Welsh Zero Carbon Housing Performance Hub

Annex B – Literature Review

August 2021

Introduction

This Review is intended to inform the March 2021 Scoping Report and Routemap for the proposed Welsh “Hub”.

The information contained in the Review is mainly extracts (cut and pasted) from publicly available documents. It provides a flavour of key publications and a basis for future Hub website content. Over time, more documents could be added.

The information in this report should not be reproduced. The original source material should always be consulted.

Contents

Section 1 – Welsh policy and regulation

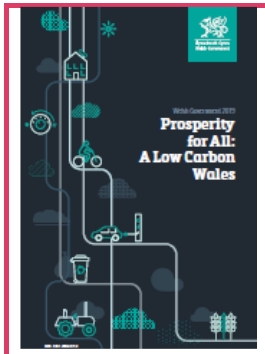
	**Development Quality Requirements**, Welsh Government, 2005 Development quality requirements for housing associations (gov.wales)	[*Due to be replaced by the Mandatory Quality Standards for New Homes, consulted on in 2020 – see below*]. Housing schemes built using Social Housing Grant (SHG) and other forms of public subsidy are currently required to be meet Welsh Government Development Quality Requirements 2005 (DQR). "All housing acquired or developed by housing associations should meet Development Quality Requirements." **New build**: "Associations should take every opportunity to develop schemes that contribute towards achieving a sustainable housing stock… • All general needs schemes and housing for the elderly should be built so as to achieve a British Research Establishment (BRE) 'ECOHomes' rating level of 'GOOD' • Irrespective of the ECOHomes score achieved the minimum standard for energy efficiency in all dwellings should meet the Best Practice Standard (basic requirements) set by The Energy Efficiency Best Practice in Housing, General Information Leaflet 72 (www.est.org.uk/bestpractice) **Existing homes**: "Meeting heating bills can be difficult for many tenants. Associations should do whatever they reasonably can to minimise the cost of heating homes to a comfortable level". "The following standards should be achieved in all refurbishment schemes receiving SHG funding. These are minimum's and Associations will be expected to improve upon these values where possible: • Walls to have a minimum U-value of 0.45 W/m2K (or 0.35 if EWI), Roofs 0.16, Windows 2.00 (where replaced), Ground floor 2.00 (where replaced), etc. "Advice for designers on how to approach the putting together a pack of energy efficient refurbishment measures is contained in GOOD PRACTICE GUIDE 155 Energy Efficiency Best Practice in Housing.

		www.est.org.uk/bestpractice)". "As an alternative to achieving the target 'u' values and specific measures referred to above a Target SAP** can be set. A rating of 75 should be regarded as an absolute minimum and should be exceeded wherever practically and financially feasible."

	**Welsh Housing Quality Standard**, Welsh Government, 2008 welsh-housing-quality-standards-guidance-for-social-landlords.pdf (gov.wales) and Welsh housing quality standard | GOV.WALES	Guidance for Social Landlords on the interpretation and achievement of the Welsh Housing Quality Standard (existing social housing). The accompanying website states: "All social housing must be updated and kept in good condition. Housing associations and local authorities with council houses are responsible for this. They must make sure that their houses meet the standard by the end of December 2020." To meet the standard, houses must be: • in a good state of repair • safe and secure • adequately heated, fuel efficient and well insulated • contain up to date kitchens and bathrooms • well managed (for rented housing) • located in attractive and safe environments • where possible, suitable for the specific needs of those living there, such as those with disabilities Requirement 3a – "Heating systems must be reasonably economical to run and capable of heating the whole of the dwelling to a comfortable level in normal weather conditions (Primary)…The annual energy consumption for space and water heating must be estimated using the Government's Standard Assessment Procedure for Energy Rating of Dwellings 2005 (SAP 2005) method. A minimum rating of 65 out of 100 must be achieved." "Lack of adequate ventilation and poor thermal performance of external walls and windows, in addition to inadequate background heating levels, are significant contributors to condensation in older dwellings. Of particular concern are kitchens and bathrooms in which large amounts of moisture are generated. All cost-effective opportunities to upgrade the thermal and ventilation performance of the dwelling must be taken."

		Example requirements: • Loft insulation - It is recommended that at least 200mm of glass wool insulation or the thermal equivalent, is provided in the loft • Ensuring that all the pipes and tanks in the roof space are lagged • Ensuring that the thermal performance of the external walls is adequate to avoid the likelihood of condensation • The hot water tank must be effectively insulated

	**Code for Sustainable Homes Technical Guidance,** [then] CLG, November 2010 Code for Sustainable Homes: Technical Guide. November 2010 (gov.wales)	As of November 2019 "The code for sustainable homes has been withdrawn by England. It remains a requirement for new housing funded by or built on land disposed of by us" [the Welsh Government]. "Sustainable standards for all new housing promoted or supported by us or our sponsored bodies." Includes assessment of: • Dwelling emission rate • Fabric energy efficiency • Energy display devices • Drying space • Energy labelled white goods • External lighting • Low and zero carbon technologies • Cycle storage • Home office Example of assessment criteria: Minimum Percentage Improvement in Dwelling Emission Rate over Target Emission Rate (10 achievable credits) • Level 4 – 25% • Level 5 – 100%

		• Level 6 - Net Zero C02 Emissions For a semi-detached house a Fabric Energy Efficiency ("Energy demand for space heating and cooling") of 46 kWh/m2/year or less is equivalent to Level 6.
	**Prosperity for All: A Low Carbon Wales (Low Carbon Delivery Plan)**, Welsh Government, March 2019 low-carbon-delivery-plan_1.pdf (gov.wales	The Plan "sets the foundations for Wales to transition to a low carbon nation". At the time of writing, the Government was operating under a statutory duty to reduce emissions of greenhouse gases in Wales by at least 80% for the year 2050". This has been overtaken by the adoption of a 95% reduction target and an ambition to achieve net zero carbon. The Welsh Government wants to "see greater energy efficiency in buildings and appliances, and the use of new building fabrics turning buildings into power stations…more than 26 full-scale demonstrator sites incorporate various aspects of the active buildings concept…Our buildings will be more resource efficient and designed for adaptability and deconstruction at the end of their lives. Thanks to designing and running our buildings differently, buildings will be cheaper to run and people will be able to adapt to their buildings easily so they can stay in their homes longer in life." Proposal 8 – "We are developing a programme of action to decarbonise all homes in Wales by at least 80% by 2050, regardless of their tenure…" "Wales has 1.4 million homes across a wide range of housing types, including a significant proportion of older buildings." Buildings Chapter – "If Wales is to meet its climate targets, [all] buildings will need to operate at close to zero emissions by 2050…The amount of energy used in our buildings will have to be significantly lower. The electricity we use to light and increasingly heat our buildings will be from low carbon and renewable sources…The speed of retrofit of existing buildings will need to be greatly increased and new building will need to be built to higher energy standards…At 4.3 MtCO2e, buildings accounted for 9% of Welsh emissions in 2016." "The dominant source of emissions is from residential buildings, which make up 82% of the sector emissions and 7.5% of total Welsh emissions...Total emissions from the buildings sector in Wales have decreased by 31% between the base year (1990) and 2016, driven largely by a change to the fuel mix from coal to natural gas and

		energy efficiency measures…[interim target] Buildings sector emissions will reduce by 40% from [the 1990] baseline levels by the year 2030...” Policy 39 – “Part L of our Building Regulations…was revised in 2014. It has helped achieve emissions reductions of 8% and 20% in new residential buildings and all other buildings respectively…. We have recently commenced a further review of Part L...this will inform future measures to improve energy efficiency standards for new and renovated buildings. The review will also consider the role of on-site renewable energy sources, the relationship between improved energy performance and indoor air quality and increasing concerns over summer overheating.” Proposal 10 – “Further work is needed to decarbonise fossil fuel heat in Wales, both through decarbonising the existing gas network and finding alternative sources of heat.” “Another key policy improving the energy efficiency of existing buildings is the Welsh Housing Quality Standard (WHQS). There are over 225,000 social homes in Wales (16% of total homes) provided by Registered Social Landlords (RSL) and Local Authorities who still have their housing stock and all these properties must meet the WHQS by December 2020 and maintain it thereafter. The average energy efficiency band has improved from Band E in 2008 (Living in Wales Property Survey 2008) to Band D in 2017-18 (Welsh Housing Conditions Survey 2017-18).” “Nearly 204,500 social homes (91% of the stock) now meet the Welsh Housing Quality Standard (subject to acceptable fails) and we are on track to ensure all meet it by the 2020 deadline”. “WHQS includes achieving an energy efficiency standard of SAP 65 or higher. This is the equivalent to EPC D rating on a scale of A to G. Currently 200,431 (89%) social homes have achieved SAP 65 or higher and work will continue on this up to and beyond 2020.” “Our current Help to Buy Wales policy allows eligible purchasers to buy new-build homes with assistance from Welsh Government in the form of a shared equity loan. The Help to Buy Wales mortgage calculator now includes an energy efficiency element. This means when people look at the cost of mortgages, they will be given different options depending on the energy efficiency of the property they are looking to buy and loans will be adjusted according to the energy rating of the home they choose.”

	**Independent Review of Affordable Housing Supply,** April 2019 independent-review-of-affordable-housing-supply-report_0.pdf (gov.wales)	Review responds to The Welsh Government's strategy Prosperity for All: A Low Carbon Wales which recognises that "If Wales is to meet its climate targets, buildings will need to operate at close to zero emissions by 2050. This will require a substantial change in how we heat and power buildings in the future. The amount of energy used in our buildings will have to be significantly lower." "The Panel therefore wished to consider whether the current standards and requirements remain the best way of meeting the housing needs of tenants accessing social housing, or whether alternative approaches offer better value for money and support increased supply. In addition, the Panel also "evaluated the impact of moving to deliver zero carbon homes by 2020…" "In relation to a moving towards zero carbon housing, it is important to clarify what is meant, as people often talk about 'zero carbon', but sometimes they mean 'almost zero carbon…" Thus, a 'nearly zero-energy building' is defined in the EU Energy Performance in Buildings Directive as: "...a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby." "The UK Climate Change Committee suggests new homes should deliver ultra-high levels of energy efficiency as soon as possible, and by 2025 at the latest. The Assembly's Climate Change, Environment and Rural Affairs Committee has recommended the Welsh Government prepare and publish a ten year low carbon housing strategy, including milestones and targets to be delivered." "There are some doubts on whether the industry could deliver step-change in a decade and, even if it could, with the focus of the policy squarely on new homes this will arguably take a long time to have any meaningful impact. However, those representing the house building industry have accepted that a move to zero carbon is achievable if the market is given sufficient time to adapt. Despite these challenges, there is an acknowledgement that house building must change, and that if Wales is going to meet its obligations the housing sector must do more to adapt and help address this challenge. However, the Panel have not seen any evidence that suggests that Wales (or any other part of the UK) would be able to move towards near zero carbon by 2020. There are various studies into the additional costs for constructing to near zero carbon. By using a fabric first approach estimates of between 1% to 2% of overall costs have been cited. These and other studies have also highlighted the increase in the value of properties which can offset the costs and importantly savings on energy costs for occupiers."

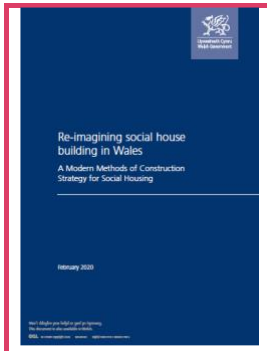
		"Given well-argued and lengthy examinations of a move to near zero carbon, the Panel has concluded that it will take some time to introduce this. Indeed, it seems reasonable to conclude that such a move by 2020 is unrealistic and unachievable. The Panel's evaluation of the evidence is that the impact of this would most likely result in fewer houses being built in Wales, as opposed to more. However, with proper planning and sensible lead in times, there is nothing to stop a move to near zero carbon or the increased energy performance rating of EPC 'A' over a longer time period. The Panel is therefore recommending that all affordable homes should be near zero carbon / EPC 'A' using a fabric first approach from 2021, with the same goal being set for all homes irrespective of tenure by 2025 at the latest to meet the recommendations of the UK Climate Change Commission." "The Welsh Government should continue to support the trialling of Modern Methods of Construction (MMC) to help establish which methods can contribute to the objective of increasing the scale and pace of affordable housing with the existing resources available…The Welsh Government should develop a strategy to map out how Wales could further use off-site manufacturing (OSM) and MMC to deliver near zero carbon homes along with an appropriate timetable for achieving this." "The Panel believe that there is insufficient robust evidence to date, to suggest that Wales can deliver zero carbon homes by 2020 in anything more than pilot site numbers using MMC given the supply chain and skills development required. It is the Panel's view that we should not build non-traditional housing in Wales that will also then require retrofitting to meet carbon standards in years to come…Given this, the Welsh Government should develop a strategy to map out how Wales could further use OSM and MMC to deliver near zero carbon homes along with an appropriate timetable for achieving this." "…in May 2018 the then Minister for Housing and Regeneration announced that the Help to Buy - Wales equity loan affordability calculator was to include an energy efficiency element, a first in the UK."

	**Better Homes, Better Wales, Better World – Decarbonising Existing Homes in Wales**, Decarbonisation of Homes in Wales Advisory Group, July 2019 Independent review on decarbonising Welsh homes: report (gov.wales)	The Review notes that "On 2 May 2019, the UK Committee on Climate Change (UKCCC) recommended that the UK Parliament legislate, without delay, to reduce domestic greenhouse gas (GHG) emissions to net zero by 2050. The UKCCC assessed the contribution that Wales can make to net zero in the UK under its statutory framework, and for Wales it recommends a 95% reduction in GHG emissions by 2050. Welsh Government's response to this has been inspiring. On 12 June 2019, the Welsh Minister for Environment, Energy and Rural Affairs declared the ambition "to bring forward a target for Wales to achieve net zero emissions no later than 2050". There is real appetite across all parts of Welsh society to tackle the climate emergency. It is right that Wales takes a lead on this issue." In terms of housing, the review is mostly focused of the decarbonisation of existing homes. "In Wales, 1.4 million homes are responsible for 27% of all energy consumed and 15% of all demand-side GHG emissions. The Chair, Christopher Jofeh said: "The Welsh Government should set ambitious housing targets to meet its ambition of achieving net zero carbon by 2050." "The Welsh Government should continue to monitor and test new solutions to decarbonise homes." "Wales has some of the oldest and least thermally efficient housing stock in the UK and Europe. 32% of the Welsh housing stock was built before 1919, when there were no construction standards in terms of thermal performance. Just 10% of Welsh homes were built in the last 18 years, during which time energy performance requirements have changed dramatically. The WHCS also showed social rented dwellings had the highest average SAP rating of 68. Since 2003, over £1billion has been spent on improving over 220,000 social homes through WHQS." "The Advisory Group recognised from the outset that decarbonising Welsh homes is not just, or even principally, a technical problem. It is about people and their homes. Decisions about home improvements emerge from the conditions of everyday domestic life." "Action 1.3 – No later than 2025, all new homes in Wales must be built to be low carbon, energy and water efficient and climate resilient. Independent checks must be made to ensure these higher standards are delivered. This will prevent the challenge to retrofit homes becoming larger and more expensive. All homes built with public sector funding should meet these standards no later than 2021." "New homes built with Welsh Government or public sector support, for example new social homes, should be built to this higher standard no later than 2021. All new homes built privately in Wales should also meet this standard from 2025."

		"Additional cost is frequently cited as a factor for not taking this action, but we must recognise the much higher cost of having to retrofit these homes to meet higher energy performance standards at a later date. The UKCCC report indicates that it will cost four times more to retrofit measures at a later date than to design and build them in from the beginning. Requiring higher build standards is not enough." "Requiring higher build standards is not enough. Long standing performance gap issues must be addressed urgently and this will require, among other things, an effective, independent building control system." "Action 2.1 – By 2050 the housing stock must be retrofitted to beyond SAP 90 to achieve an EPC Band A rating, recognising that not all homes will be able to achieve this."

	**Building Regulations Part L and F Review**, Welsh Government Consultation Document, 19 December 2019 consultation-document-building-regulations-part-l-review.pdf (gov.wales)	The consultation applies to energy standards for new build homes Part L Volume 1 and Part F Volume 1 (on ventilation) of the Building Regulations. The proposals are for an "achievable but significant uplift" to energy efficiency standards in 2020, and a significant uplift in 2025. (See below – the Government response was published in March 2021). **Proposal for 2020**: • Option 1: 37% CO2 reduction (on 2014) – high fabric standards (see Annex A), natural ventilation, gas boiler, WWHR and PV • Option 2: 56% CO2 reduction (on 2014) – high fabric standards (see Annex A), MVHR and high air tightness, gas boiler, WWHR and PV • Uplifts in minimum fabric standards: e.g. walls uplifted from 0.21 to 0.18 W/m2K (0.21 remains for high-rise/flats) • Propose to continue with no separate target fabric energy efficiency (unlike England) • The Impact Assessment includes analysis as follows: "SAP predicts that Part L Option 2 would have a space heating demand around 15kWh/m2/year…" **Proposal for 2025**: • "We envisage our Part L 2025 standard will have very high fabric standards that limit heat loss and reduce the demand for heat….based on the fabric specification proposed for Option 1" (but with triple glazing).

		• "Anticipate that an average semi-detached home built to meet the Part L 2025 Standard would produce 75-80% less carbon dioxide emissions than one built to the 2014 Part L requirements." • "We anticipate that the installation of heat pumps, particularly air-to-water and air-to-air heat pumps, will play a major role." It should be noted that changes in carbon factors in SAP 10.1 (to reflect the decarbonisation of the electricity grid) make CO2 reductions easier to achieve. "We consider that both of the uplift options presented in Chapter 3 meet the definition for nearly zero-energy buildings and meet the 'cost optimal' definition [in the EPBD]."

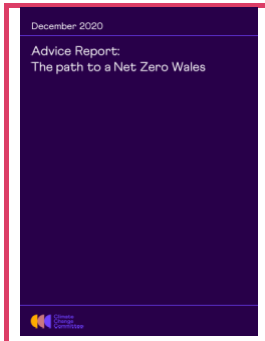
	**Re-imagining social house building in Wales - A Modern Methods of Construction Strategy for Social Housing**, Welsh Government, February 2020 Social house building strategy (gov.wales)	One of the key recommendations that came out of the review is for the Welsh Government to produce a strategy focusing on how to scale up and normalise modern methods of construction including off-site manufacturing (OSM), as well as looking at opportunities for delivering zero carbon homes. "Welsh Government will set the quality standards expected for housing that receives public subsidy, specifically with regards to space, energy efficiency and, as far as it can be defined, beauty…" "The standards will apply equally to homes built traditionally or using MMC approaches. Design, building performance and quality will be monitored through new technical scrutiny activity throughout the development process and when schemes are completed. Increased oversight will help understand value for money from homes constructed in different ways, and the information will inform the type of social and affordable homes that will be funded in future…" "Welsh Government is prepared to encourage the market, so that Welsh SMEs can develop MMC solutions, supply chains, factories, skills development centres that meet the needs of the next generation of social housing in Wales… It is expected that materials and components used in this next generation of MMC homes will, whenever possible, back Welsh business so that arrangements allow materials and labour to be sourced with the maximum social and ethical value to the people of Wales…"

		"Ultimately, evidence suggests the full benefits of MMC will be realised with more volumetric approaches, but right now, most MMC producers in Wales supply panelised systems. This strategy sets out an incremental approach to MMC adoption, which over time will see more homes, and parts of homes manufactured in this way, as part of a potential journey towards volumetric MMC housebuilding over a longer timeframe. It also ensures the industry retains the agility to respond to innovation and entrepreneurship in this nascent new industry for Wales… Simply put, encouraging the use of MMC for the delivery of social housing means we can provide more homes for the residents of Wales. They can be produced in a way which is good for the economy and businesses, for communities and individuals and the public purse…" "MMC offers significant improvements in the delivery of homes and assists in closing the construction "performance gap".

	**Beautiful Homes and Spaces**, Welsh Government Proposed Standard, July 2020 Beautiful Homes and Spaces (gov.wales)	"Beautiful Homes and Spaces" (BHS) sets out "minimum functional quality standards for new and rehabilitated general needs affordable homes." The standard states that homes should be "high quality, innovative and sustainable", and covers various requirements including on value for money, size and responsiveness, safety, and Modern Methods of Construction (MMC). "Delivery of homes via MMC should be viewed as a technological "step change" and not merely the inclusion of elements of the construction that are already traditionally produced off-site." Developers are encouraged to use best practice on the circular economy for example, by "choosing materials that are capable of being recycled and maximising the use of timber in construction to help Wales meet its carbon reduction targets." The proposed standard does not include carbon or energy standards, but the linked consultation in August 2020 "Mandatory Quality Standards for New Homes" (next item) contains proposals on this theme.

	**Mandatory Quality Standards for New Homes**, Welsh Government Consultation Document, 1 August 2020 Mandatory quality standards for new homes | GOV.WALES	"The Welsh Government proposed a standard to replace the 2005 Development Quality Requirements following an Independent Review of Affordable Housing Supply in April 2019 which stated that new consolidated and simplified standards for new build grant funded homes and affordable homes should be developed. The new standards should concentrate on minimum space standards, including storage inside and outside." "The Review also recommended a requirement for all new affordable homes to be near zero carbon, using a fabric first approach from 2021 and recommended that the Welsh Government set a longer term goal of 2025 at the latest to have the same standards for all homes irrespective of tenure." "The consultation document notes the proposed amendments to the Building Regulations Part L (conservation of fuel and power) for new build together with Part F (overheating). The Welsh Government is considering the early introduction of the Part L standards for affordable housing in advance of any building regulation transitional arrangements and is also considering "the early introduction to achieve EPC A (SAP 92) for new affordable homes." "The new standard is expected to promote the use of Modern Methods of Construction (MMC) and encourage due consideration for the circular economy process with regard to waste and embodied carbon." Response due to be published as of 24 March 2021.
	**Building Regulations Part L and F Review – Existing Buildings**, Welsh Government Consultation, 25 November 2020 building-regulations-part-l-and-f-review-stage-2a-	The consultation covers Part L (energy and caron) and F (ventilation) for existing buildings, changes to implement the recast EPBD, plus proposals on overheating. **Proposed key changes to Part L in 2020/21**: • Existing homes (upgrading retained thermal elements) – E.g. cavity wall insulation 0.55 W/m2K (see Table 11.1 in the draft Approved Document). Where the U-value set out in Table 11.1 is not "economically, functionally or technically feasible, then the thermal element should be upgraded to as close to the maximum U-value as is practicably possible." • Existing homes (new/replacement thermal elements, including extensions) – Aligns the fabric specification with minimum standards for new build (e.g. walls at 0.18 W/m2K) (Table 4.1) (see Table 4.1) • New windows – Small uplift in minimum standard from 1.6 to 1.4 W/m2K (Table 10.1)

	consultation-document.pdf (gov.wales)	• Boilers – Minimum efficiency of 92% • Replacement heating systems should be future-proofed/sized to run at 55C or lower so they are heat pump-ready **Proposed key changes to Part F in 2020/21:** • New sub-section with additional ventilation provisions when installing energy efficiency measures (simplified method – additional ventilations requirements depending on what measures are installed, or the option to rely on expert advice). Each energy efficiency measure is categorised as minor or major, and affects what level of ventilation would be needed • New or extended mechanical ventilation in a retrofit should be subject to the same rigour as for systems installed in new dwellings e.g. commissioning and verification of flow rates **Proposed new Part S on Overheating (new dwellings):** • Dwellings shall be designed and constructed in such a way to provide reasonable mitigation from the risk of summertime overheating, and any mitigation measures shall be safe, secure and reasonably practical for occupants • Preferred means of mitigating overheating is through passive means as far as practicable • Focus is on flats and on houses (e.g. terraced, semi-detached and detached houses, bungalows) which do not have two or more parallel aspects to facilitate cross-ventilation • Two approaches to compliance: simplified (prescriptive approaches to reducing overheating risk e.g. glazing areas), or the dynamic thermal modelling approach to identify mitigation measures • Information about any systems the building uses to mitigate overheating risk must be given to the owner

	**Advice Report, the Path to a Net Zero Wales**, CCC, December 2020 Advice-Report-The-path-to-a-Net-Zero-Wales.pdf (theccc.org.uk)	The CCC recommends that for decarbonisation "by the early 2030s all new cars and vans and all boiler replacements in homes and other buildings must be low-carbon – we expect largely electric." On the "balanced pathway" [scenario] sales of gas boilers will be phased out in residential homes by 2033, and oil boilers by 2028 – with a backstop date in "operation" by 2050. The 'Balanced Net Zero Pathway' is informed by the range of solutions across the 'exploratory' scenarios, that would put the UK on track to Net Zero and would meet the recommended carbon budget…[it] takes a whole-system approach to decarbonisation, reflecting the range of opportunities across behaviour, efficiency, land, low-carbon energy supply and end-use technologies, and how these potentially interact." The "Balanced Pathway reaches a 96% reduction for all greenhouse gases compared to 1990". It assumes a "25% of eligible households pre-heat, 3% reduction in space heat demand from smarter heating management and use, low-flow shower heads." The overall recommendation to the Welsh Government is to "Design and retrofit homes to be energy efficient, climate resilient and healthy. The dual need to reduce domestic CO2 emissions whilst building and retrofitting healthy and climate-resilient homes requires a fine balance of interventions that will depend on the age, design and location of homes. New building standards should be revised to become near-zero or zero-carbon with flexibility to adapt to local environmental needs." The recommendation for "buildings" is to "implement a strong set of standards – with robust enforcement – that ensure buildings are designed for a changing climate and deliver high levels of energy efficiency, alongside low carbon heat…Publish a robust set of standards for new-build homes and legislate in advance of 2023". For new buildings "the Welsh Government has devolved powers on building standards for new-build properties. These should be used to ensure new buildings have ultra-high standards of energy efficiency and are heated through low-carbon heating systems from the outset. This will avoid costly retrofit in future and ensure energy bills are no higher than needed. As a devolved power, this is an area in which Wales can play a leading role in UK action to reduce emissions." Overall "a clear direction is needed for buildings heat and efficiency in Wales, which sets the direction for the next 30 years, reaching zero emissions from Welsh [all] buildings by 2050 at the very latest."

	**Summary of responses and Welsh Government response to Building Regulations Part L and F Review, Welsh Government, March 2021** summary-of-responses-building-regulations-part-l-review.pdf (gov.wales)	108 responses received. **2020/21 Standard**: Question 4: What level of uplift to the energy efficiency standards in the Building Regulations should be introduced in 2020? "49% of those who responded supported Option 1 – a 37% CO2 reduction. The most cited reason in support was that the proposals (including the proposed 2025 standard) allow the market to transition and the technology and skills to scale up. Some respondents also noted that the standard provides designers with a high degree of flexibility. A number of the respondents supported Option 1 because of concerns around maturity of specific technologies included in Option 2 (MVHR and heat pumps in particular) or capital costs for Option 2 which were considered significant relative to bill savings. 30% of the respondents chose Option 2 – a 56% CO2 reduction as their preferred option. Most respondents highlighted the need for action given the climate emergency and national net zero targets. Reasons cited in support were that the standard is technically feasible and can be achieved with heat pump technology now, it will prime the market for scaling up the roll out of heat pumps and avoid costly retrofits in the future. One respondent stated that the cost of delivering the standard may be cheaper in reality. 19% of the respondents supported an alternative view. The majority of the respondents, 10 of them, were of the view that both the proposed options were too ambitious. The prevalent view was that the industry needs time to prepare (including for product development) and reduce reliance on unproven technologies. One respondent raised the issue of increased build costs affecting affordability. Four respondents were of the view that proposed options were not ambitious enough and that the government should look to set a target that is or close to net zero. Four of the respondents advocated the need for alternative and/or additional metrics, with one respondent arguing that CO2 is not the right metric given grid emissions are falling and advocated setting FEES and delivered energy standard. Another advocated the need for operational energy and whole life carbon emission targets, while two respondents stressed the need for more focus on minimum fabric performance standards." **Response**: Almost half of all respondents agreed with the preferred 37% option, and almost a third proposed the alternative option of a 56% uplift. Therefore, there was significant support for a very considerable step up in energy efficiency standards compared to the level currently required.

		60% of respondents agreed our concerns raised in relation to MVHR systems at this time. Despite this view, we also understand some other respondents views on the potential role this technology has for the future, and therefore, we propose to consider this area again for the next Part L review. In considering all the responses, we conclude that the preferred option of 37% is the appropriate next step up in energy efficiency standards for 2021 in preparation for our envisaged Part L 2025 standard. This option should encourage some developers to use low carbon heating technologies such as heat pumps (which is estimated to have a lower capital cost than the use of gas heating and PV given in the notional specifications for the 37% option) to meet the 37% target but also gives some flexibility for developers that do not yet have confidence and/or experience to use these technologies. The notional building specification for the next Part L 2021 standard is available in Annex A of this response document. The target emission rate to achieve the 37% is technology neutral and designers have flexibility they need to use the materials and technologies that suit the circumstances of a site and their business." **2025 Standard**: "Question 1: Do you agree with our expectation that a home built to our Part L 2025 should produce 75-80% less CO2 emissions than one built to current Part L requirements?" "72% of the respondents agreed with the level of CO2 emissions reduction expected from new homes built to the proposed Part L 2025. There were three key points that figured repeatedly in the responses. Firstly, the need to close the gap between predicted and operational performance, and therefore the need for relevant testing, monitoring and reporting mechanisms to be put in place. Some of the respondents advocated the introduction of operational performance targets to ensure that the expected level of emissions reduction is achieved in practice. Secondly, the respondents emphasised the importance of a fabric-first approach and the need for high fabric standards to ensure that homes built from 2025 are fit for the future. Thirdly, the need for a clear policy roadmap was highlighted to enable the industry to invest in developing the requisite skills, quality assurance frameworks, supply chains and manufacturing capability, with some respondents in support of a stepped/ incremental approach towards tightening performance targets.

		Other points raised included the need for performance standards to be technology agnostic thereby allowing for future innovation; inclusion of embodied carbon in the performance metric to allow whole life carbon to be taken into consideration; and rewarding/ incentivising the delivery of higher standards that go beyond the stipulated minimum or where these are delivered earlier than 2025. Of the respondents that did not agree with the proposal (25%), the majority were of the view that the reduction in CO2 emissions being considered is too low (16% of the total respondents). Some of the respondents believed that given the climate emergency and national targets, all new building should be net zero or, where possible, energy positive. Other respondents argued that the focus should be on energy intensity rather than CO2 emissions given the expected decarbonisation of the electricity gird over time, with a move towards absolute energy targets as against percentage reduction relative to a notional building. 3.4 9% of the total respondents considered the level of ambition to be too high. The main reason cited was around lack of evidence on the viability of delivering these standards within the proposed timescales given the skills gap and supply chain constraints. An incremental approach was considered more appropriate. Another 3% were unsure citing concerns around high energy costs associated with heat pumps and lack of infrastructure needed to deliver this level of ambition." **Response**: "Part L 2025 target and fabric specification: The consultation envisaged that an average semi-detached home built to meet the Part L 2025 Standard would produce 75-80% less carbon dioxide emissions than one built to the 2014 Part L requirements. Although there were mixed views on the suggested specification used in the consultation to set the target (i.e. triple glazing and low carbon heating systems), the vast majority of respondents agreed with the 75-80% expectation, and the majority of those who disagreed thought that 75-80% was too low. There was mixed views on the specification used to set the target, however, it should be noted that actual specification choices to meet the target are a matter for the developer. Building regulations set minimum standards which are performance-based target requirements not to act as a barrier to innovation. Therefore, a developer can choose to achieve the target using alternative specification such as higher standards of fabric or specifying Mechanical Ventilation and Heat Recovery (MVHR) instead of triple glazing if this is preferred method to meet or exceed the target.

		Although the final dwelling specification to set the target for the 2025 notional dwelling will need to be reviewed closer to the date, industry should note that given the increased urgency to tackle climate change, we plan to start the next Part L review in 2023 with the minimum expectation of a 75% improvement option (compared to current Part L 2014 standards) in carbon dioxide emissions for our Part L 2025 standards.”

Section 2 – Low energy standards and zero carbon definitions

Passivhaus – An introduction, Passivhaus Trust, 2012
Guidance (passivhaustrust.org.uk)

"The Passivhaus standard can be applied to new build and retrofit buildings of all types, providing a robust method to help the industry achieve the carbon reductions leading towards Zero Carbon."

"Passivhaus buildings achieve a 75% reduction in space heating requirements, compared to standard practice for UK new build."

The Passivhaus criteria for a central European climate:

Space heating demand ≤ 15kWh/m²/yr
or space heating load ≤ 10W/m²

Space cooling demand ≤ 15kWh/m²/yr
or space cooling load ≤ 10W/m²

Primary energy demand ≤ 120kWh/m²/yr
(including hot water, space heating & cooling, fans, lighting, appliances)

Airtightness n50 ≤ 0.6ac/hr

"The Passivhaus Institut has developed a series of certification processes to ensure the quality of any official Passivhaus buildings and practitioners:

- The Passive House Planning Package (PHPP), used to inform the design process and to assess or verify compliance with the Passivhaus Standard
- Certification for designers, consultants and tradesmen who have the expertise to deliver Passivhaus buildings
- A certification process for Passivhaus buildings, which applies both to the proposed design and the completed building."

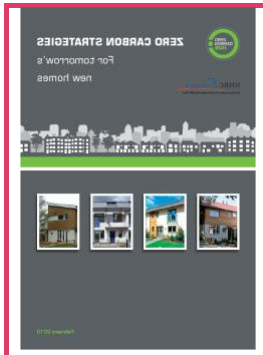
		A number of different versions of the Passivhaus standard exist, including: • Passivhaus Low Energy Building – E.g. Space heating demand relaxed to 30 kWh/m2/yr • Passivhaus Plus - Similar to the Passivhaus Classic standard other than the delivered energy demand reduces to 45 kWh/m2/yr inclusive of an allowance for storage losses of around 30%. The space heating demand limit remains at 15 kWh/m2/yr • Passivhaus Premium - Similar to Passivhaus Plus other than the delivered energy demand reduces further to 30 kWh/m2/yr including storage losses and the generation requirement increases to 120 kWh/m2/yr

	**AECB Building Standard** AECB-Standard-Further-Information.pdf	"The AECB Building Standard is aimed at those wishing to create high-performance buildings using widely available technology at little or no extra cost. We estimate that this low-risk option will reduce overall CO2 emissions by 70% compared to the UK average for buildings of each type – a highly significant result given the relative ease and low cost with which this standard can be met. Individual self-builders and large-scale residential and non-residential developers could make a valuable contribution to low-carbon building by meeting the AECB Building Standard." "The AECB Building Standard can be said to be achieved where a building that is designed and modelled using the Passivhaus Planning Package in accordance with current Passivhaus methodology meets the following requirements:"

Parameter	Target	Notes
Delivered Heat and cooling	≤ 40kWh/(m².a)	According to the methodology described in the PHPP* handbook.
Primary Energy (P.E.)	Varies kWh/(m².a)****	As per PHPP for each country
Primary Energy Renewable (P.E.R)	⩽ 75 kWh/(m².a)	ditto
Air tightness (n50)	≤ 1.5 h^{-1} (≤ 3 h^{-1})	With MVHR (with MEV) **
Thermal Bridges ***	Psiexternal <0.01 W/mK	Calculated if > 0.01 W/mK
Summer overheating	<10%	<5% recommended

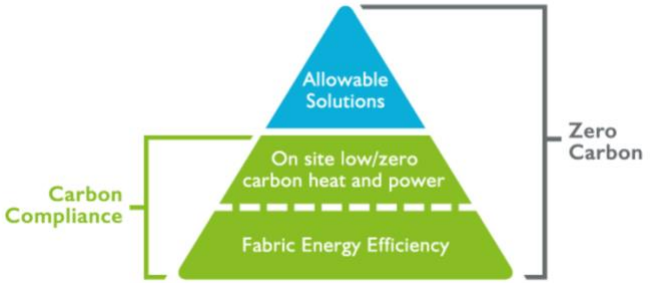
TABLE 1: Summary of AECB Standard Performance Requirements

See also the AECB Lifetime Carbon Standard which aims "to encourage the use of simple operational and embodied carbon calculations as part of the design process in UK construction projects." AECB Lifetime Carbon Standard - AECB



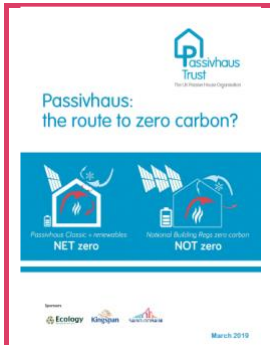
Zero Carbon Definition, Zero Carbon Hub, 2008 to 2016 Zero Carbon Policy | Zero Carbon Hub

The former Zero Carbon Hub's definition has three elements:



		Fabric Energy Efficiency Standard – "The FEES sets a maximum limit on the amount of energy that would normally be needed to maintain comfortable internal temperatures in a home: • Apartments and mid terrace target – 39/kWh/m2/yr • Semi-detached end- terrace, and detached - 46 kWh/m2/yr" "Achievement of the FEES is affected by building fabric U-values, thermal bridging, thermal mass, and features which affect lighting and solar gains." Fabric Energy Efficiency for Zero Carbon Homes-A Flexible Performance Standard for 2016.pdf (zerocarbonhub.org) Carbon Compliance - Any CO2 emissions that remain after consideration of heating, cooling, fixed lighting and ventilation, must be less than or equal to the Carbon Compliance limit established for zero carbon homes. • 10 kg CO2(eq)/m2/year for detached houses • 11 kg CO2(eq)/m2/year for attached houses • 14 kg CO2(eq)/m2/year for low rise apartment blocks Carbon Compliance Target | Zero Carbon Hub Allowable solutions - Any remaining CO2 emissions, from regulated energy sources must be reduced to zero Allowable Solutions | Zero Carbon Hub
	**EnergieSprong** Home (energiesprong.uk)	"Originating in the Netherlands, Energiesprong is taking a market transformation approach, which delivers fully integrated refurbishment packages with long-term guarantees that make the solution commercially financeable and scalable. The retrofit is non-intrusive and can usually be completed within one week, and without the resident needing to move out." "Energiesprong uses an energy performance contract to guarantee the performance of the improvements over a long-term (minimum 30-year) period. This provides financial security to the property owner as they know that it will perform at the expected level." In terms of EnergieSprong New Build:

		"The space heating demand target is 40 kWh/m2.year. Hot water demand is set at 64+26N where N is the number of residents…Lighting and Unregulated energy target is 2300 kWh/year…There is no specific [energy] generation target for Energiesprong, however, the standard does commit to achieve net zero (consumption – export) in some dwellings and to achieve <1500 kWh/yr net consumption in others. For the purposes of this paper, it is assumed that net zero is achieved when using an Air Source Heat Pump." Text from Building-Standards-Comparison-October-2020-v1.2.pdf (goodhomes.org.uk)

	**Passivhaus: The Route to Zero Carbon**, Passivhaus Trust, March 2019 2019.03.20-Passivhaus and Zero Carbon-Publication Version1.2(1).pdf (passivhaustrust.org.uk)	"This paper…examines the validity of Zero Carbon as a concept and then goes on to suggest how Passivhaus might be used as part of a Zero Carbon strategy." "Setting a Zero Carbon target for our new housing would be a clear and bold step to achieve genuine emissions reductions…However, understanding what this actually means and how to achieve it is far from clear." "There are three problems with adopting a net zero emissions approach: 1. There is a performance gap between predicted heating energy demand and actual energy use 2. There is a seasonal disparity between energy demand (heating in winter) and renewable energy generation (solar PV in summer alongside wind in the autumn and winter). This indicates a need for inter-seasonal energy storage which will result in storage losses 3. There are limits to how much renewable energy can be deployed and managed through the national grid." "As a result of these problems, a notionally zero carbon home (according to Part L calculations), would not have zero CO_2 emissions, but would still emit 18 Kg CO_2/m_2.year, and an average 68m_2 new home in the UK would need 28 solar panels to actually achieve zero net operational carbon emissions, far greater than the amount of roof space it has available." "In contrast, an equivalent Passivhaus would need only 14 solar panels, dramatically reducing the requirement for grid and storage enhancements and halving the amount of renewable generation capacity required. Reducing the heating energy demand through a fabric first approach is therefore the only practical way to achieve zero carbon homes in reality."

		"If the zero carbon 'boundary' is expanded beyond the individual building to the national level, then achieving a net zero operational carbon built environment is possible if the fabric efficiency levels of our new homes are increased to Passivhaus levels." "Our ultimate aim must be to look holistically at carbon emissions…This suggests that we should be considering both embodied carbon and operational carbon… we continue to build homes which are inefficient in operation and, unless we correct this first, operational carbon will remain the dominant factor for many years to come."
	**Net Zero Carbon Buildings, A Framework Definition**, UKGBC, April 2019 Net-Zero-Carbon-Buildings-A-framework-definition.pdf (goodhomes.org.uk)	"Businesses, government and civil society are all grappling with what net zero carbon will mean for them and how it can be achieved in practice. This report aims to make sense of this for the construction and property industry, and build consensus about the actions needed to achieve a net zero carbon built environment." "The framework set out in this report is intended as a first step towards delivering buildings that are in line with the aims of the Paris Agreement – namely net zero carbon across the whole life of a building. In practice, however, such an ambition would be challenging to deliver today without more accurate measurement and data of emissions. So, the framework presented here refers to two definitions for net zero carbon buildings – one for in-use operational energy and one for emissions from the construction process…" "In the UK, the operation of buildings accounts for around 30 per cent of emissions, mainly from heating, cooling and electricity use. While for new buildings, the embodied emissions from construction can account for up to half of the carbon impacts associated with the building over its lifecycle." "Whereas historical 'zero carbon' policies focused only on operational energy and modelled performance in new buildings, this report very clearly expands the scope to in-use performance and to encompass the whole life carbon impacts of both new and, crucially, existing homes and buildings."

Net zero carbon – construction (1.1):

"When the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy."

"A whole life carbon assessment should be undertaken to determine the building's carbon impact, in line with the RICS Professional Statement 'Whole life carbon assessment for the built environment'."

Net zero carbon – operational energy (1.2):

"When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."

"This covers energy used for heating and cooling, cooking, lighting and plug-loads."

"A third approach for net zero carbon – whole life (1.3) is also proposed at a high level, but further work will be needed to define the scope and requirements for this approach."

Steps to Achieving a Net Zero Carbon Building

1. Establish Net Zero Carbon Scope*

1.1 Net zero carbon – **construction**

1.2 Net zero carbon – **operational energy**

2. Reduce Construction Impacts

2.1 A whole life carbon assessment should be undertaken and disclosed for all construction projects to drive carbon reductions

2.2 The embodied carbon impacts from the product and construction stages should be measured and offset at practical completion

3. Reduce Operational Energy Use

3.1 Reductions in energy demand and consumption should be prioritised over all other measures.

3.2 In-use energy consumption should be calculated and publicly disclosed on an annual basis.

4. Increase Renewable Energy Supply

4.1 On-site renewable energy source should be prioritised

4.2 Off-site renewables should demonstrate additionality

5. Offset Any Remaining Carbon

5.1 Any remaining carbon should be offset using a recognised offsetting framework

5.2 The amount of offsets used should be publicly disclosed

D New buildings and major refurbishments targeting net zero carbon for construction should be designed to achieve net zero carbon for operational energy by considering these principles.

* Please also note, a further scope for net zero whole life carbon (1.3) will be developed in the future.

		"Public disclosure is required throughout the framework to demonstrate the achievement of a net zero carbon building… This form of public disclosure is intended for building developer, owner or occupier to 'show their working' on how they have achieved net zero carbon…A net zero carbon building for operational energy is required to annually disclose in-use energy performance. A verified net zero carbon building is one that is based on in-use, rather than modelled, energy performance…"
	**LETI Climate Emergency Design Guide, How new buildings can meet UK climate change targets,** LETI, 2020 Climate Emergency Design Guide | LETI	"LETI is a network of over 1,000 built environment professionals who are working together to put London on the path to a zero carbon future." LETI "believe that in order to meet our climate change targets all new buildings must operate at net zero (operational) carbon by 2030…and achieve a 65% reduction in embodied carbon emissions….and all buildings must operate at net zero carbon by 2050…" "LETI believe that in order to meet our climate change targets, in 2020 10% of all new projects developers and designers are involved in, should be designed to meet the requirements set out in this guide." "The focus on new buildings has been prioritised…" Energy demand is measured as the Energy Use Intensity (EUI). This "is an annual measure of the total energy consumed in a building. LETI believes that setting an EUI requirement for new buildings is fundamental to meeting our climate change targets. It is a good indicator for building performance as the metric is solely dependent on how the building performs in-use; rather than carbon emissions, which also reflect the carbon intensity of the grid."

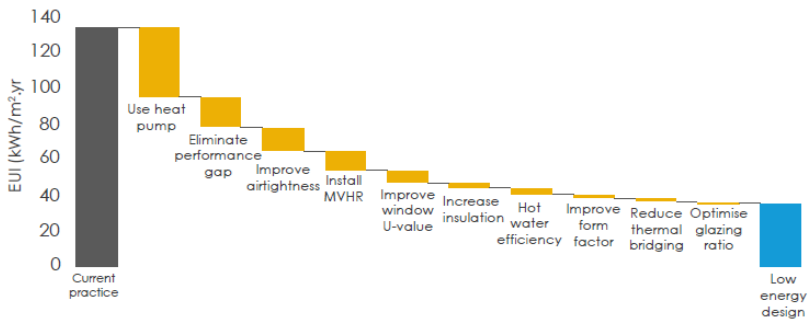


Figure 1.9 - Opportunities to reduce energy consumption in a new residential development

Trajectory taken from the lined Embodied Carbon Primer:

feedback form on the primer.

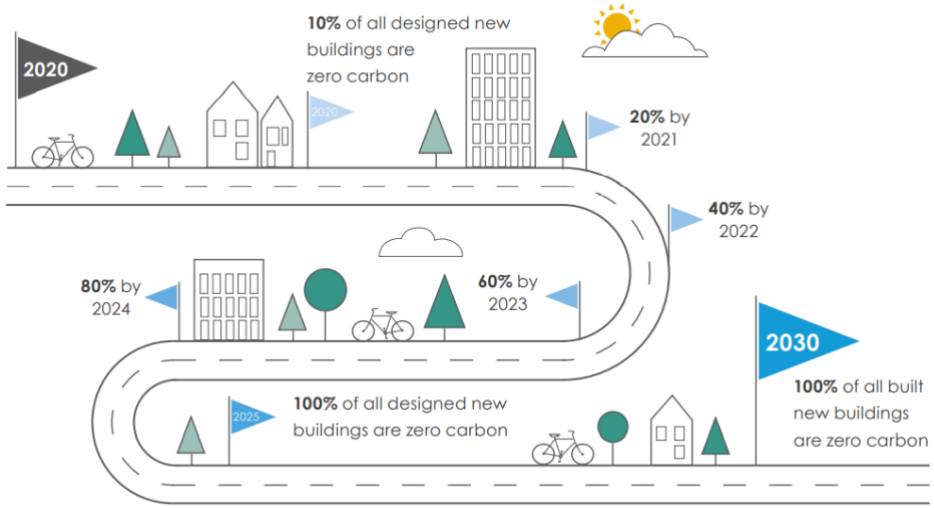
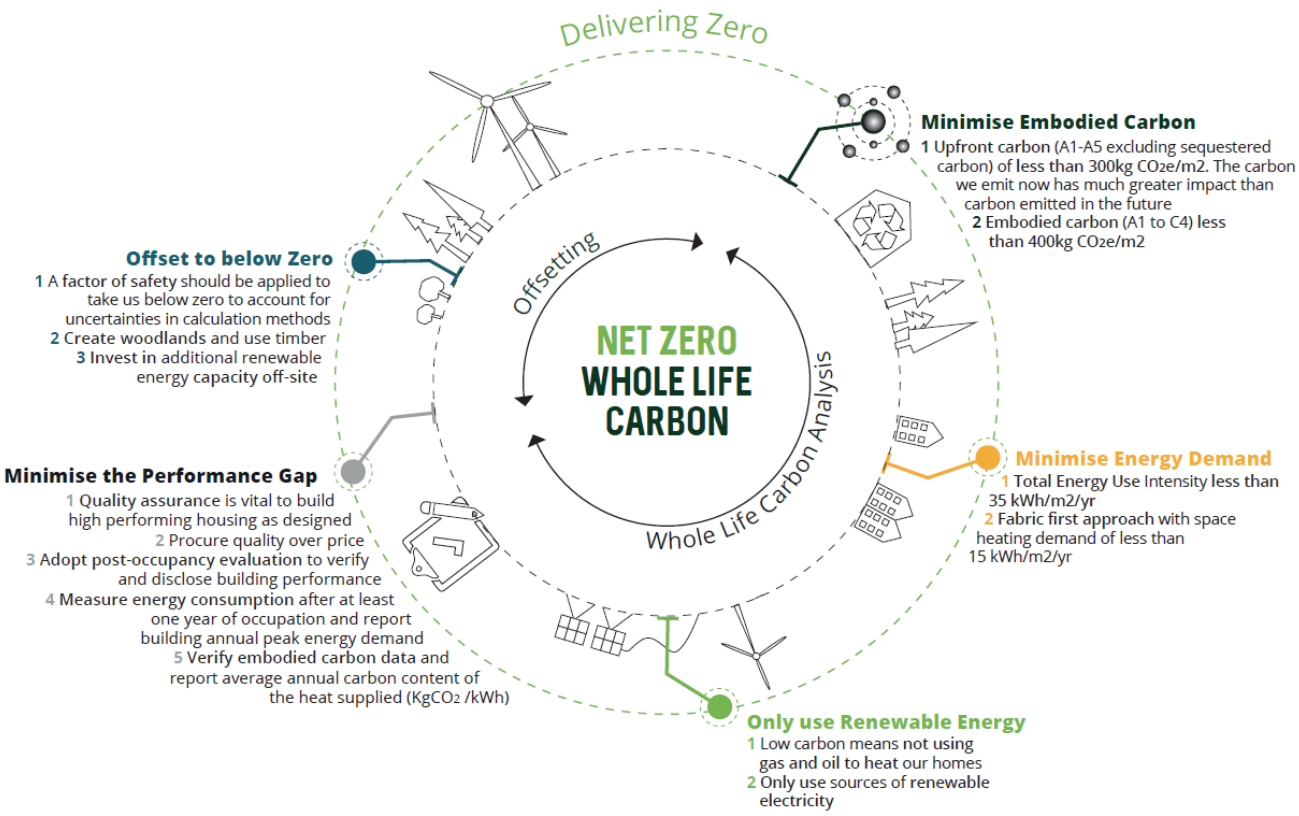
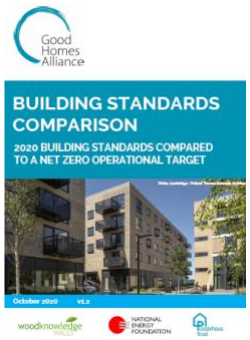
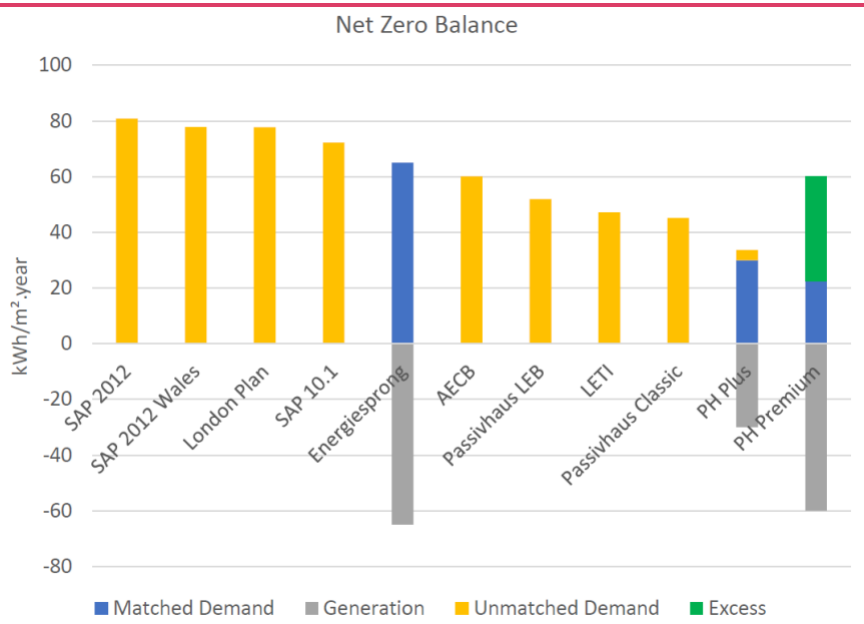


Figure i - LETI – Getting to Zero

Net Zero Targets for Wales, Woodknowledge Wales, September 2020 Net-Zero targets for Wales - Woodknowledge Wales. "Building on the work of the UKGBC and LETI, the Home-Grown Homes Project have developed a graphical net-zero guide with a set of targets and principles that we believe are achievable within a Welsh context. The guide is aimed at helping developers, designers and manufacturers achieve net-zero whole life carbon. This means tackling upfront carbon, energy demand, use of renewables and embodied carbon in order to reduce the overall emissions associated with any proposed development."

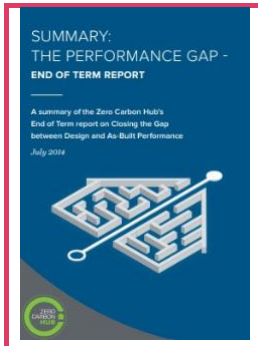


	**Building Standards Comparison, 2020 Building Standards Compared to a Net Zero Operational Target**, Good Homes Alliance and Woodknowledge Wales, October 2020 Building-Standards-Comparison-October-2020-v1.2.pdf (goodhomes.org.uk)	"The paper seeks to illustrate clearly how the choice of selecting a building standard affects the amount of renewable energy generation that is required to comply with a net zero operational outcome." Electricity generation and net zero – "To get to a net zero position on-site (i.e. just considering our individual building), we must generate sufficient renewable energy over the course of a year to match the energy consumed by the building – i.e. the delivered energy. Note that this definition of net zero is independent of changing carbon factors… In contrast, burning gas will result in immediate emissions at the point of use. These cannot be offset by electrical generation – the CO_2 has been emitted." The standards compared are: • SAP 2012/ Part L - Current English building regulations • SAP 2012/ Part L – Current Welsh building regulations • SAP 10.1 / Part L – Proposed improvement in English standards • Energiesprong New Build • Passivhaus Classic • Passivhaus Low Energy Building • AECB Standard • London Plan • LETI Net Zero Operational Carbon standard • Passivhaus Plus • Passivhaus Premium



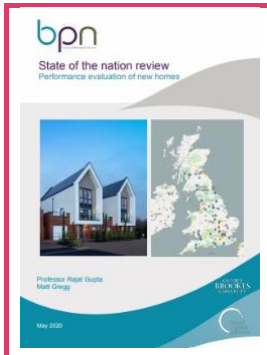
"It is not necessarily possible to generate enough from the available space to get to a net zero position…Therefore, once again, minimising demand becomes the key point in creating the best opportunity for net zero."

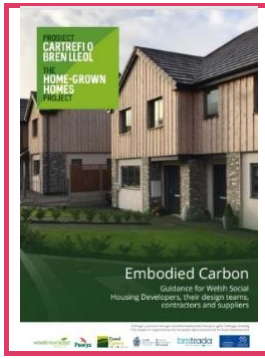
Section 3 – Reports and guidance on zero carbon themes

	**Summary: The Performance Gap – End of Term Report**, Zero Carbon Hub, July 2014 EndofTerm_Summary.pdf (zerocarbonhub.org)	The ambition: "From 2020, to be able to demonstrate that at least 90% of all new homes meet or perform better than the designed energy/carbon performance." "In recent years, the housebuilding industry and government have grown increasingly concerned over the potential gap between design and as-built energy performance. It could undermine a building's vital role in delivering the national carbon reduction plan, present a reputational risk to the housebuilding industry and damage consumer confidence if energy bills are higher than anticipated. In response, the Zero Carbon Hub was commissioned to review evidence for the significance of this gap, explore potential reasons for it and set out proposals to address these reasons. The Zero Carbon Hub were also asked to identify potential methods for industry to demonstrate progress in achieving the '2020 Ambition'. Evidence and Prioritisation: With the involvement of 160 experts from across industry, potential issues creating the gap were identified, from across the design and delivery process. Next, detailed evidence was gathered, including questionnaires, a SAP2 analysis, a study of existing literature and a Housebuilding Process Review, gathering primary evidence from live sites. This revealed a widespread Performance Gap, and was used to prioritise research on high impact issues with a strong evidence base, as well as identifying areas for further research. This identified three cross-cutting themes as primary concerns: unclear allocation of responsibility; inadequate communication of information; and a lack of understanding, knowledge and skills. This document summarises the End of Term Report, which draws together project findings, building on the Interim Progress Report (July 2013), the Evidence Review Report (March 2014)3 and the proposed solutions and recommendations."

	**Whole Life Carbon Assessment for the Built Environment**, RICS, November 2017 whole-life-carbon-assessment-for-the-built-environment-1st-edition-rics.pdf	The document is "a professional statement, which RICS members must act in accordance with." "The built environment industry has so far been addressing mainly operational emissions via reduction targets in building regulations (Part L), planning requirements by local authorities and sustainability assessment rating schemes (BREEAM, LEED, etc.) with the embodied aspect of carbon emissions not being fully addressed. To acquire an overall understanding of a built project's total carbon impact, it is necessary to assess both the anticipated operational and embodied emissions over the whole life of the asset. Considering operational as well as embodied carbon emissions together over a project's expected life cycle constitutes the whole life approach. A whole life carbon approach identifies the overall best combined opportunities for reducing lifetime emissions, and also helps to avoid any unintended consequences of focusing on operational emissions alone. For example, the embodied carbon burden of installing triple glazing rather than double can be greater than the operational benefit resulting from the additional pane. Therefore, whole life carbon needs to be effectively integrated into the sustainability agenda in order to achieve a lower carbon future."
	**Zero Carbon Homes, Actions to Integrate our Welsh Forest Industries with Modern Methods of Construction,** Woodknowledge Wales, June 2019 Zero Carbon Homes - Woodknowledge Wales	The Welsh Government "commissioned Woodknowledge Wales to prepare a strategy for the integration of the Welsh forest industries supply chain with offsite timber construction. This document provides a strategic action plan to transform the use of home-grown timber in house building and help deliver the aspirations of the Well-being of Future Generations Act." "Manufacturing homes with timber from Welsh forests provides an opportunity to exceed the objectives outlined in a Prosperity for All: A Low Carbon Wales (March 2019). This requires action to sequester atmospheric carbon through forest planting and the construction of homes as carbon stores." "A low carbon building is one that optimises the use of resources both to build it and to use it over its lifetime. As is shown in the chart above, embodied emissions are responsible for more than 50% of whole life carbon emissions and yet currently remains entirely unregulated…A focus on reducing the embodied carbon of housing will inevitably favour the use of low carbon materials such as timber." Recommendations include:

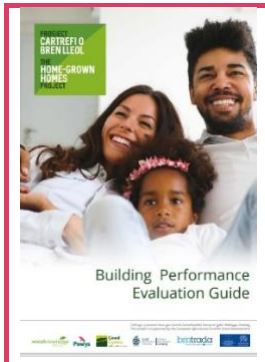
		• "Reduce operational carbon emissions by changing Part L and Part F of the Welsh Building Regulations to deliver performance-based outcomes. Passivhaus standard performance levels should be mandated by 2025 and proven through a compulsory quality assurance process by 2028." • "Establish a building performance hub to support the transition to regulations aligned to performance-based outcomes rather than design requirements." • "Bring embodied carbon emissions into the regulatory framework. Target levels for the embodied carbon emissions from homes should be created by 2023. Embodied carbon emissions reduction should be mandated for all housing projects over £2 million through building regulation, planning policy and/or encouraged through alternative policy levers such as carbon taxation."
	**Embodied Carbon Primer**, LETI, 2020 Embodied Carbon Primer | LETI	The document "is intended to provide designers including architects, engineers, interior designers, urban designers with easy-to-follow best practice and toolkits for reducing embodied carbon in buildings. The document can also aid planners to be aware of strategies available to designers to reduce embodied carbon in building design, and how planning recommendations on materials, massing and treatment of sites may affect embodied carbon. For everyone working in the construction of buildings the leap of knowledge and skill required to be able to fulfil this goal is still relatively large, but far from insurmountable." "Net Zero carbon needs to be considered in the context of whole life carbon." **Whole life carbon = Operational carbon + Embodied carbon** A new building that meets net zero operational carbon does not burn fossil fuels, is 100% powered by renewable energy, and achieves a level of energy performance in-use in line with our national climate change targets. See Appendix 0 of the Climate Emergency Design Guide. SIGNPOST *LETI Climate Emergency Design Guide* Best Practice targets for embodied carbon are met, the building is made from re-used materials and can be disassembled at end of its life - in accordance with the circular economy principles. SIGNPOST *LETI Embodied Carbon Primer*

		"Of the annual carbon emissions associated with buildings about 80% is associated with ongoing operational carbon emissions relating to the existing building stock and the remaining 20% is related to the embodied impact of new construction…Addressing climate change has traditionally focused on reducing carbon emissions from operational energy consumption. However, as buildings become more energy efficient, (and electricity generation has decarbonised), operational carbon of new buildings has significantly reduced. This means that embodied carbon can represent a higher proportion of whole life carbon than it used to. Thus embodied carbon has become significant and can represent 40-70% of Whole Life Carbon in a new building…" Suggested actions for policy makers: • Adopt a policy hierarchy that advocates circular economy principles: reuse and refurbishment in preference to demolition and new construction • Adopt a policy that mandates embodied carbon reduction strategies based on embodied carbon and whole life carbon analysis on all projects • Adopt embodied carbon targets • Recognise a consistent methodology and dataset for embodied and whole life carbon analysis e.g. RICS Professional Statement WLC, reporting embodied carbon across the chosen life cycle stages of EN 15978, as explained in Appendix 3 - How to measure embodied carbon • Phasing in the mandatory requirement of EPDs for at least all building parts forming Substructure, Frame and Upper Floors
	**State of the Nation Review – Performance Evaluation of New Homes**, Building Performance Network, May 2021 State-of-the-nation-report-June-release-FINAL-	"There has been an increase in studies undertaken over the last 10 years to understand the actual performance of homes addressing issues such as energy consumption and outcomes for residents and building owners. However, many of these studies are not widely publicised and are limited to a small audience. Funded by the Building Performance Network (BPN), the inaugural State of the Nation study has produced this comprehensive report that provides an accessible review of key studies on new-build housing performance and building performance evaluation methods adopted, analysis of meta-data, as well as a look at the future of housing performance studies." "The study has also created for the first time, an online and interactive spatial map of housing performance studies undertaken in the UK. The housing performance map spatially locates 91 housing performance studies along with

	UPDATED.pdf (goodhomes.org.uk)	their meta-data such as number of dwellings studied, location tenure, study duration, study type and data availability." The report is structured into five chapters as described below: • "CHAPTER 1: Introduction to housing performance: why, what, when? This chapter introduces the fundamentals of why, what and when housing performance studies are undertaken. Key metrics of housing performance are introduced and how they can be assessed • CHAPTER 2: Tools and methods to assess housing performance This chapter reviews major tools and methods that have been used in research for assessing the as-built and in-use performance of new-build housing • CHAPTER 3: Past studies on housing performance This chapter provides an accessible review of the objectives, scope and main findings of past studies and meta-studies on housing performance • CHAPTER 4: Meta-analysis of housing performance data This chapter conducts meta-analysis of large amounts of housing performance data (covering building fabric thermal performance, in-use energy, indoor environment and resident perception) to provide insights into housing performance studies at scale • CHAPTER 5: Key findings, recommendations and the future of housing performance evaluation This chapter describes what the diffusion of low-cost sensors, smart meters and wearables means in terms of assessing housing performance at scale in the future."
	**Embodied Carbon – Guidance for Welsh Social Housing Developers, their Design Teams and Suppliers**, Home Grown Homes Project, December 2020 Embodied	Extract from Foreword by Gary Newman, CEO Woodknowledge Wales: "Currently, around 50% of carbon emissions from new build housing is caused by the building materials, the build process, maintenance and end of life - known as the Embodied Carbon emissions. These carbon emissions currently fall largely outside the scope of current regulation, although we do hope and expect regulations to be introduced over the coming months and years… In any case, my experience of working with Welsh social housing clients, architects and the wider supply chain over the past 5 years, has convinced me that many organisations and individuals do not intend to wait for regulation.

	Carbon Guidance for social housing developers, their design teams, contractors and suppliers – GHA Knowledge Base (goodhomes.org.uk)	They want to do what they can to reduce carbon emissions now. The barrier is not willingness to act, but simply an incomplete understanding of what to do. If you're one of them, then this guidance is for you. The guidance is primarily written for providers of new build social housing, their consultants and contractors, but it is relevant to everyone operating in the built environment sector, including retrofit… Over the past few decades a huge amount of work has been done to develop construction product data and the internationally agreed standards that are required to underpin consistent measurement. There are now 1000's of construction product Environmental Product Declarations (EPDs) which provide much of the hard data. There are many assessment tools that make embodied carbon analysis and reduction easy to assimilate into the design process, many of which are described in this guidance… Now in 2020, there is no technical reason not to embark on your embodied carbon reduction journey and this guidance is designed to support you. That said, reducing embodied carbon does require us to confront the short-termism of the dominant models of house delivery. In particular, the manner in which materials and systems are put together with little thought given to their environmental impact or future resource needs. In that sense, embodied carbon reduction provides both the context and a measurement method to enable a profound re-framing of construction for the substantial benefit of current and future generations."

	**Innovation Insights – Reducing Operational Carbon**, UKGBC, January 2021 Innovation Insights: reducing operational carbon - UKGBC - UK Green Building Council	"This document provides an overview of a pilot solutions crowdsourcing project run by UKGBC over the latter half of 2020, focused on supporting the achievement of net zero carbon buildings. We also present an introduction to our ongoing work to address sustainability challenges across the built environment through increasing solution identification, dissemination, and adoption." The report "outlines the process adopted for this pilot project, including the reasons behind our choice of challenges and the most relevant associated solutions. It also sets out UKGBC's plan to scale up our solutions work through the creation of a whole new part of our website launching in Spring 2021."

	**Building Performance Evaluation Guide**, Homes Grown Homes Project, January 2021 Building Performance Evaluation Guide – GHA Knowledge Base (goodhomes.org.uk)	Extract from Foreword by Fionn Stevenson: "Housing is responsible for 78% of all the territorial carbon emissions from the UK built environment (BEIS statistics 2018). At the same time, the performance gap between expected carbon emissions from new housing and what actually happens is often shockingly underestimated. It's a sobering fact that we need to reduce all these emissions to net zero by 2050 according to government targets, and a lot sooner according to many respected NGOs… How did this happen? How could there be so much ignorance about the reasons for this vast performance gap? And how are we going to reduce the gap in time? One reason it's there, is that no-one bothered to find out what the gap was, and so housing development in the UK continued for decades in ignorance of the design and construction failures mounting up. Thankfully, we now have an organisation like Woodknowledge Wales, which is pioneering a new way of thinking, taking account of real performance and dealing with carbon emissions in the round by designing every aspect of a holistic and ecological circular economy to produce genuinely net zero carbon housing. This organisation is committed to making sustainable, affordable, and healthy housing that is fit for purpose and really does what it says on the tin… This new guide is part of that way of thinking. It explains how to carry out successful and effective building performance evaluation of new homes to provide essential feedback for design validation and improvement. It provides much needed support for policymakers, housing developers, clients, contractors and design teams alike to help them navigate through the various methods needed to build up a true picture of housing performance – one that takes account of people and processes as well as buildings. It is the first of its kind and is destined to reach all key housing organisations not only in Wales, but across the whole of the UK."

	**Zero Carbon Homes – Zero Carbon Timber Solutions for Wales**, Home Grown Homes Project, February 2021 Zero Carbon Homes—Zero Carbon Timber Solutions for Wales - Woodknowledge Wales	"Purpose of the Study: What is the zero carbon timber solution for Wales? The Home Grown Home project has taken this objective as our initial and primary goal. Firstly through examining and analysing an appropriate and future proofed definition for 'zero carbon', then through design and calculation developing an understanding of the quantifiable factors of embodied and operational carbon. An examination of existing and alternative timber construction methods, materials and systems offers a range of developed timber solutions that are capable of meeting the target fabric specification. Results to a range of investigations are presented, culminating in whole carbon emission and offsetting calculations for a range of key typologies, shown overleaf, demonstrating the routes to Zero." Key findings: "When arranged as a semi-detached structure, House Type 1 (a traditional 2-storey home designed for four people) presents a significant challenge in terms of reducing total energy demand and in reducing the overall carbon footprint, even when combined with an exceptionally high performance fabric. The large form factor and the disconnected arrangement reduces the energy and material saving benefits that a terrace would provide. The consequence of higher carbon emissions (via materials used and high energy requirements) is that a greater offset is required to compensate if a development is to reach net-zero whole life carbon. A terraced arrangement both reduces the heating demand and the overall carbon footprint so offsetting requirements are reduced significantly." "House type 7 is designed as a town house; with a smaller footprint, and is taller with the same quantity of space allocated over three storeys. This performs better as a semi-detached than house type 1 but when arranged as a terrace the total energy demand is significantly below the RIBA targets for 2030, 10 years ahead of schedule. The embodied carbon impacts however are still challenging and we need to work much harder to reduce these if we are to achieve the targets established by RIBA. Structural timber solutions and renewable insulation products offer significant potential savings, particularly in upfront carbon, and store more carbon within the building's fabric for the life of the building. These solutions are supported by a rigorous process of evidence gathering. The detail is presented in our report." Elements of zero carbon: **Minimise Operational Energy Demand Key Results**:

		1. Integrate Energy Modelling into Design: We have remodelled a typical 2-Bed, 4-person home so that its Total Energy Use Intensity is less than 35 kWh/m2/yr and its Space Heating Demand is designed to be less than 15 kWh/m2/yr. 2. It's in the Detail: RIBA's 2030 target of a space heating demand of 15kWh/m2 is challenging but can be achieved using a high quality, high performance airtight fabric with U-Values in the region of 0.1W/m2k which is thermal bridge free. 3. High Form Factor comes at a Cost (Money and Carbon): Less compact designs (e.g. bungalows, detached and semi-detached) have higher form factors so require either a higher performing fabric (i.e. < 0.1W/m2k) to achieve the desired 15 kWh/m2/yr or will require a higher rate of energy to heat them. 4. Maximise Solar Energy through Glazing: Rethinking the orientation of structures and layouts including glazing allows us to maximise the use of the sun's energy to heat our homes whilst managing overheating risk. Our modelling shows benefits in the region of up to 3.5 kWh/m2 through optimising orientation and layout. **Minimise Embodied carbon Key Results**: 1. Achieving Targets is Challenging: We have modelled 5 advanced timber frame panels which emit up-front carbon of less than 69kg CO2e/m2 and whole-life embodied carbon of approximately 180kg CO2e/m2, reductions of over 60% and 23% respectively over a standard timber frame solution. 2. Focus on Up-Front Carbon: The most important time to reduce CO2 emissions is now. Carbon emitted during construction, also known as Up-Front Carbon, must be minimised. 3. Timber helps us get there: Achieving up-front CO2 emissions of less than 300kgCO2e/m2 is challenging but can be achieved if high-value timber components are employed in the manufacture and construction of housing. 4. Consult then Procure: Clients should consult with the supply-chain to ensure that fabric solutions can be delivered that achieve both embodied carbon and operational energy targets. **Only Renewable Energy Key Results**: 1. Energy Creation: Micro-renewables such as solar panels installed on a roof will create energy that can be used to heat a home, to charge an electric vehicle or to sell energy to the national grid. Solar panels and heat pumps also reduce the reliance of our homes on energy derived from burning fossil fuels. They therefore have the potential to reduce CO2 emissions. 2. Renewables also Emit CO2: However there is no such thing as clean energy – there is a carbon footprint incurred in manufacturing and installing pumps, panels and batteries, and like all emerging technologies their predicted lifetime can be shorter (and thus have a higher carbon footprint) than designed.

		3. Inefficiencies through SAP: The existing SAP calculation method relied upon by Building Regulations incentivises the use of renewables to achieve a high EPC rating whilst the fabric performance (in terms of both embodied carbon and operational energy demands) of that building may be neglected. **Minimise the Performance Gap Key Results**: 1. Joined up Thinking about Quality: A performance gap is created when the building stage of a project (including manufacturing) deviates from the specification and design based predictive modelling. There are ways in which the performance gap can be minimised which includes ensuring a level of joined up thinking between client, designer, main contractor, manufacturer(s), and any sub-contracted businesses. 2. Appoint a QA Tsar: The energy performance gap must be closed through the adoption of a strict and contractually robust quality assurance system. It is crucial to identify a key member of the team who can assure quality. One way to address this would be to appoint an individual whose responsibility is to ensure quality at all levels including monitoring final material choices, manufacturing processes, construction detailing, and key performance characteristics such as levelling, airtightness, and moisture ingress. This individual should be qualified and trained to analyse in detail the impact of any changes and report deviations to the client. They should at least: • Adopt post-occupancy evaluation to verify and disclose performance • Measure energy consumption after at least 1 year of occupation and report building annual peak energy demand • Verify embodied carbon data and report average annual carbon content of the heat supplied (KgCO2 /kWh) 3. Utilise Standardisation and Building Information Modelling: Through the combination of standardised and repeatable specifications for fabric proposals and the development of repeatable housing models it is possible to employ Building Information Modelling incorporating detailed whole life cycle carbon modelling. In addition to offering opportunity for economies of scale, establishing repeatable models ensures consistency and familiarity from design modelling through manufacture to delivery. **Offset to Below Zero Key Results:** 1. Offset as a Last Resort: To achieve net-zero an offset is required but only after every effort has been employed to reduce CO2 emissions through design including material choices and construction methods. 2. The Numbers: As an example a development of 100 homes would emit approximately 8000 tonnes of CO2, would store around 2500 tonnes of carbon in the form of timber products and would therefore need an offset planting scheme that captures the remaining 5500 tonnes. This is equivalent to a 30 hectare woodland containing a mix of broadleaf and conifers.

		3. The Cost of Offsetting: Our modelling suggests an offset, through the creation of a UK Forestry Standard woodland planting scheme that costs around 1.5% of development costs if the proposed reductions are delivered to embodied and operational carbon emissions - and of course the woodland is an asset that remains in your ownership.

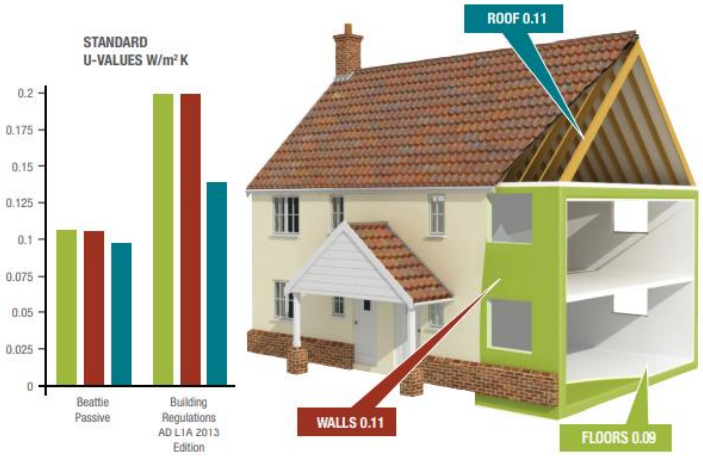
Section 4 – Welsh case studies

Creative Enterprise

See Social enterprise unveils ambitious plans for 350 zero carbon homes and 50 new jobs with AECB member Beattie Passive – AECB

TechnicalSheet-0815v3-web.pdf (beattiepassiveprojects.com)

- "A social enterprise and subsidiary of housing association Cartrefi Conwy, plan to build 350 zero carbon homes in North Wales over the next five years to 2025
- The scheme is expected to use the pioneering Beattie Passive, Passivhaus build system
- The venture is believed to be the first of its kind by a social enterprise in Wales
- Around 50 new jobs will be created
- The homes will be locally manufactured using readily available materials from local suppliers and the frames will be constructed in on-site pop-up factories, lowering our carbon footprint
- The overall focus is to deliver affordable, zero carbon housing across North Wales
- The average fuel cost for a three-bedroomed house will be around £100 to £150 per annum"



- "Timber-framed homes, built from sustainable materials, using modern methods of construction"

The Beattie Passive Passishaus system:

	Energy demand and airtightness: • "The homes will be up to the passive standard, meaning they are amongst the most energy efficient homes you can build • All walls, floor and roof construction details are tested with hot box testing and Passivhaus modelling • The design methodology details each junction for air tightness and achieves levels as low as 0.16m3 /hm2 (@50pa)" Acoustics: • "Party wall and ceiling designs give high levels of sound proofing up to 57db, six times better than building regulations. Sound and impact testing is carried out on each build"

Parc Hadau  See Parc Hadau (parc-hadau.wales)	• "35 "true zero carbon" homes by Cardiff based Sero Homes are due to begin construction in Spring 2021 in Pontardawe, South Wales • It will also be the first scheme to meet the UK Green Building Council's (UKGBC) definition of net zero carbon (see the UKGBC's case study) • And the first neighbourhood in the UK to actively monitor time-of-use grid emission factors and adjust the energy consumption accordingly to reduce carbon • Emissions will be zero or lower through the intelligent energy management of the homes, together with fabric, storage and on-site renewables • Live measuring from multiple in-home meters will be operating from completion of the houses to manage the operation of the homes and demonstrate performance. This will be used to continuously monitor and control the net zero carbon balance"

Reduce	
Number of Homes in Neighbourhood	35 homes
Average Number of Occupants per Home	4 people
Average Size of Homes	100.00 m²
Average Space Heating Demand per m²	25.00 kWh/m²/Yr
Average Space Heating Heat Pump CoEfficient of Productivity	275.0%
Average Space Heating Energy per Home per year	0.91 mWh
Average Mains Incoming Water Temperature	12.0˚C
Interim Water Temperature (Heat Pump hands to Immersion)	45.0˚C
Average Hot Water Temperature	55.0˚C
Average Hot Water Immersion CoEfficient of Productivity	99.0%
Average Hot Water Use per Person *(25 litre/person is normal)*	25 litres/person
Average Hot Water Use per House *(inc. 36 litre baseline)*	136 litres/home
Average Hot Water Demand per Home	1.28 mWh
Average Electricity Annual Demand per Home	3.80 mWh
Average Electric Vehicle Mileage per Year per Home	10,000 miles
Average Electric Vehicle Efficiency	0.248 kWh/mile
Total Neighbourhood Annual Energy Demand (no EV)	**209.5 mWh**
Total Annual Energy Demand per Home (no EV)	**6.0 mWh**
Total Neighbourhood Annual Energy Demand (with EV)	296.3 mWh
Total Annual Energy Demand per Home (with EV)	8.5 mWh

Key features:

- “All homes will be net zero carbon, including regulated and unregulated energy use
- Designed to comply with Welsh social housing Design Quality Requirements
- Will include high performance fabric with integral thermal mass, with air leakage at less than 2 m3/hr/m2
- The homes will feature large, networked photovoltaic arrays to provide energy to the residents and the national grid, combined with significant energy storage (thermal and electrical)
- Excess energy produced on-site will be fed back into the grid to displace carbon emissions from the national grid generation
- Materials chosen for their low embodied carbon. This includes the use of Cross Laminated Timber for the primary wall structure of the homes – capturing and storing significant volumes of carbon”

Milford Way

See Architype / What We're Doing / The first of two new Passivhaus social housing schemes in Swansea completes / The UK's Leading Passivhaus Sustainable Architects

Homes of Today for Tomorrow stage 1 report Appendix A case studies.pdf (cf.ac.uk)

- "16 new social housing homes in Swansea designed to the Passivhaus standard by Architype from 2017
- Direct links with achieving Welsh Housing Quality Standard
- Optimum thermal comfort at radically reduced rates, with energy bills due to total as little as £70 a year
- Timber frame construction
- Majority local supply chain employed to complete the work"

Key features:

- "Fabric First strategy, focussing on building elements such as insulation and windows – those that would be expensive to upgrade at a later date
- Low U-values (W/m2k): walls (0.127), roof (0.095), floor (0.131) and glazing (0.8)
- Highly airtight building, target of 0.6ach@50Pa
- Primary energy requirement < 120 kWh/m2
- MVHR and gas combi boiler with radiators
- No renewables
- Post occupancy monitoring is being carried out by the Welsh School of Architecture
- Monitoring temperature throughout the year/seasons and taking account of tenant lifestyle"

Active Homes

- "16 "active homes" built on the site of a former care home off Wenham Place, Neath Port Talbot
- The homes have solar roofs, exterior steel walls, airtight panels, and Tesla batteries to store and release excess electricity
- It is pilot project for the regional "Homes as Power Stations" City Deal project
- The homes are being built by south Wales-based construction company TRJ
- The project is a partnership between Neath Port Talbot Borough Council, housing association Pobl Group, and Swansea University's SPECIFIC Innovation and Knowledge Centre

See Neath`s energy efficient homes | Active Building Centre, Active Homes Neath » Specific	• Welsh Government Innovative Housing Programme has funded the innovative aspects of Active Homes Neath, and the project was seen as a pathfinder in the IHP programme. Remaining funding is from the Social Housing Grant as well as private finance" Key features: • "Active Buildings integrate renewable energy technologies to provide heat, power and transport. They are designed for high performance beyond the minimum Building Regulations • The homes use well insulated construction from SO Modular, solar technologies and the grid to provide heating • The Active Homes have no gas supply. Homes combine BIPVCo solar PV and Tesla battery technology. TATA's transpired solar collector cladded wall provides heating in combination with Ariston's air source heat pump • Active Homes Neath use Tesla Powerwall batteries to enable solar generated electricity to be used later in the day as it's needed. When less sun is available, the batteries can be charged overnight, which is cheaper than charging during the day" Embodied carbon: • "Active buildings focus mainly on operational carbon to date, although they aim to use low embodied carbon elements where possible • A PhD student at the University of Bath is currently undertaking a Life Cycle Assessment (LCA) of both the Active Classroom and the Active Office. Learnings from this research will aid future Active Building projects and should be available in summer 2021 • The projects strive to be Net Zero in operational carbon but, if when including embodied carbon, they are not classed as completely Net Zero Carbon • The first tenants of a new housing scheme moved in Autumn 2019"

Solcer House

See SOLCER | Smart Operation for a Low Carbon Energy Region, SolcerHousebrochure-Englishsingle1.pdf

- "Wales' first low cost 'energy positive' house, located at the Cenin site, Stormy Down near Bridgend
- Designed and built by the Welsh School of Architecture at Cardiff University
- Capable of exporting more energy to the national electricity grid than it uses
- Designed to meet social housing standards
- Estimated cost of the house is £1,000m2 , compared with social housing benchmark of £800 - £1,000m2
- The components of the building were sourced, as far as reasonably practicable, from Welsh manufacturers and installers, and the house was used as a demonstration of advanced Welsh construction technologies
- SOLCER is an output of research project that ran from September 2012 to February 2015. It funded by Wales ERDF and forms part of the Low Carbon Research Institute (LCRI) programme"

Key features:

Energy Demand:

- "The house was built with high levels of thermal insulation and reduced air leakage
- It uses an innovative energy efficient design that includes low carbon cement, structural insulated panels (SIPS), external insulated render, transpired solar air collectors and low emissivity double glazed aluminum clad timber frame windows and doors"

Renewables:

- "Uses renewable energy systems as building elements
- The upper first floor wall incorporates a transpired solar air collector The south facing roof has a 4.3kWp PV panel system
- Based on the 'Buildings as Power Stations' concept developed by the SPECIFIC Innovation and Knowledge Centre, but incorporates additional features"

Heat:

- "Space heating is provided by passing external air through the upper south facing transpired solar air collector, then through a mechanical ventilation heat recovery unit (MVHR), and then delivered to the space.
- Exhaust air is passed through the MVHR and then through an exhaust air heat pump, which heats the thermal water store, which heats the domestic hot water"

	Embodied carbon: • "The embodied CO2 of the house materials is 340 kgCO2 /m2" Integration: • "The energy systems combine solar generation and battery storage to power both its combined heating, ventilation, hot water system, and its electrical power systems which includes appliances and LED lighting"

Flatline  See The UK's largest domestic Demand Side Response trial gets off the ground as first residents move in – Sero Group	• "The UK's largest domestic "Demand Side Response" trial • Specially built pilot homes at The Mill development site in Cardiff, provided by Tirion Homes • Residents moved in Summer 2020 • Aims to significantly reduce residents' energy bills using a combination of domestic Demand Side Response and demand shifting for both heat and electricity • The trial will be closely followed by a further 46 homes at a separate site, Parc Eirin in Tonyrefail • The project is being coordinated by Sero who have created an app which will control the energy network for each home, and intelligently draw, discharge and anticipate energy demands, working collaboratively with energy optimisation software developer PassivSystems • The project is supported by the UK Government's Energy and Industrial Strategy competition for Domestic Demand Side Response • The Welsh Government's Innovative Housing Programme has also supported delivery of Parc Eirin"

SPECIFIC	• "SPECIFIC was one of seven Innovation and Knowledge Centres set up in 2011 to foster new industries by closing the gap between scientific research and its commercial exploitation. The centre is based at Swansea University

See About Us » Specific

- The team works on energy technologies and systems, from the fundamental science of materials and products to full-scale demonstrators, including the Active Home in Neath
- This comes together in one design concept Active Buildings, in which buildings are designed to generate, store and release their own renewable energy”

Croft Court and Pentland Close

- Woodknowledge Wales and Cardiff Metropolitan University reported in 2020 on detailed performance measurements on two newly built timber frame low rise blocks of flats as part of their Home-Grown Homes Project
- “The purpose of the work was to test out novel methods of building performance evaluation being pioneered by Build Test Solutions, who specialise in making practical building performance measurement technologies”

The two sites were:

- Crofton Court in Welshpool, a development for Mid-Wales Housing Association. built by Mid Wales Properties Ltd, with AC Roof Trusses providing the timber frame
- Pentland Close site in Cardiff, a development for Wales and West Housing Association. Built by Hale Construction who procured Sevenoaks Modular as a specialist timber structures supplier using their Trisowarm system

See Demonstration of Practical Building Performance Measurements - Woodknowledge Wales

- In both cases the measured performance was very similar to the design values

Croft Court:

Croft Court, Welshpool	Design/SAP	Measured
Heat Loss Parameter (W/m^2K)	0.73	Coheat: 0.79 SmartHTC: 0.69
Total HTC (W/K)	42	Co-heat: 46±9 SmartHTC: 40±6
Air Permeability ($m^3/h.m^2$)	4.67@50Pa	Pulse: 0.53@4Pa, 3.03@50Pa Blower Door: 4.23@50Pa
External wall U-value (W/m^2K)	0.15	0.15±0.02

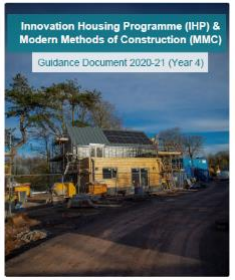
"Currently the most widely used method to measure building thermal performance is the co-heating test. It has been a crucial tool in revealing the performance gap but at a cost of thousands of pounds per test and requiring a building to be empty for two weeks it is not practical on a wide scale. Build Test Solutions make building performance measurement equipment and methods to address this gap, which they applied alongside traditional methods on these two demonstration projects."

Pentland Close:

	Flat 4, Ground Floor		Flat 18, Top Floor	
	Design/SAP	Measured	Design/SAP	Measured
Heat Loss Parameter (W/m^2K)	1.05	1.00	0.89	0.81
Total HTC (W/K)	46	Co-heat: 44±6	40	Co-heat: 33±5
Air Permeability ($m^3/h.m^2$)	5@50Pa	Pulse: 1.30@4Pa Blower Door: 4.94@50Pa	5@50Pa	Pulse: 1.33@4Pa Blower Door: 5.91@50Pa
External wall U-value (W/m^2K)	0.13	Not measured	0.13	0.17±0.02

	“The measurements included airtightness using BTS’ Pulse equipment and a blower door test, whole building thermal performance using BTS’ SmartHTC and a co-heating test and the thermal performance of the external walls using BTS’ heat flux plate kit. The performance measurement demonstrations provide quality assurance on these three flats, and a demonstration of what’s feasible using performance measurement.”

Section 5 – Funding programmes for developers

	**Innovation Housing Programme (IHP) and MMC**, Guidance Document 2020-21, Welsh Government, July 2020 Innovation Housing Programme guidance (gov.wales)	Announced in February 2017, the "Innovative Housing Programme (IHP)…has been developed to help inform the Welsh Government about the type of homes it should financially support in the future." For 2020-21 "the main theme of the programme is Modern Methods of Construction (MMC) and is only open to schemes located in Wales from registered social landlords (RSLs) and local housing authorities (LHAs), including local authority owned companies." Support can cover new build and buildings subject to change of use. Funding is in the form of "grant support and Financial Transaction Capital loans." The loan element is provided as a "private finance swap out" and is available only to RSLs, at 0% interest over a maximum 20-year repayment timeframe for affordable housing. Schemes are: • Evaluated against a Technical Specification by an Independent Assessment Panel • Must be delivering against the key objectives of 'Re-imagining social house building in Wales' (summarised in Section 1 of this Review) • Subject to a Design Commission for Wales design review The IHP had a target of 1,000 affordable homes as part of the Welsh Government's 20,000 affordable homes target for this term of government, and had approval for three years, with a budget of £90 million. In 2020 an extension to the IHP was granted for an additional year, with a capital grant budget of £25m and Financial Capital Transaction loan funding of £10m "to support MMC to build the next generation of social housing in Wales." The scheme has many objectives, including to: "increase the supply of high-quality affordable housing", "Promote uptake of MMC solutions", and "Support wider regeneration and economic development of indigenous Welsh supply chains and the use of materials and resources." Schemes must deliver as per the "MMC definitions framework."

 *Two new homes at ClwydAlyn's development at Llanbedr Dyffryn Clwyd*	**Examples of projects using Innovation Housing Programme (IHP) funding**	See full lists of funded schemes between 2017 and 2020 here: Innovative housing programme | GOV.WALES See also "Research to identify early lessons emerging from the Innovative Housing Programme", 2020 Research to identify early lessons emerging from the Innovative Housing Programme (thinkhouse.org.uk)

	**Welsh Social Housing Grant**, guidance, Welsh Government, September 2019 Social Housing Grant: guidance for registered social landlords and local authorities (gov.wales)	The document provides "guidance to Registered Social Landlords (RSLs) and Local Authorities on the procedures for the management of Social Housing Grant (SHG), which is the main source of Welsh Government funding for affordable housing in Wales." The SHG It is used to fund housing schemes that meet local housing need and priorities. All schemes are required to comply with Welsh Government Development Quality Requirements (DQR). And the process requires an "early design review and "sign off" prior to detail planning approval." (Housing Quality Standards team). The application process requires housing providers to "Record if Modern Methods of Construction (MMC) or Off Site Manufacture (OSM) have been a consideration for the project." A post completion review is undertaken, which includes checks for compliance with DQRs. The funding has recently been increased. Stuart Ropke, Chief Executive at Community Housing Cymru, responded: "In a year when the importance of home has been highlighted more than ever, we are delighted to see £200m of capital investment in new homes announced today. It is nearly three times the amount committed to social housing in 2016 and a reflection of the increased priority given to social housing in Wales over this Senedd term…we need to see all parties commit to build on this level of investment, to support the construction of 20,000 social homes over the next five years that are energy efficient and affordable, supporting jobs, and improving the nation's health." Inside Housing - News - Welsh Budget: social housing funding increased to £200m next year

	**Welsh Optimised Retrofit Programme**, Welsh Government, August 2020	Covers existing homes. Launched in August 2020 and initially worth £9.5m (The Welsh Government announced an additional £10m of investment in November 2020). The Optimised Retrofit Programme (ORP), part of the Innovative Housing Programme, will fund the fitting of energy efficiency measures in up to 1000 existing homes owned by registered social landlords and councils. The ORP will support the sector to test different approaches to reach the goal of carbon neutrality…The knowledge and learning gained will influence the future of the Welsh Housing Quality Standard. The ORP is "a key part of the £45 million Innovative Housing Programme announced earlier this year, which focuses on building new carbon neutral homes using modern methods of construction." "Julie James, Minister for Housing and Local Government, launched the…Programme during a visit to Craig Cefn Parc in Swansea. This retrofit scheme of six 1970s bungalows undertaken by Swansea Council trials an approach of how to reduce residents energy bills, improve tenant comfort and reduce carbon emissions." It is hoped technologies and skills created through the programme can be rolled out across wider private sector homes, ensuring Wales' place as 'first mover region' for decarbonisation of homes by reducing carbon emissions from around 300,000 social and fuel poor homes. In January 2021 CE in Wales hosted the first of a programme of events, Construction Opportunity Knocks: Optimised Retrofit, geared towards introducing and explaining Optimised Retrofit, what it is, what the opportunities are and what the benefits will be for the whole Welsh built environment supply chain. Constructing Excellence in Wales :: Optimised retrofit, opportunity knocks (cewales.org.uk) "Optimised Retrofit is a £20m government-funded initiative aimed at boosting the energy efficiency of around 1,300 social homes. Through the scheme, 28 Welsh social landlords have received funding to retrofit homes and test the way that heat and energy are produced, stored and supplied. Between them the landlords manage around half of Wales' 226,000 social homes." Social Housing - Insight - Net gain: funding zero carbon in Wales

Section 6 – Cost analysis

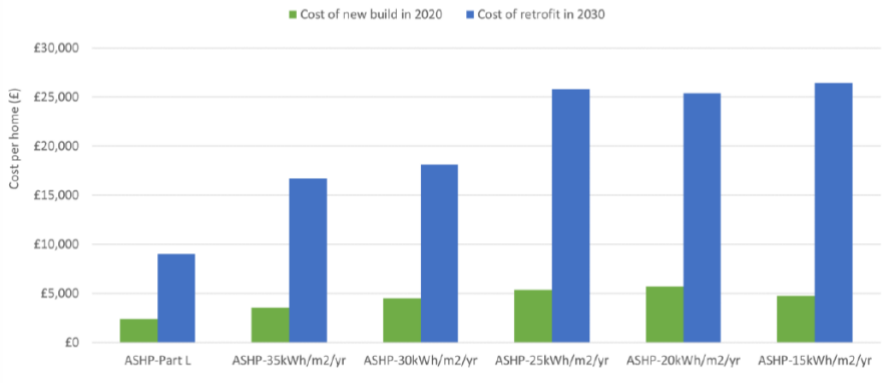
The costs and benefits of tighter standards for new buildings, Currie and Brown for the CCC, 2019 The-costs-and-benefits-of-tighter-standards-for-new-buildings-Currie-Brown-and-AECOM.pdf

"The study considers a range of tighter standards for selected housing and non-domestic buildings in tandem with a range for technologies for space heating and hot water; namely gas boilers, air source heat pumps (ASHP) and low-carbon heat networks (LCHN)."

It "examines the 'social cost-effectiveness' of packages of fabric and low-carbon heating measures in new buildings. The cost-effectiveness of a package of measures to reduce emissions can be evaluated by its abatement cost. Expressed in £/tCO2e, the abatement cost is the total lifetime cost of the package of measures divided by the associated total lifetime emissions savings. A measure is considered cost-effective if its abatement cost is lower than the Government's target-consistent carbon values."

A key finding is that: "Low-carbon heat is cost-effective when built into new homes from 2021. Low-carbon heating in the form of an ASHP is cost-effective in all new homes built from 2021, when compared against central carbon values. In housing, lifetime carbon savings of over 90% are achieved at a capital cost uplift of around 1-2%. Connecting to a LCHN may also be a cost-effective carbon reduction solution in situations where the heat density and scale enable efficient operations."

Figure E.2 Additional cost of installing ASHP and meeting space heating standards in a new semi-detached house or via retrofit[17]



	**Passivhaus Construction Costs**, Passivhaus Trust, 2019 2019 PHT Costs Summary web.pdf (passivhaustrust.org.uk)	"Innovation costs associated with early Passivhaus projects are now reducing as the methodology has become more widely adopted. This study shows that the extra over costs associated with building to the Passivhaus standard in the UK has reduced over the past three years and, as of 2018, best practice was around 8% higher than comparable non-Passivhaus projects." This is compared to a costs research paper published by the Passivhaus Trust in 2015 "identifying Passivhaus extra costs between 15% and 20%, largely associated with the innovative nature of the standard." "The new analysis examines several Passivhaus certified multi-unit residential developments of differing construction types, completed between 2014-2018, to derive typical cost premiums and identify a wide variation of extra-over costs per m2. Results have been compared with the average costs of the equivalent normalised projects and other studies, such as Currie & Brown analysis for the UKCCC, to provide a robust analysis." "Overall, this analysis has shown that by following some key principles and leveraging prior experience, Passivhaus projects in the UK are likely to be achieved for a modest extra over cost of around 4% or less once adopted at scale." The full report is here: Passivhaus Construction Costs (passivhaustrust.org.uk)
	**Cost Analysis – Meeting the Zero Carbon Standard**, Sweet Group and the Zero Carbon Hub, 2014 Cost_Analysis-Meeting_the_Zero_Carbon_Standard.pdf (zerocarbonhub.org)	"At today's prices, the typical additional cost of building a semi-detached house1 to the Zero Carbon Standard could be less than £5000. It is impossible to estimate with absolute precision what the costs could be for every type of house in every scenario. But what we can see clearly is a trend of significant cost reductions over time. In the seven years since the zero carbon policy was first announced by the Government we have seen costs fall by tens of thousands of pounds." Key findings:

		"Our analysis shows a continuing reduction in the cost of meeting the Zero Carbon Standard for homes, with particular reductions seen in the cost estimates for the solar PV, air tightness and thermal bridging components. The following cost allowances are considered to be reasonable for achieving the proposed Zero Carbon Standard: • Detached homes = ~£6,700-7,500 • Semi-detached and mid-terraced properties = ~£3,700-4,700 • Apartments (low-rise) = ~£2,200-2,400 It is likely that the relative costs of meeting the Standard for each house type will reduce further between 2014 and 2016 and continue to fall through to 2020. For a detached house this might mean additional costs in 2020 of ~£5,700-6,300 per home, and for semi-detached and mid-terraced homes costs could be around £2,900-3,600 per home. For low-rise apartments costs could be between £1,900-2,000 per home. The findings highlighted above emphasise the assumed lowest capital cost options for meeting the proposed Zero Carbon Standard, which involves the use of solar PV as a significant carbon reduction technology." Example scenario:

Table 1.

Cost above Part L1A **2013** for achieving the Zero Carbon Standard for different house types via the assumed lowest cost route to compliance
(Scenario 1 FEES + Efficient gas boiler + PV + AS)

ELEMENT	DETACHED HOUSE	SEMI-DETACHED HOUSE	MID-TERRACED HOUSE	LOW-RISE APARTMENT
PER HOME				
FEES	£1,728	£61	-£76	-£32
Heating and LZC technology	£3,270	£2,824	£2,477	£978
Carbon Compliance	£4,998	£2,885	£2,401	£947
Allowable Solutions	£2,118	£1,504	£1,508	£1,375
Total (central)	**£7,116**	**£4,389**	**£3,910**	**£2,322**
Range	**£6,700 - £7,500**	**£4,100 - £4,700**	**£3,700 - £4,200**	**£2,200 - £2,400**
PER M^2 [2]				
FEES	£15	£1	-£1	£0
Heating and LZC technology	£28	£37	£32	£18
Carbon Compliance	£42	£38	£31	£18
Allowable Solutions	£18	£20	£20	£25
Total (central)	**£60**	**£58**	**£51**	**£43**
Range	**£57 - £64**	**£54 - £62**	**£48 - £55**	**£42 - £44**

	**Technical Insight, Whole-life costs of Passivhaus**, Encraft, 2014 WLCA: Whole-life costing analysis for domestic Passivhaus buildings (passivhaustrust.org.uk)	"This paper demonstrates that in the majority of scenarios (and even if it costs 10% more to build), a Passivhaus will have lower whole-life costs than a traditional new build. Choice of building services is critical, however, and selecting those with lower maintenance and replacement costs is highly recommended." The study "looked at a series of variables for each of the 5 cases outlined…: • WLCA lifetimes of 30, 60 and 100 years • Four different fuel price forecasts (all predicting price rises) • MVHR filter replacement carried out by professional or by homeowner • Steel or plastic ductwork • Including and excluding tax "Choice of building services is especially important as a traditional gas boiler produces lower whole-life costs than an all-electric heating and DHW system (such as the compact unit, or ASHP). Not only is it cheaper to install, but the maintenance costs are lower, as is the cost of gas when compared with electricity." "These analyses clearly demonstrate that it is not sufficient to look at capital costs or annual running costs for buildings in isolation, but that maintenance and replacement costs are equally as important."