbonisation retrofit desirable for tenants. Renewables reduce energy demand, in turn reducing pressure on the energy supply network. This could be an increasingly important consideration.

Unengaged tenants can significantly reduce the effectiveness of retrofit. Accurate modelling, holistic retrofit that benefits the tenant, and tenant engagement are critical to decarbonisation being perceived positively by tenants.

* Retrofit strategies should always be modelled as accurately as possible prior to retrofit taking place. In situations where the dwelling fabric is difficult to improve, the fabric is already performing to a high standard, or renewables are already in-situ, replacement of the existing heating systems with low carbon heating systems is currently more likely to result in increased fuel bills for tenants. This relationship needs to be explored, and understood, to avoid causing negative perceptions around retrofit for decarbonisation.

8. TOOLS

Four tools to help with retrofit decision making

The following pages contain four tools that have been designed to help Social Housing Landlords make informed decisions regarding retrofit of their stock. This includes establishing opportunities to utilise or adapt existing RMI activities so that they contribute to a wider decarbonisation strategy.

The tools have been developed from the learning that was generated by the case studies, but also from the wider conversations with participating Social Housing Landlords, the Welsh Government housing decarbonisation team and supporting steering and advisory groups.

These tools acknowledge that landlords (and to a certain extent homeowners) think about their stock in terms of component performance and replacement. The tools outline the decision-making process for successful decarbonisation, by linking component-based thinking with holistic planning and action, as follows:

TOOL 1 describes the interconnected relationship between data, fabric, systems and renewables. It discusses the order that successful retrofit for decarb should adopt.

TOOL 2: Retrofit decision making – improving fabric

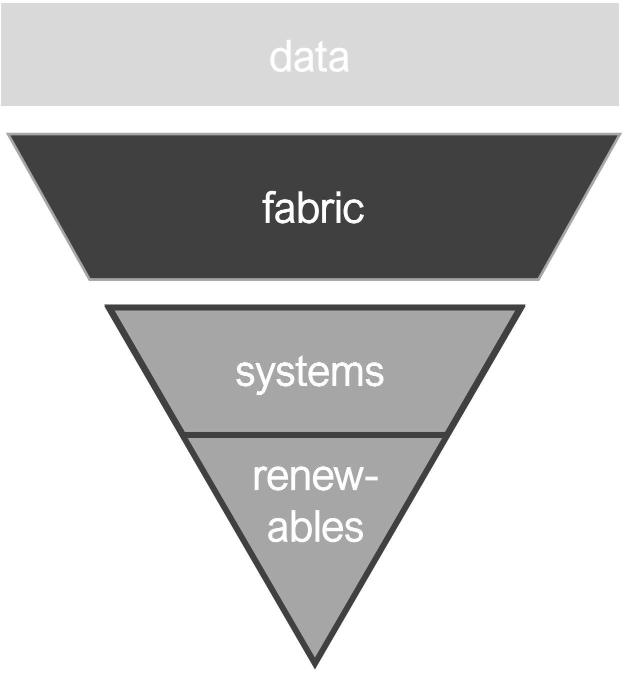
TOOL 3: Retrofit decision making – upgrading systems

TOOL 4: Retrofit decision making – renewables

Tool 1: understanding holistic retrofit

Reasons to retrofit:

- meeting decarbonisation targets
- providing affordable warmth
- Improving quality of homes



affordable decarbonisation

1. data:

Retrofit options must be modelled using accurate data.

An appropriate and accurate data set provides the foundation for good decision making – in terms of *what* to retrofit, *when* and *how*.

2. fabric:

Fabric must be improved such that step 3A [retrofit of lower carbon systems] does not negatively impact on fuel bills.

The dwelling fabric must meet certain standards, or decarbonisation will cause unacceptable increases in fuel bills. Fabric improvements are not dependent on other retrofit actions, and it may be desirable to approach retrofit in a component-based way, but carrying out other work at the same time may reduce cost longer term.

3A. systems:

Low carbon systems should be installed, but only after step1 [data] and step2 [fabric] are completed.

A transition to electric heat is the most likely future for much of the housing stock. Typically, this will result in increased fuel costs for occupants unless retrofit includes fabric and/or renewables. Without this, potential to decarbonise is limited.

3B. renewables:

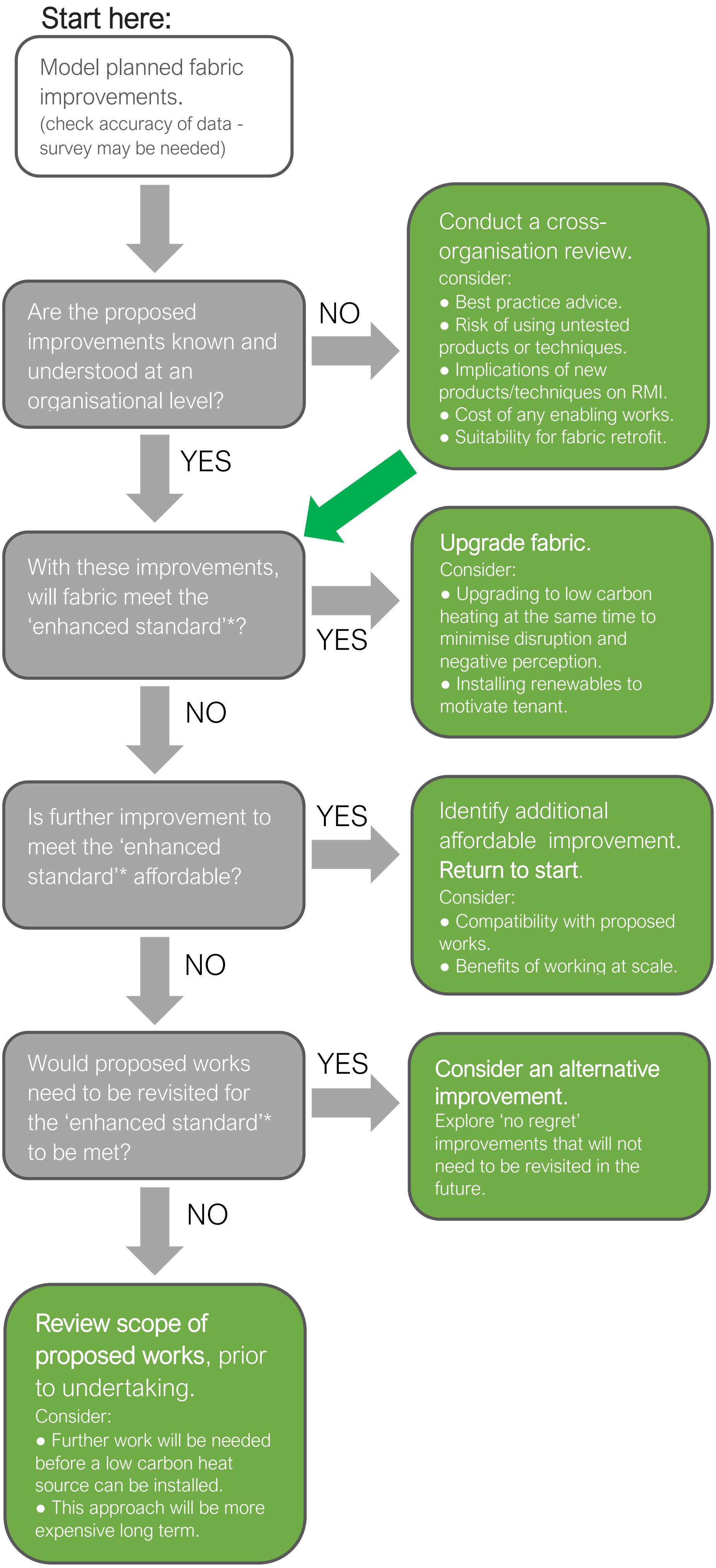
Renewables significantly reduce fuel bills for tenants, and reduce energy demand.

Short term, renewables are an essential part of meeting decarbonisation targets. Longer term (as energy becomes cleaner), they may not be. Renewables make the transition from mains gas to low carbon heat desirable for occupants, by significantly reducing fuel bills. They also reduce the increasing demands being placed on energy infrastructure.

Tool 2: improving fabric

Reasons to improve fabric:

- Fabric failure
- Decarb strategy
- Affordable warmth
- Poor quality home
- Stock-wide activity



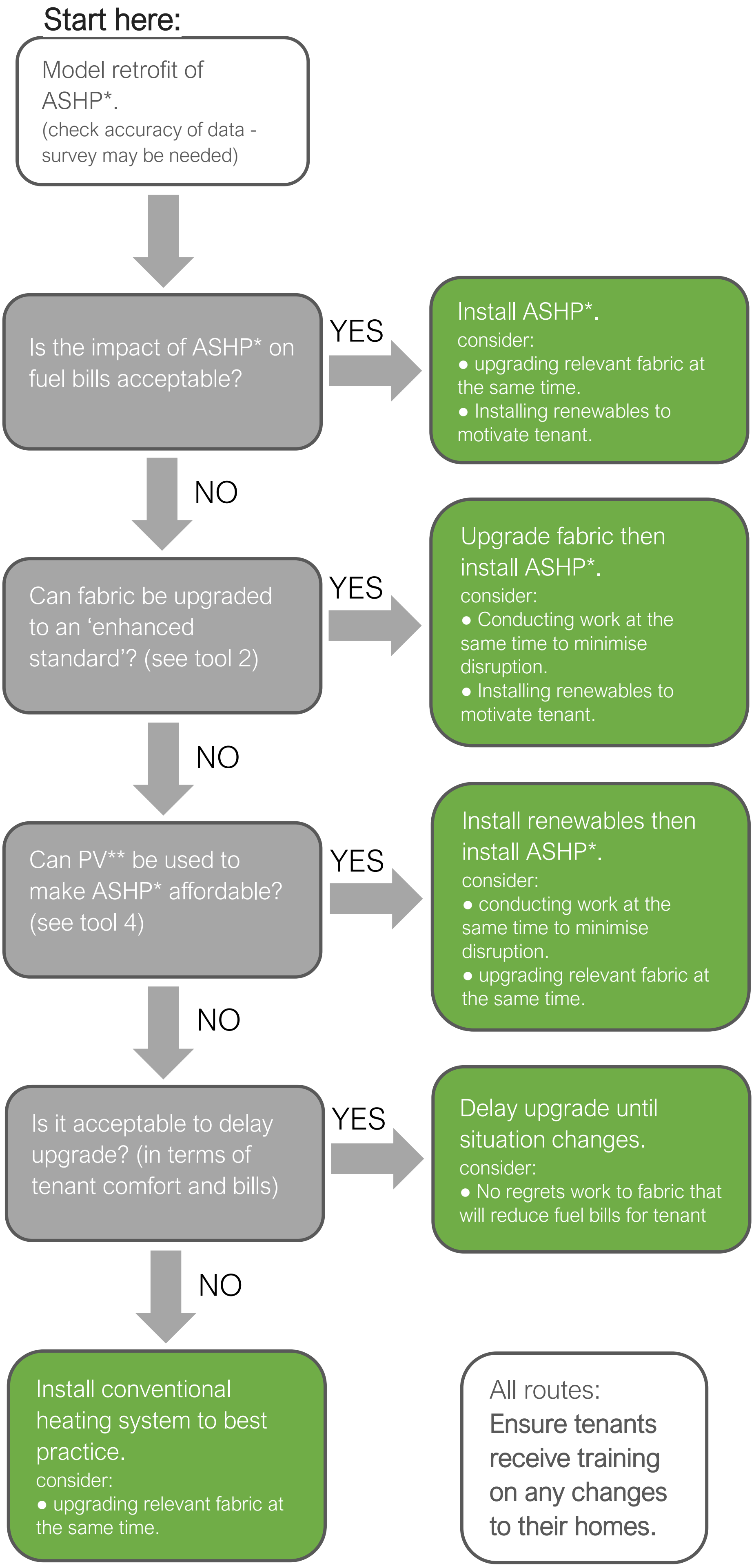
* 'Enhanced standard' describes a fabric specification at which transferring from the existing heating system to a low carbon heating system (e.g. air source heat pump) does not cause unacceptable increases in fuel bills for tenants.

See Tool 3 for more details. Case studies provide worked examples of an enhanced standard.

Tool 3: upgrading systems

Reasons to improve fabric:

- Replacement cycle
- Boiler failure
- Decarb strategy
- Affordable warmth
- Poor quality home



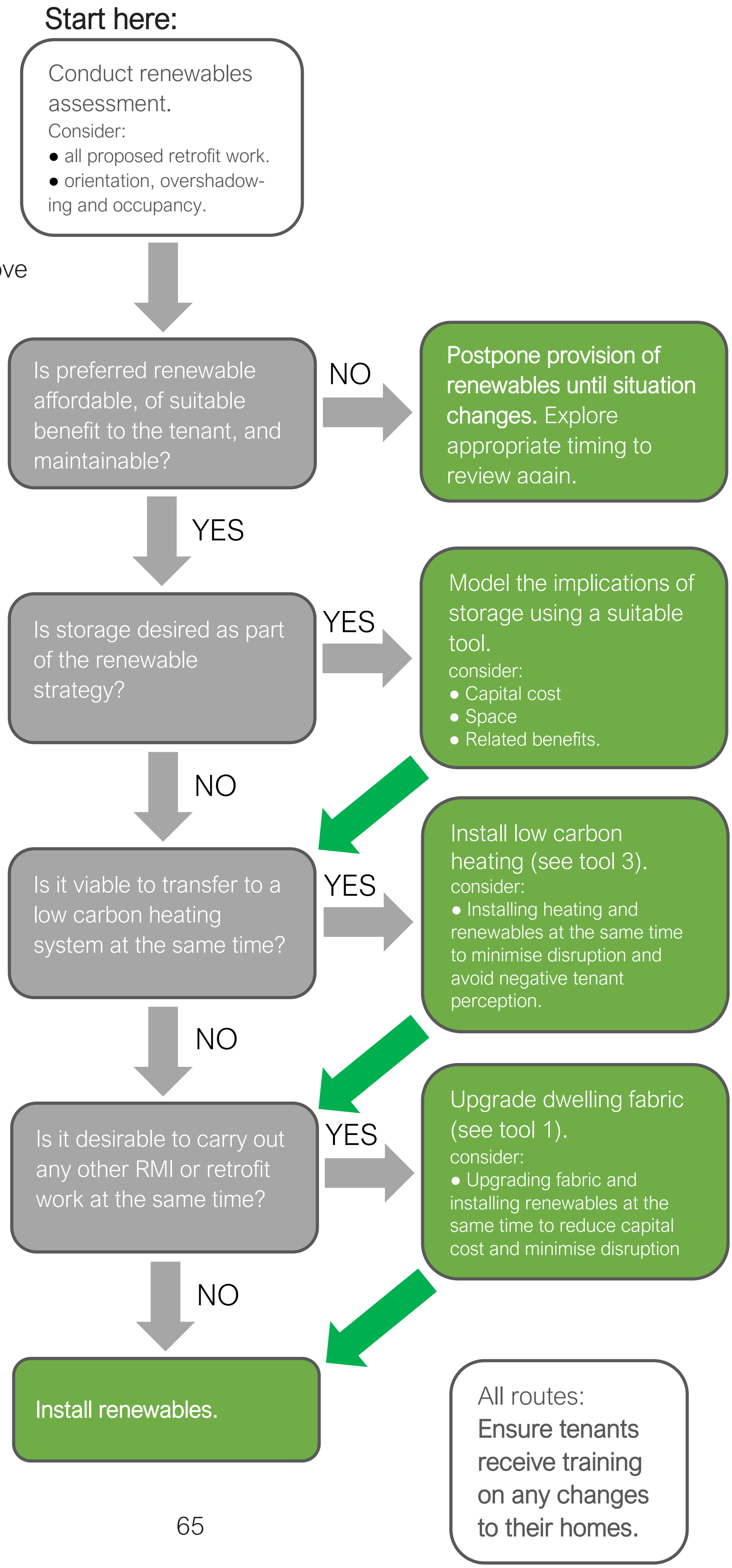
* ASHP – For simplicity, and based on the case studies, this tool assumes that air source heat pumps (ASHP) are the preferred low carbon heating system. Other systems may offer greater benefit.

**PV – Photovolatics (PV) are assumed to be the preferred renewable, based on case studies. Other options may be more effective / desirable – see tool 4.

Tool 4: renewables

Reasons to provide renewables:

- Off grid location
- Difficult home to improve
- Decarb strategy
- Affordable warmth



9. REFERENCES

Glossary of abbreviations referred to in this report (in alphabetical order):

ARBED	Welsh Government's strategic 'Warm Homes' fuel poverty scheme
ASHP	Air source heat pump – a lower carbon heat source
BEIS	UK government's Department for Business, Energy & Industrial Strategy
CCC	Committee for Climate Change (international and national panels exist)
CHC	Community Housing Cymru – the body for housing associations in Wales
CHP	Combined heat and power – a lower carbon heat source
Decarbonisation	the reduction of carbon dioxide emissions production, through increased efficiencies, lower carbon energy sources and carbon sequestration
EPC	Energy Performance Certificate – required at point of sale of any home
EWI	External wall insulation
GHGs	Greenhouse gases - compound gases that trap heat in the atmosphere, leading to global warming. Carbon dioxide is the most prevalent GHG.
IWI	Internal wall insulation
MVHR	Mechanical Ventilation with Heat Recovery provides fresh filtered air into a home, retaining most of the energy that has been used to heat it.
PV	Photovoltaic (panel) – a renewable energy source
RDSAP	Reduced Data SAP was introduced in 2005 as a lower cost method of assessing the energy performance of existing dwelling (see also SAP).
Retrofit	changes to a building's fabric or systems, occurring after construction is complete and the building has been occupied
RMI	Repair, maintenance and improvement (programme)
SAP	Standard Assessment Procedure – a tool for predicting fuel consumption and energy efficiency, developed by the BRE
SAP90	A rating of 90 using the BRE's Standard Assessment Procedure
SHL	Social housing landlord
uPVC	Unplasticised polyvinyl chloride, also known as PVCu, a rigid plastic.
WG	Welsh Government
WHCS	Welsh Housing Conditions Survey – most recently completed in 2018.
WHQS	Welsh Housing Quality Standard is a set of standards that all council and housing association homes in Wales must meet. Currently under review.

Referenced sources for citation within this report include:

BEIS. (2017a). Summary of analysis using the National Energy Efficiency Data Framework (NEED). London: Department for Business, Energy and Industrial Strategy (BEIS).

BEIS. (2017b). Updated energy and emissions projections. London: Department for 791 Business, Energy and Industrial Strategy (BEIS).

BEIS. (2018). UK local authority and regional carbon dioxide emissions national statistics: 2005 to 2016. London: Department for Business, Energy and Industrial Strategy (BEIS). https://www.gov.uk/government/statistics/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics-2005-2016

Bonfield, P. (2016). Each home counts: An independent review of consumer advice, protection, standards and enforcement for energy efficiency and renewable energy. London: Department for Communities and Local Government (DCLG).

BRE. (1998). The Government's Standard Assessment Procedure for Energy Rating of Dwellings. Garston: Building Research Establishment (BRE) for Department of the Environment, Transport and the Regions (DETR).

CCC. (2018). Progress report to Parliament. London: Committee for Climate Change (CCC).

CCC. (2019). Net zero—The UK's contribution to stopping global warming. London: Committee for Climate Change (CCC). Retrieved February 19, 2020, from https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

Communities and Local Government Committee. (2008). Existing housing and climate change—Seventh Report of Session 2007–08 (House of Commons Report). Retrieved February 19, 2020, from https://publications.parliament.uk/pa/cm200708/cmselect/cmcomloc/432/432i.pdf 809

Green, E., Lannon, S., Patterson, J., & Iorwerth, H. (2018). Homes of today for tomorrow Stage 1: Scoping review. Cardiff: Cardiff University. Retrieved from http://orca.cf.ac.uk/115442/

Green, E., Lannon, S., Patterson, J., & Iorwerth, H. (2019). Homes of today for tomorrow Stage 2: Exploring the potential of the Welsh housing stock to meet decarbonisation targets. Cardiff: Cardiff University. Retrieved from http://orca.cf.ac.uk/115442/

Johnston, D., Lowe, R. J., & Bell, M. (2005). An exploration of the technical feasibility of achieving CO2 emission reductions in excess of 60% within the UK housing stock by the year 2050. Energy Policy, 33(13), 1635–1651.

Knight, I., Iorwerth, H., & Lannon, S. (2017). Re-energising Wales project work package 1—Half-hourly energy demand profiles for Wales for 2016. IWA. Retrieved February 19, 2020, from https://www.iwa.wales/wp-content/uploads/2019/03/20190312-UPDATED-FINAL-Half-Hourly-Energy-Demand-Profiles-for-Wales-for-2016.pdf

Lowe, R. (2007). Technical options and strategies for decarbonizing UK housing, Building Research & Information, 35(4), 412–425.

ONS. (2018). UK local authority and regional carbon dioxide emissions national statistics: 2005 to 2016. Office for National Statistics (ONS). Retrieved February 19, 2020, from https://www.gov.uk/government/statistics/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics-2005-2016

PPIW. (2015). Future need and demand for housing in Wales (original content written by A. E. Holmans. Cambridge: Cambridge Centre for Housing and Planning Research. Retrieved February 19, 2020, from https://sites.cardiff.ac.uk/ppiw/files/2015/10/Future-Need-and-Demand-for-Housing-in-Wales.pdf

StatsWales. (2018). Housing supply statistics (Wales) (last updated 26 April 2018). Retrieved September 4, 2020, from https://gov.wales/housing-supply-statistics

StatsWales. (2019). Housing supply statistics (Wales) (last updated 15 October 2019). Retrieved February 19, 2020, from https://gov.wales/housing-supply-statistics

Warm homes Arbed EU, Final report for Welsh Government. Welsh Government. (2018).

Welsh Government. (2019a). Better Homes, Better Wales, Better World (Report to Welsh ministers from the Decarbonisation of Homes in Wales Advisory Group, 18 July). Retrieved February 19, 2020, from https://gov.wales/sites/default/files/publications/2019-7/independent-review-on-decarbonising-welsh-homes-report.pdf

Welsh Government. (2019b). Oral Statement from the Minister for Housing and Local Government. In The independent review on decarbonising Welsh homes, 24 September 2019. Retrieved February 19, 2020, from https://record.assembly.wales/Plenary/5844#A53270

Welsh Government. (2019c). Welsh Housing Quality Standard (WHQS), as at 31 March 2018-Revised, reference SFR 88/2018 (R), published 27 June 2019. Retrieved September 12, 2020, from https://gov.wales/sites/default/files/statistics-and-research/2019-06/welsh-housing-quality-standard-31-march-2018-revised.pdf

VOA. (2011). Housing census data. Valuation Office Agency (VOA), Office for National Statistics (ONS). Retrieved February 19, 2020, from https://www.ons.gov.uk/census/2011census/2011censusdata